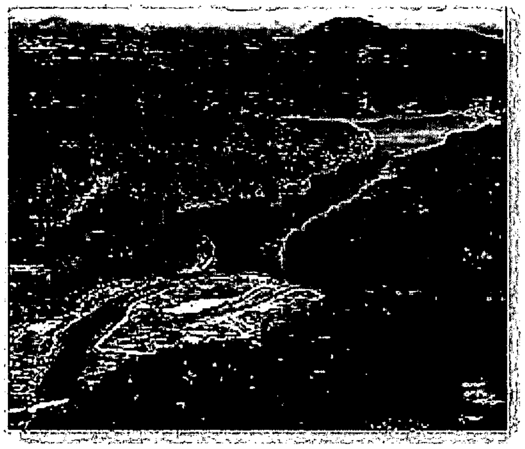
Sec 2.3 Ref 20

Broad Basinwide Water Quality Management Plan

Foreword and Executive Summary

July 1998



Lake Lure
Rutherford County, NC

Prepared by the:
NC Division of Water Quality
Water Quality Section
Planning Branch
P.O. Box 29535
Raleigh, NC 27626-0535
(919) 733-5083

The final Broad Basinwide Water Quality Management Plan is tentatively scheduled for final review by the NC Environmental Management Commission on July 9, 1998 to be used as a guide by the NC Division of Water Quality in carrying out its Water Quality Program duties and responsibilities in the Broad River Basin. Copies of the entire plan may obtained by contacting the Division of Water Quality at the above address and phone number.

FOREWORD

The Broad River is formed in the mountains of North Carolina and flows southeasterly into the Piedmont region before entering South Carolina. Major tributaries include the Green River, the First Broad River, the Second Broad River and Buffalo Creek. Water quality in the basin is generally good, but there are areas that are impacted by both point and nonpoint sources of pollution. The surface waters of the basin receive waste from both industrial and municipal discharges, as well as runoff from land use activities such as agriculture and construction.

The waters of the Broad River basin are an important resource for residents and visitors. They are used as a source of drinking water and for various recreational activities in addition to providing the benefit of assimilation of municipal and industrial wastes.

Of the 1,472 miles of freshwater streams and rivers in the Broad basin, use support ratings were determined for 96% or 1,416 miles of water. Only three (3) percent (or 49 miles) of these waters are considered impaired (partially supporting or not supporting their uses). Of the impaired waters, almost all of them are affected by nonpoint source pollution to some extent, and roughly 40% are impacted by industrial and/or municipal effluent. Sedimentation is the most significant water quality problem in the basin. Others include oxygen-consuming wastes and color in treated wastewater effluent, and fecal coliform bacteria in nonpoint source runoff.

There are two major management challenges in the Broad basin: to protect existing high levels of water quality, and to take actions to improve those waters that have impaired quality. These tasks are beyond the capabilities of any one agency or group. State and federal government regulatory programs will play an important part, but much of the responsibility will be at the local level. Those who live, work and recreate in the basin have the most at stake.

This document provides a summary of the causes and sources of water pollution in the basin, a summary of water quality rules and statutes that apply to water quality protection, and recommended measures to protect and enhance the quality of the surface waters and aquatic resources. The Broad River Basinwide Water Quality Management Plan will be used as a guide by the NC Division of Water Quality in carrying out its water quality program responsibilities in the basin. Beyond that, it is hoped that the plan will provide a framework for cooperative efforts between the stakeholders in the basin to work toward a common goal of protecting the basin's water resources while accommodating reasonable economic growth.

Top of Page

EXECUTIVE SUMMARY

NORTH CAROLINA'S BASINWIDE APPROACH TO WATER QUALITY MANAGEMENT - PURPOSE OF BROAD RIVER BASIN PLAN

Basinwide management is a watershed-based approach to water quality protection. The plan is being prepared by the North Carolina Division of Water Quality (DWQ), however implementation of the plan and protection of water quality involve the efforts of all stakeholders in the basin. The *Broad River Basinwide Water Quality Management Plan* (Broad Plan) is the seventeenth in a series of basinwide water quality management plans that are being prepared by DWQ for all seventeen of the state's major river basins by the year 1998. The plan will be used as a guide by DWQ in carrying out its water quality program duties and responsibilities in the Broad River Basin.

A basinwide plan is prepared for each basin in order to communicate to policy makers, the regulated community and the general public the state's rationale, approaches and recommended long-term water quality management strategies for each basin. The draft plans are circulated for public review and comment and are presented at public meetings in each basin. The plan for a given basin is completed and approved prior to the scheduled date for basinwide wastewater discharge permit renewals in that basin. The plans are then re-evaluated and updated at five-year intervals.

The Broad Plan is due for completion in July of 1998 and will be updated in the year 2003. Basinwide NPDES permitting is scheduled to commence in November of 1998.

BASINWIDE GOALS

The primary goals of DWQ's basinwide program are to 1) identify and restore full use to impaired waters, 2) identify and protect highly valued resource waters, and 3) manage problem pollutants throughout the basin to protect water quality standards while accommodating reasonable economic growth. In addition, DWQ is applying this approach to each of the major river basins in the state as a means of better identifying water quality problems; developing appropriate management strategies; maintaining and protecting water quality and aquatic habitat; assuring equitable distribution of waste assimilative capacity for dischargers; and improving public awareness and involvement in management of the state's surface waters.

PUBLIC WORKSHOPS

Broad River Basinwide Planning Workshops were conducted on June 2 and 3 in Spindale, Lake Lure and Shelby, North Carolina. There were a total of 90 registered participants representing local government, business and industry, farmers and landowners, state and federal government, academic institutions and citizen organizations. The purpose of the workshops was to familiarize stakeholders in the basin with DWQ's basinwide approach and to solicit their input about what they see as the major water quality issues in the basin. The workshops were co-sponsored by the North Carolina Cooperative Extension Service (CES), the North Carolina League of Municipalities and DWQ. A summary of the comments received at these workshops is provided in Chapter 6 of the plan. DWQ examined the comments received at the workshop and grouped them into six broad categories: sedimentation, color, education, enforcement, management of nonpoint source pollution and the need for fair, equitable, common-sense regulations.

Top of Page

BROAD BASIN OVERVIEW

The Broad River Basin encompasses a 1,506 square mile watershed drained by 1,472 miles of streams and rivers. The headwaters of the Broad and its major tributaries are located within the mountain physiographic region and flow towards the foothills before entering the piedmont southeast and east of Lake Lure. Figure 1 provides a general map of the North Carolina portion of the basin, including major hydrology, municipalities and county boundaries.

The three major tributaries into the Broad River before it enters South Carolina are the Green River, the Second Broad River, and the First Broad River. Several areas in the basin are classified for water supply use and approximately 30% of the streams are supplementally classified as trout waters to protect for the propagation and maintenance of that fishery.

The basin encompasses all of Cleveland, Polk and Rutherford counties, as well as portions of Buncombe, Henderson and Gaston counties. There are 29 municipalities in the basin including Lake Lure, Rutherfordton, Spindale, Forest City, Shelby and Kings Mountain.

The Broad River basin has an estimated population of 169,001 people based on 1990 census data. The entire basin has experienced moderate population growth between 1970 and 1990, with higher levels of growth occuring in the extreme eastern and western portions of the basin. In the eastern part of the basin in the Kings Mountain area, the population increase may be related to the high growth of the Charlotte area. In the western part of the basin, which is characteristically more mountainous, increases may be related to second home development or settlement of retirees.

Over 60% of the land in the Broad River basin is covered in forests. Based on data from the USDA Natural Resources Conservation Service, the most significant land cover change between 1982 and 1992, was a 71% increase in the amount of urban land. In 1992, approximately 20% of the land in the basin was covered by cultivated or uncultivated crop or pastureland.

Agriculture is an important industry in the basin. According to the NC Department of Agriculture (1996), revenues are higher for crop production than for livestock production for the counties that are either wholly or partly in the basin. Crops grown include, but are not limited to, sorghum, barley, oats, corn, soybeans, wheat and hay. There are twelve registered livestock operations within the basin, including cattle, poultry and swine.

The Broad River Basin is home to 97 rare animal and plant species. Two aquatic animals that are listed as Threatened by the State of North Carolina are the Bog Turtle and the Squawfoot (a mussel). There are five Natural Heritage Program Priority Areas in the basin. These are: the Rollins/South Mountains Natural Area; Hickorynut Gorge; Green River Headwaters and Gorge; the Tryon Region and Pacolet River Gorge; and Pinnacle Mountain.

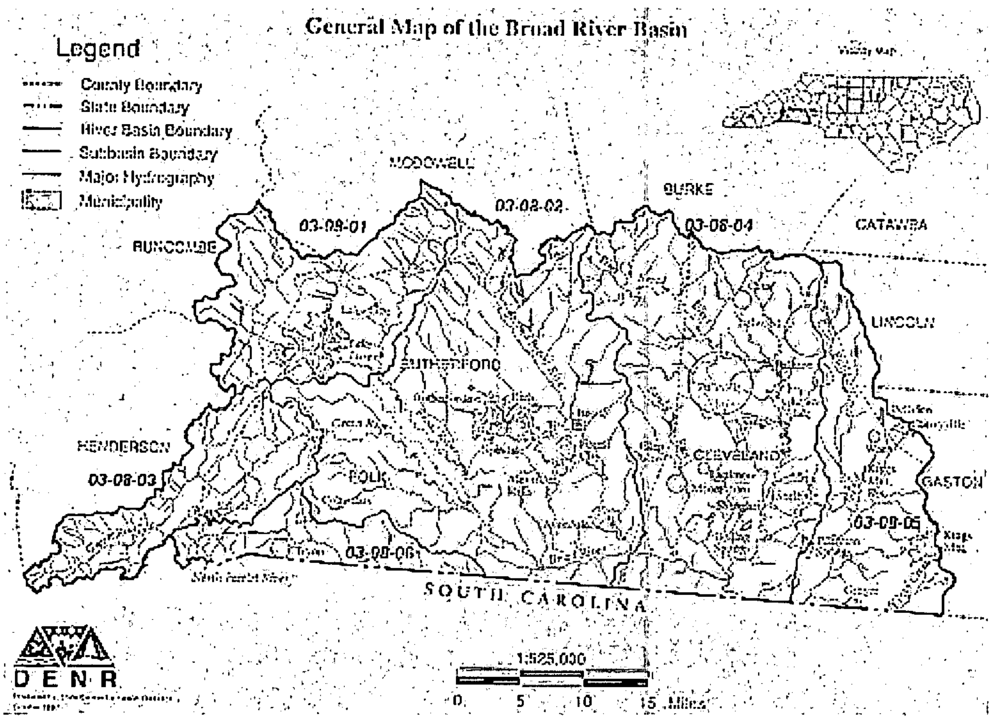


Figure 1. General Map of the Broad River Basin

Top of Page

ASSESSMENT OF WATER QUALITY IN THE BROAD RIVER BASIN

An assessment of water quality data collected by DWQ and others reveals that the Broad River basin has generally good water quality. There are areas, however, that are impaired and in need of attention. Below is a summary of some key monitoring data that reflect water quality in the basin. A more detailed presentation of this information can be found in Chapter 4.

Summary of Biological Indicators

- Benthic Macroinvertebrates - Benthic macroinvertebrates (or benthos) are primarily bottom-dwelling aquatic insect larvae such as species of stoneflies, mayflies and caddisflies. Measurements of the number, types and diversity of these organisms at strategic sampling sites is an important means of assessing water quality. Since 1983, 108 benthic macroinvertebrate samples have been collected at 69 different locations within the Broad River basin. Of these 108 samples, an Excellent bioclassification was found for 6%, 34% were Good, 37% were Good-Fair, 17% were Fair and 6% were Poor. More Recently, in 1995, 33 sites were sampled which give an indication of present water quality of mainstem and major tributary sites. Of these sites, 9% were Excellent, 46% were Good, 33% were Good-Fair, 12% were Fair and none were Poor.

- Fish Community Evaluations - In 1995, six sites in the Broad River basin were sampled and rated using the North Carolina Index of Biotic Integrity (NCIBI). The NCIBI ratings at these six sites were: Good-Excellent (1 site), Good (4 sites), and Fair-Good (1 site).
- Fish Tissue Analyses - Fish tissue samples were collected at 8 sites within the Broad River basin between 1988 and 1996 and were analyzed for metals contaminants. All fish tissue samples collected throughout the Broad River basin during this time contained levels of metals contaminants below federal Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) criteria.
- Lakes Studies - Five lakes in the Broad River basin have been sampled as part of the Lakes Assessment Program. These are Lake Lure in subbasin 01, Lake Adger and Lake Summit in subbasin 03, and Lake Montonia and Kings Mountain Reservoir (also known as Moss Lake) in subbasin 030805. All of these lakes were sampled most recently by DWQ in 1995 except for Lake Montonia, which was sampled in 1996. They all have been assigned the trophic status classification of oligotrophic based on the North Carolina Trophic State Index (NCTSI).

Use-Support Ratings

Another important method for assessing surface water quality is to determine whether the quality is sufficient to support the uses for which the waterbody has been classified by the state. All surface waters in the state have been assigned a classification. These classifications are discussed in Chapter 2, Chapter 5 and Appendix I. The word *uses* refers to activities such as swimming, fishing and water supply. All water quality data for a particular stream segment have been assessed to determine the overall *use support* rating; that is, whether the waters are *fully supporting*, *partially supporting* or *not supporting* their uses. A fourth rating, *fully supporting but threatened,* applies where all uses are currently being supported but water quality conditions are marginal. Streams referred to as *impaired* are those rated as either partially supporting or not supporting their uses. Use support ratings in the Broad River basin, described more fully in Chapter 4, are summarized below.

Of the 1,472 miles of freshwater streams and rivers in the Broad basin (based on measurements made from USGS topographic maps), use support ratings were determined for 96% or 1,416 miles of water. The relative breakdown of percentages for the use support categories is as follows:

SUPPORTING	93%
Fully supporting	(67%)
Fully supporting but threatened	(26%)
IMPAIRED	3%
Partially supporting	(3%)
Not supporting	(0%)
NOT EVALUATED	4%

These use support values are different from the values in the 1994-1995 305(b) Report. The total waters supporting their uses appear to have increased, while those that are impaired appear to have decreased. While the water quality may have improved since the 1992-1993 305(b) report, the changes in values are due to revisions in the methodology for assigning use support (this is discussed in section 4.6.5 of Chapter 4).

Top of Page

MAJOR WATER QUALITY ISSUES AND RECOMMENDATIONS

Several water quality issues emerge as being of particular importance in light of factors such as the degree of water quality degradation, the value of the resources being impacted and the number of users potentially affected. Those issues considered most significant on a basinwide scale are presented below. Chapter 6 of the Broad Plan provides recommendations for many other issues including managing inputs of fecal coliform bacteria and oxygen consuming wastes, in addition to specific recommendation for the impaired waters in the basin. The issues presented here are the larger issues of most concern to the Broad basin.

A. RECOMMENDATIONS FOR SPECIFIC, IMPAIRED WATERBODIES

Table 1 provides a description of the four waters in the basin that have been determined to be impaired based on recent monitoring data. These waters, as well as other waters that are considered impaired based on older data, are described in more detail in Chapter 6.

Table 1: Recommended Management Strategies for Monitored Impaired Waters in the Broad River Basin*

Waterbody (subbasin)	Use Support Rating	Probable Source of Impairment	Recommended Management Strategy	Chapter 6 Reference Section
Walnut Creek (030802)	PS	nonpoint source(s) (possibly agricultural runoff)	The landuse in the immediate vicinity of the monitoring location is primarily fallow agricultural fields. DWQ should work with the local agricultural agencies to help farmers in this watershed ensure that appropriate measures are taken to minimize runoff into surface waters from agricultural activities (resources permitting**).	6.4.2
Catheys Creek (030802)	PS	point source (Spindale) and nonpoint source(s) (possibly agricultural runoff)	DWQ will continue to work with point sources to ensure protection of the surface waters through compliance with effluent limits. DWQ should also work with local experts to assess NPS contributions to impairment (resources permitting**).	6.4.2
Beaverdam Creek (030804)	PS	point sources (four small discharges) and nonpoint sources (erosion, sand dredging)	DWQ will require that four discharges upstream of the monitoring site conduct instream monitoring to determine to what extent they are contributing to impairment. DWQ should	6.4.4

			also work with local experts to assess NPS contributions to impairment as well as the impact of the dredging project (resources permitting**).	
Lick Branch (030805)	PS	point source (New Minnette Textiles)	DWQ will monitor the stream for progress since improvements were made to point source situation in late 1995.	6.4.5

** Based on monitored data collected between 1992 and 1996.*
*** Only limited progress towards developing and implementing nonpoint source strategies for these impaired waters can be expected without additional resources.*

B. ADDRESSING IMPACTS FROM WASTEWATER TREATMENT PLANTS

Although much progress has been made in the treatment of wastewater over the past 20 years, three of the four streams in the basin that are impaired based on recent water quality sampling are impacted by point source discharges. In most of the cases, actions have been or will be taken in the forseeable future to mitigate these impacts. However, it will be important during this basinwide planning cycle for DWQ to continue to work with the wastewater discharges of concern to make appropropriate improvements to protect water quality.

In addition, in the Broad River basin's larger river systems (i.e. the First Broad River and Second Broad River) there are issues related to assimilative capacity and wasteload allocation that need to be addressed. These rivers receive waste from a number of both industrial and domestic wastewater treatment facilities and are also influenced by water withdrawals from water treatment systems. DWQ intends to develop calibrated water quality models for these systems during this basinwide cycle to ensure that permitted effluent limitations will protect water quality. Specific recommendations and comments regarding facilities discharging to these rivers are made in Chapter 6 (Section 6.4) of the Broad River Basinwide Water Quality Management Plan.

C. CONTROLLING SEDIMENTATION

Erosion, and resulting sedimentation, are prevalent throughout the basin. Workshop participants (Section 6.2.3) and Nonpoint Source Team members (Section 6.2.2) have expressed that a priority issue for the basin is sedimentation control. Many waters in the basin are thought to be impacted or impaired, at least in part, by sedimentation (Table 4.17 in Chapter 4). The sources of sedimentation are discussed in detail in Chapter 3. Programs to address erosion and sedimentation are discussed in Chapter 5 and Appendix VI. Some of the actions being taken at the local level are discussed in Chapter 5, Section 5.6. General management strategies for controlling sedimentation are presented in Section 6.6.1 of Chapter 6.

Recommendation

Chapter 6 includes recommendations for controlling sedimentation from a variety of land disturbing activities including road and home construction, agriculture and forestry. Tools include use of appropriate best management practices, better enforcement of sediment control regulations and improved eduction.

D. GROWTH MANAGEMENT

Based on data from the USDA Natural Resources Conservation Service, the most significant landcover change between 1982 and 1992, was a 71% increase in the amount of urban land. Proactive planning efforts at the local level are needed to assure that development is done in a manner that maintains the good water quality that is presently attracting people to the area. These planning efforts will need to find a balance between water quality protection, natural resource management and economic growth. Growth management requires planning for the needs of future population increases as well as maintaining a strong tourism base. These actions are critical to water quality management and the quality of life for the residents of the basin.

Recommendation

It is recommended that local governments in the Broad River basin, particularly those in the eastern and western sections, take steps to plan for growth that protects water quality; however, limited progress can be expected without additional resources and technical assistance. The recommendations in Section 6.6.4 for urban stormwater control contain ideas that can help alleviate the impacts resulting from growth.

E. ADDRESSING NONPOINT SOURCE IMPAIRED WATERS

Although point sources of pollution continue to impact water quality in the basin, pollution from nonpoint sources is identified as a significant contributor to some impairment including areas that are identified as supporting their uses but threatened. Ninety-five percent of the 48 miles of waters that are impaired are thought to be impacted, at least in part, by nonpoint sources of pollution. It is recognized that in some cases the information that DWQ has concerning nonpoint source contributions from land uses such as agriculture are dated and general. Accomplishments in managing runoff from agriculture and animal operations that have occurred during the last five years or so (such as Conservation Management Plans in compliance with the Farm Bill, or improved management of waste from animal operations in compliance with new regulations) are not reflected in this information. The reason for this is that the implementation of these programs is just beginning to occur or has occurred subsequent to water quality monitoring. However, agriculture remains prominent in the landscape of the river basin and it will be important to work toward further gains in this area in order to protect water quality.

In addressing nonpoint sources of pollution it is important to acknowledge agency resource constraints. The task of confirming and clearly identifying exact sources, developing management strategies, implementing best management practices and monitoring for water quality improvements is clearly beyond the current resources of DWQ, other agencies involved in managing nonpoint sources and local governments. Only limited progress can be expected unless substantial resources are put toward solving nonpoint source problems. Therefore this basinwide plan lacks specific strategies to address nonpoint source pollution.

Recommendation

As one means of addressing this problem with available resources, DWQ has formed a voluntary nonpoint source team (NPS Team) for the basin. Working with the NPS Team (a knowledgeable team of local professionals and stakeholders) is an avenue for developing NPS priorities as well as targeting and coordinating existing resources within a basin. The NPS Team for the Broad River basin is currently working to develop a project proposal for funding through the federal NPS program (Section 319). The team members participate voluntarily on the team within their existing resource constraints. Limited progress can be expected in restoring impaired waters through the team without additional resources. The NPS team is further discussed in Chapters 6 and 7.

Top of Page

FUTURE INITIATIVES IN THE BROAD RIVER BASIN AND STATEWIDE

There are a number of initiatives that will be occurring in the basin over the next several years. Some are highlighted here. Chapter 7 provides a more thorough characterization of these initiatives.

DEVELOPMENT OF A FIELD - CALIBRATED MODEL

DWQ will be pursuing the development of a more sophisticated model for the larger rivers of the basin, especially the Second Broad River, to better predict point source impacts to surface waters. This model will be used to apply appropriate wastewater treatment effluent limits to dischargers to protect water quality.

INVESTIGATION INTO LONG-TERM IMPACTS OF CHIP MILLS

In response to citizens' increasing concerns regarding the growing chip mill industry, Governor Hunt directed the NC Department of Environment and Natural Resources (NC DENR) to conduct an environmental and economic study of wood chip production in the state. These are facilities that produce wood chips for use in the production of paper products. One of the big concerns about these facilities is their potential to increase the amount of timber harvesting, especially clearcutting. For several months, NC DENR staff have been gathering information needed to identify issues that should be examined in the study. In October of 1997, public meetings were held across North Carolina to receive general public input into this process. Attendance was good and many ideas regarding the scope and nature of the forthcoming study were received.

EFFORTS TO IMPROVE NC'S SEDIMENTATION AND EROSION CONTROL PROGRAM

Recently, there has been an initiative in the Division of Land Resources to address sediment and turbidity water quality problems across the state. The Sedimentation and Erosion Control Commission has recognized the need to evaluate the implementation of the existing programs. A Technical Advisory Committee was established, along with three subcommittees, to perform the evaluation and develop recommendations. The committee and subcommittees met for several months during the fall of 1997 and presented a list of recommendations to the Commission in November. The Commission supported the recommendations and instructed the staff to implement the ones which can be implemented without rule or statute changes and have established a schedule to implement the others. It is believed that the changes initiated will result in program implementation improvements and reduction in sediment losses to our streams.

THE NORTH CAROLINA WETLANDS RESTORATION PROGRAM

The North Carolina Wetlands Restoration Program (NCWRP) was established by the General Assembly in 1996. The purpose of the NCWRP is to protect and improve water quality, flood prevention, fisheries, wildlife and plant habitats, and recreational opportunities through the protection and restoration of wetlands and riparian areas. The NCWRP will accomplish this purpose by implementing projects that will restore wetland and riparian area functions and values throughout North Carolina. Beginning July 1, 1997, comprehensive Basinwide Restoration Plans will be developed for each river basin in conjunction with the Basinwide Water Quality Management Plans. GIS-based mapping methodologies will be used to assess the status of the existing wetlands and riparian area resources within each basin and to identify degraded wetlands and riparian areas. Potential restoration sites will be prioritized based on the ability of the restored sites to address problems that have been identified in the Basinwide Water Quality Management Plans. The restoration plans will provide the framework for the Wetlands Restoration Program, therefore it is essential that the public, local governments, state and federal agencies and others be involved in the development of these plans. Requests for information concerning the NCWRP and the Basinwide Restoration Plans should be sent to the following address: NC Wetlands Restoration Program, Division of Water Quality, P.O. Box 29535, Raleigh, NC 27626-0535.

Top of Page

Ref 2.3 Ref 21

CHAPTER 3
TRANSPORT OF GRAVEL AND SEDIMENT MIXTURES

3.1 FLUVIAL PHENOMENA ASSOCIATED WITH SEDIMENT MIXTURES

When ASCE Manual No. 54, "Sedimentation Engineering," was first published in 1975, the subject of the transport and sorting of heterogeneous sediments with wide grain size distributions was still in its infancy. This was particularly true in the case of bed-load transport. The method of Einstein (1950) was one of the few available at the time capable of computing the entire grain size distribution of particles in bed-load transport, but this capability had not been extensively tested against either laboratory or field data. Since that time there has been a flowering of research on the subject of the selective (or non-selective) transport of sediment mixtures. A brief attempt to summarize this research in a useful form is provided here.

A river supplied with a wide range of grain sizes has the opportunity to sort them. While the grain size distribution found on the bed of rivers is never uniform, the range of sizes tends to be particularly broad in the case of rivers with beds consisting of a mixture of gravel and sand. These streams are termed "gravel-bed streams" if the mean or median size of the bed material is in the gravel range; otherwise they are termed "sand-bed streams." The river can sort its gravel and sand in the streamwise, lateral and vertical directions, giving rise in each case to a characteristic morphology. Summaries of these morphologies are given in Whiting (1996) and Powell (1998); Parker (1992) provides a mechanistic basis for their study.

a) b)

Figure 3.1 Contrasts in surface armoring between a) the River Wharfe, UK, a perennial stream with a low sediment supply (left) and b) the Nahal Yatir, Israel, an ephemeral stream with a high rate of sediment supply (right). From Powell (1998).

Sorting phenomena range from very small scale to very large scale. In many gravel-bed rivers the bed is vertically stratified, with a coarse armor layer on the surface. This coarse layer acts to limit the supply of fine material from the subsurface to the bed-load at high flow. Some gravel-bed streams, however, show no stratification in the vertical. An example of each type is shown in Figure 3.1. The difference between the two is that the image on the left pertains to a perennial stream with low sediment supply and moderate floods, whereas the image on the right pertains to an ephemeral stream with a high sediment supply and violent floods.

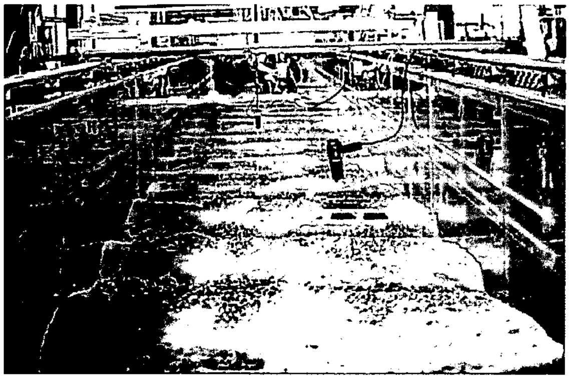


Figure 3.2 Sediment sorting in the presence of a dune field. Flow was from top to bottom. Image courtesy A. Blom.

If the flow is of sufficient strength bedforms such as dunes can form in gravel-bed streams (e.g. Dinehart, 1992). Dunes are the most common bedform in sand-bed streams. Depending on the strength of the flow the parent grain size distribution can interact with the bedforms to induce strong vertical and streamwise sorting, with coarser material accumulating preferentially in dune troughs. This is illustrated in Figure 3.2. Note that the transition from lower-regime plane bed to dunes, which is illustrated in Figure 2.19 thus engenders a reversal of vertical sorting, with a coarse layer at the top of the bed in the former case and near the base of the dunes in the latter case.

Under conditions of weak transport the dunes devolve into bed-load sheets, which are rhythmic waves expressing downstream variation predominantly in terms of alternating zones of fine and coarse sediment rather than elevation variation (Figure 3.3). Both dunes and bed-load sheets result in a bed-load transport that strongly pulsates in terms of both total rate and characteristic grain size.

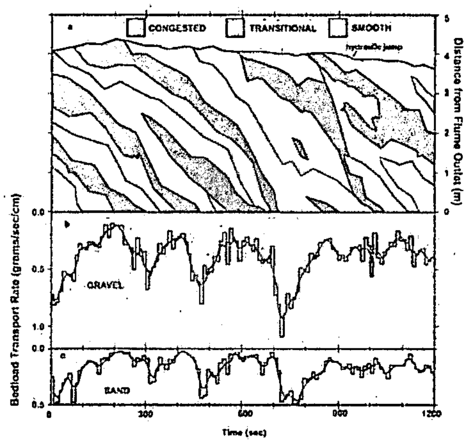


Figure 3.3 Pulsations associated with experimental bedload sheets composed of a mixture of sand and gravel. a) Alternating arrangement of three bed states. b) Fluctuation in gravel transport rate. c) Fluctuation in sand transport rate. From Iseya and Ikeda (1987).

When bars and bends form in rivers they interact with the sediment to produce sorting morphologies at larger scale. Figure 3.4 shows a mildly sinuous reach of the Ooi River, Japan. It is readily apparent that bar heads tend to be coarser, whereas bar tails tend to be finer. Similar patterns can be observed in the bars of braided streams.

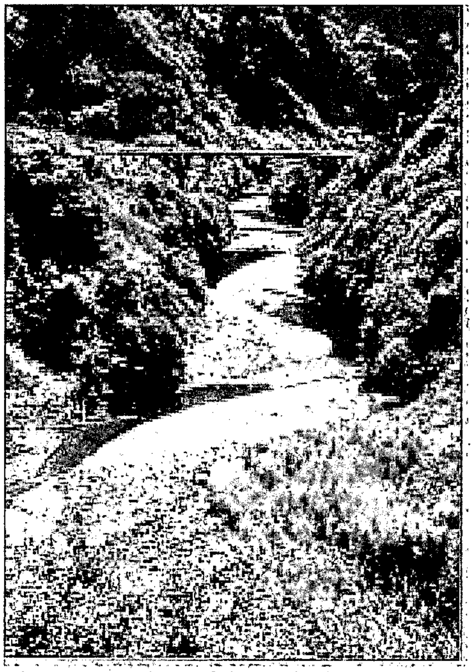


Figure 3.4 View of the Ooi River, Japan, showing sorting of gravel and sand on bars. From Ikeda (2001).

At sufficiently steep slopes bars give way to pool-riffle sequences, which are bar-like undulations in bed elevation and grain size that are for the most part expressed in the streamwise rather than the lateral direction. As opposed to dunes and some bars, pool-riffle patterns usually show little tendency to migrate downstream. At even steeper slopes, which support flow that is supercritical in the Froude sense during floods, the bed devolves into a well-defined step-pool pattern. Each step is defined by what might be described as a boulder jam, as seen in Figure 3.5; the pools between steps contain much finer material.

A lake or reservoir interrupts the downstream transport of sediment. As a result, the river bed often aggrades upstream of the dam and degrades downstream. Figure 3.6 shows the aggradational deposit upstream of a sediment retention dam on the North Fork Toutle River, Washington, USA. Over the 10 km upstream of the dam, characteristic bed sediment size shows a pronounced pattern of downstream fining, declining from about 7.4 mm to 0.4 mm. This downstream fining appears to be abetted by the tendency of the bed to devolve into local patches or lanes of finer and coarser sediment. Figure 3.7 illustrates two such patches on the North Fork Toutle River. An extreme limiting case of such local segregation is the formation of roughness "streaks," "stripes" or "ribbons," which consist of vertical lanes of alternating coarse and fine material, with a high transport rate of the latter relative to the former. These streaks are shown in Figure 3.8.

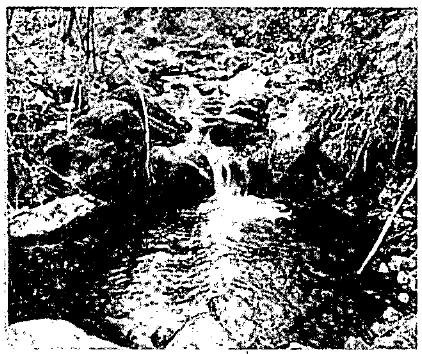
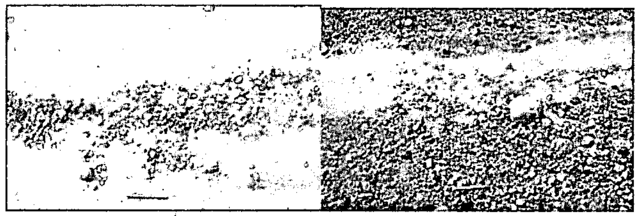


Figure 3.5 Step-pool topography in the Hiyamizu River, Japan. Image courtesy K. Hasegawa

Downstream of a dam, on the other hand, the bed often both degrades and coarsens in response to the cutoff of sediment, eventually forming a static or nearly static armor which inhibits further bed erosion. An image of the static armor downstream of the Lewiston Dam on the Trinity River, California, USA is shown in Figure 3.9. The static armor is partially covered by mobile, pea-sized gravel from a tributary entering downstream of the dam.

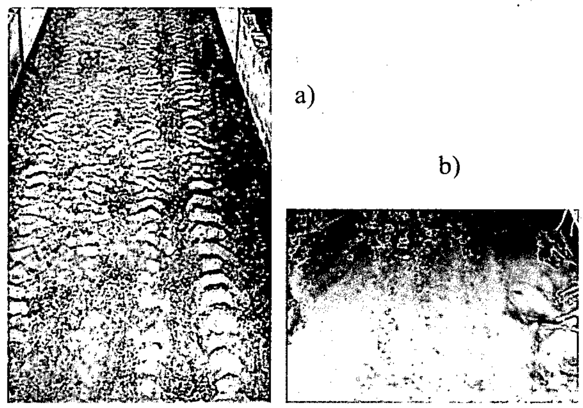
Sorting appears at the largest scale in terms of the tendency for characteristic grain size to become finer over 10's or 100's of km. This large-scale downstream fining

Figure 3.6 View of sedimentation upstream of a sediment retention dam on the North Fork Toutle River, Washington, USA. Flow is from bottom to top. From Seal and Paola (1995).



a) b)

Figure 3.7 Sorted sediment patches on the North Fork Toutle River, Washington, USA: a) coarse patch on fine sediment; b) fine patch on coarse sediment. From Paola and Seal (1995).



a) b)

Figure 3.8 Streaks of sorted sediment in a) a laboratory flume (from Günter, 1971; courtesy A. Müller), and b) a river (image courtesy T. Tsujimoto).

a) b)

Figure 3.9 Coarse static armor (dark grains) with a partial coverage of finer, mobile sediment (light grains) on the bed of the Trinity River, California, USA. The coarse grains are rendered immobile by the presence of the Lewiston Dam upstream. Image courtesy A. Bartha. a) View of the river. b) Closeup of the bed.

is typically associated with a long profile of the river that is concave upward. A famous example, that of the Kinu River, Japan is shown in Figure 3.10. This river not only displays downstream fining, but also a relatively abrupt transition from gravel-bed to sand-bed. Downstream fining is observed strongly along the gravel-bed reach, and rather more weakly along the sand-bed reach.

Abrupt gravel-sand transitions are quite common in the field, and are associated with the tendency for grain sizes in the range of pea gravel to be relatively scarce in

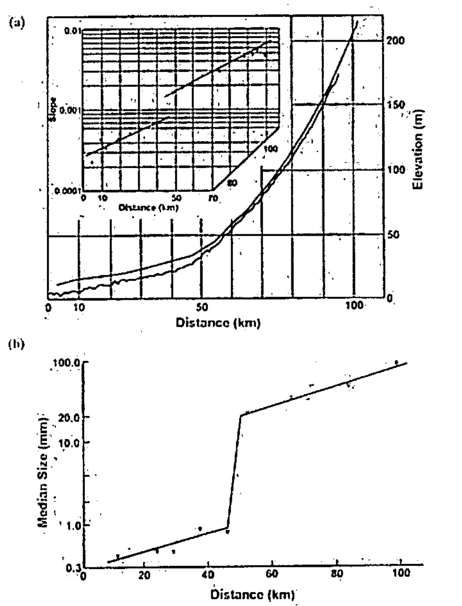


Figure 3.10 a) Long profile and b) downstream change in grain size of the Kinu River, Japan, illustrating downstream fining and a gravel-sand transition. Redrafted from an original in Yatsu (1955).

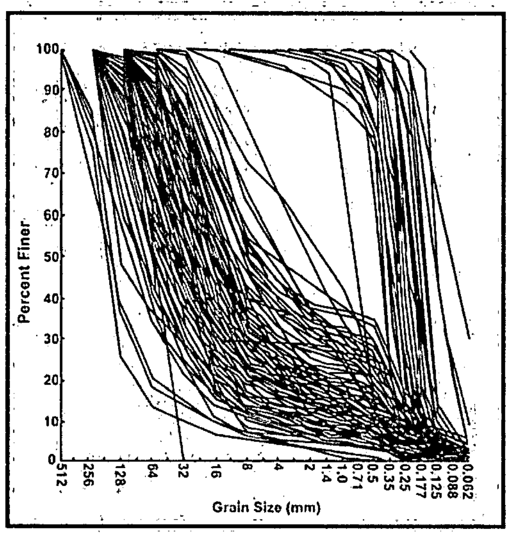


Figure 3.11 Grain size distribution of 174 samples of bed sediment from rivers in Alberta, Canada. From Shaw and Kellerhals (1982).

rivers. This tendency is common but by no means universal. An example of this tendency is shown in Figure 3.11, which shows the bed material grain size distributions of 174 river reaches in Alberta, Canada (Shaw and Kellerhals, 1982). Note that the sand-bed streams (median size in the sand range) contain very little gravel. The gravel-bed streams (median size in the gravel range) often contain a substantial amount of sand, but very little material between 1 and 8 mm.

Figure 3.12 View of a landslide that blocked the Navarro River, California., USA in 1995. Image courtesy T. Lisle.

Transient sorting can be induced by a pulse of sediment introduced into a river from a debris flow or landslide. An example illustrating a landslide that flowed into and blocked the Navarro River, California, USA is shown in Figure 3.12. Such inflows often contain copious amounts of material that is much finer than the ambient bed material. They can also contain some material that is much coarser than the ambient bed material. Grain size sorting plays a key role in the process by which rivers "digest" such sediment inputs.

Most sediment sorting in rivers is accomplished by the differential transport of different sizes. In the case of heavy minerals (placers) however, increased specific gravity replaces the role of increased size. The issue is of some interest in regard to the extraction of placer gold from rivers. It may appear to be intuitively obvious that finer grains are more mobile than coarser grains of the same specific density. This is usually but not always the case.

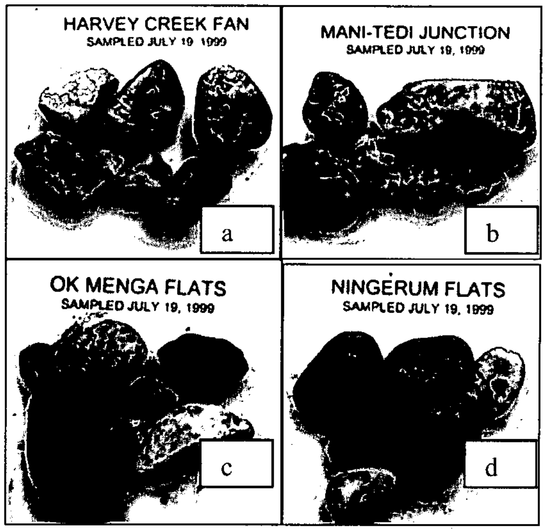


Figure 3.13 Four sediment samples from the Ok Tedi River system, Papua New Guinea.
a) 1 km downstream of the Southern Dumps of the Ok Tedi Mine, and after having passed over a high waterfall, in the Harvey Creek debris flow fan as it enters the Ok Mani;
b) 8 km downstream, at the fluvial fan of the Ok Mani where it enters the Ok Tedi;
c) 27 km downstream on the Ok Tedi near the junction with the Ok Menga; and
d) 90 km downstream on the Ok Tedi at Ningerum Flats.
Note that the grains become progressively rounder as the distance from the source increases.

In addition to selective transport, however, rivers have the opportunity to create finer grains from coarser grains. This is sometimes accomplished by shattering of grains, but is more commonly associated with a gradual abrasion and rounding of stones, yielding silt and some sand as a result. Abrasion can thus be a contributor to downstream fining. Figure 3.13 illustrates the effect of abrasion in gradually rounding grains downstream from their source.

The main focus of this chapter is on transport of mixed sizes and concomitant sorting in bed-load-dominated rivers. In the field, this usually means gravel-bed rivers. Some (typically small) sand-bed streams, such as Muddy Creek (Dietrich and Whiting, 1999) also satisfy this criterion. Near the end of the chapter, however, suspension-dominated rivers, i.e. most sand-bed streams, are considered as well.


Figure 3.14 Evidence of channel degradation on the Mad River, California under the Highway 101 bridge.

3.2 ENGINEERING RELEVANCE

Various aspects of grain sorting are of relevance to river engineering design, habitat maintenance and restoration of river ecosystems. First and foremost among these is gravel extraction, or mining from rivers for concrete aggregate and other construction purposes. The word "gravel" is used loosely in regard to gravel mining, and includes sand as well. The mining of fluvial gravels is particularly common in the western part of the United States. Gravel mining without appropriate constraints can lead to severe bed degradation downstream, with the resulting failure of bridges, exposure of buried pipelines etc. (Galay, 1983). The Mad River, California, USA has been heavily utilized for gravel extraction. The effect on bed elevation at the bridge piers where Highway 101 crosses the river is readily apparent in Figure 3.14. Gravel extraction was taking place on the day the photo was taken. Engineering models of the erosion, transport and deposition of heterogeneous gravels have an important role to play in determining how much gravel can be safely extracted without adverse effects.

A common practice in many western rivers is "bar scalping," by which high-quality material is locally stripped from the surface of bars. This is done on the supposition that the river will eventually replace the mined gravel with material of similar competence. Anadromous fish such as salmon, however, are rather particular about the gravels in which they choose to build redds (egg nests) (Reiser, 1998). If the bed material is too coarse the fish cannot excavate a redd. If the bed is too fine, and in particular if it contains too much sand and silt, the fish will avoid it, instinctively knowing that the eggs will be suffocated and poisoned by inability for groundwater flow to carry away excreta. The Ooi river of Figure 3.4 might be a good candidate for bar scalping in the United States, but in Japan gravel extraction from most rivers has been banned in order to control bed degradation. This degradation is not only a product of gravel mining in previous times, but also due to the fact that intensive sediment control works (e.g. sabou dams) in the upstream reaches of Japanese rivers have dramatically reduced the sediment supply.

Spawning grounds can also be damaged or destroyed by the activities of agriculture or forestry. Road building due to forest harvesting in particular can, if not done appropriately, cause massive inputs of sand and finer material to a stream that is intrinsically gravel-bed. This finer material is usually transient, being washed downstream by successive floods. If the bed happens to be buried in "fines," however, just before spawning, fish recruitment can drop drastically (e.g. Reiser, 1998).

The installation of a dam on a river typically blocks the downstream delivery of all but the finest sediment, creating a pattern of bed aggradation upstream. The dam raises base level, i.e. the downstream water surface elevation to which the river upstream must adjust, forcing upstream-migrating deposition. This deposition is most intense near the delta at the upstream end of the reservoir. As a result, the effect is to intensify the upward concavity of the long profile of the bed upstream of the dam. The more sharply declining bed slope intensifies selective transport of fine material, setting up strong local downstream fining. This is what has taken place in the reservoir of the North Fork Toutle River, Washington, USA illustrated in Figure 3.6.

This downstream fining has a beneficial effect in terms of engineering that should be taken into consideration when designing dams. The aggradation induced by dams can require the leveeing of towns upstream of the dam. Sorting, however, tends to concentrate the aggradation toward the downstream end of the reach in question. Indeed, Leopold et al. (1964) have observed that the upstream aggradation driven by a dam never extends infinitely far upstream, no matter how much time has passed. Part of the reason for this is the tendency for the main stem and tributaries farther upstream in the drainage basin to absorb the effect of the dam. This is because sediment sizes which deposit in the backwater zone of the dam can be carried without deposition by steeper main stem and tributaries upstream.

An extreme case of this tendency for sorting to damp upstream effects is often seen on gravel-bed streams, many of which carry loads of sand that are far in excess of the corresponding loads of gravel, yet the bed surface consists for the most part of gravel, with sand partially or completely filling the interstices. In analogy to the mud washload of sand-bed rivers, this sand load on a gravel-bed stream is called "throughput load" if it interacts only passively with the bed, i.e. simply filling the pores of a gravel deposit. Sand can be carried as throughput load over a gravel bed when the rate of sand input necessary to drown the bed in sand is higher than the prevailing sand input. In gravel-bed rivers, the disparity between the two becomes increasingly large with increasing bed slope. The threshold for major sand deposition is crossed as bed slope declines. As a result, the sandy deposit caused by a dam migrates upstream only so far as the stream becomes sufficiently steep to prevent it from covering the bed completely.

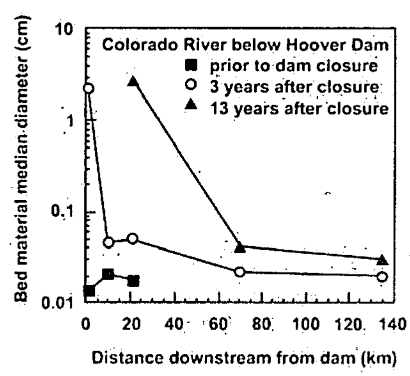


Figure 3.15 Bed surface median grain size downstream of Hoover Dam on the Colorado River before and after closure. From Williams and Wolman (1984).

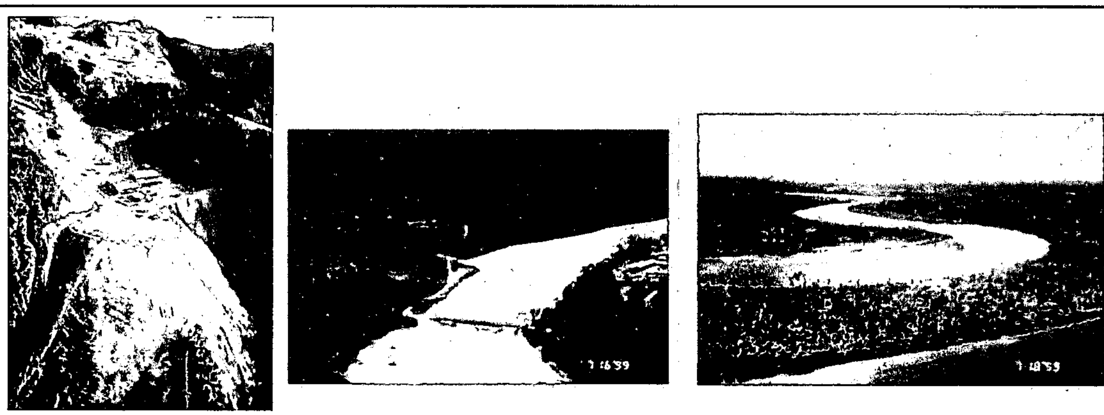
The dam in Figure 3.6 was installed as a debris control measure in the wake of the Mount St. Helens eruption in 1980. Such dams play an important role in disaster mitigation. At the time of Figure 3.6 the dam was nearly full. Understanding the process of filling requires an understanding of the transport of sediment mixtures.

The cutoff of sediment at a dam often induces bed degradation, as the river mines itself to replace the lost load. Bed degradation rarely continues unabated. Even small amounts of coarse, erosion resistant material in the substrate tend to concentrate on the bed surface as the bed degrades, eventually limiting the process through the formation of a static armor. An example of the time evolution of bed armoring is given in Figure 3.15 (Williams and Wolman, 1984) for the Colorado River downstream of Hoover Dam.

It would be a mistake, however, to believe that the installation of a dam universally causes bed degradation downstream. As illustrated in Figure 2.26, bank-full flows in gravel-bed rivers often correspond to conditions that are not greatly higher than that needed to mobilize the gravel. When dams are operated for flood control, so as to cut off the flood peaks needed to mobilize the gravel, the river can lose most of the capacity to move gravel. As a result, downstream of the first tributary the river bed aggrades, as the sediment from the tributaries reaches a main stem that is no longer competent to transport it. This process has been documented in e.g. the Peace River, Canada, downstream of the W. A. C. Bennett Dam (Kellerhals and Gill, 1973).

The Trinity River, California, USA downstream of the Lewiston Dam provides a type example of the downstream effects of a dam (Kondolf and Wilcock, 1996). This dam not only cuts off the sediment, but also maintains a constant flow that is well below bank-full flow. From the dam to the first major tributary downstream not only is the gravel not replenished, but the lack of flows necessary to mobilize it have allowed the interstices of the gravel to become filled with debris that is not cleaned out by floods (Figure 3.9). This lack of renewal not only degrades the gravel bars as spawning habitat, but leads to a general decline in the ecological productivity of the system. The first tributary brings in a substantial quantity of corn-sized grains of weathered granite that partially fill the pores of the gravel and further degrade habitat. The loss of flood flows has also caused channel narrowing associated with the encroachment of alders as well as humans, the latter being lulled by the lack of flood flows. The renewal of such a stream requires at the least controlled flood releases from the dam. How much, and how long must be determined at least partially in terms of the mobility of the various sizes of sediment in the bed (Wilcock et al, 1996).

Dam removal has become quite popular in recent years, the main motivating factor being habitat improvement and stream restoration. A lack of understanding of the transport mechanics of heterogeneous sediments has often led to the complete excavation of the deposit behind the dam, even when the sediment is uncontaminated. This lack of understanding is a relative one; the techniques necessary to evaluate the fate of both coarse and fine sediments released from a dam, and thus whether or not removal is necessary, are available, but have not usually been put into practice. Fortunately, however, a description of one version of the technology is provided as an Appendix to this manual (Cui and Wilcox, this volume, Appendix A). Developments in the area of river restoration can be found in Hay (1998) and Hotchkiss and Glade (2000).



a) b) c)

Figure 3.16 a) View of waste rock dump site at the Ok Tedi Mine, Papua New Guinea. b) View of the gravel-bed Ok Tedi downstream of the mine. The channel bed has aggraded and widened in response to disposal of mine sediment. c) View of the sand-bed Fly River downstream of its confluence with the Ok Tedi. Aggradation of bed sediment has exacerbated both flooding and the overbank deposition of fine sediment, resulting in the loss of riparian forest.

The disposal of mine waste into a river can lead to massive bed aggradation. This aggradation is almost invariably associated with a pattern of downstream fining. The Ok

Tedi copper/gold mine in Papua New Guinea is a case in point (Parker et al., 1996; Dietrich et al., 1999). Throughout much of the latter 1990s' the mine disposed some 40 Mt/year of waste rock and 30 Mt/year of tailings into a river system characterized by a steep gravel-bed reach with a fairly sharp transition to a sand-bed reach (Figure 3.16). The extreme overloading of the system has caused massive channel and floodplain deposition, as well as a major modification in the pattern of downstream fining. Input sizes range from boulders to silt. The coarse material contains several mineral types, some of which are highly subject to abrasion. The effect of wear on the coarser grains is illustrated in Figure 3.13; the degree of overloading makes it highly likely that all grains in the image originated from the mine. Any numerical model designed to track the fate of the sediment, the evolution of the river profile and the design of countermeasures must account for downstream fining, abrasion of several rock types and overbank deposition of finer material. Cui and Parker (1999) describe such a model. Part of the model was adapted for studying the effects of dam removal (Cui and Wilcox, this volume, Appendix A).

The above examples represent a subset of the engineering problems requiring a description of the selective transport of heterogeneous sediments. Other examples include woody debris in rivers, flow augmentation by diversion, the effect of extreme floods, the fate of contaminated sediments from mines and industrial sites, avulsion on alluvial fans and the competence of riprap placed on or in an alluvial bed to resist scour.

3.3 GRAIN SIZE DISTRIBUTIONS

3.3.1 Definitions and Continuous Formulation

The sedimentological phi scale introduced in Chapter 2 has the disadvantage that grain size decreases as the value of ϕ increases. With this in mind, the alternative ψ scale is introduced (Parker and Andrews, 1985); where D denotes grain size in mm

$$\psi = \frac{ln(D)}{ln(2)}, \quad D = 2^{\psi} \tag{3.1a,b}$$

Thus $\psi = -\phi$. Let $p(\psi)$ denote the probability density by weight of a sample associated with size ψ, and $p_f(\psi)$ denote the associated probability distribution. Then by definition,

$$\int_{-\infty}^{\infty} p(\psi)d\psi = 1, \quad p_f(\psi) = \int_{-\infty}^{\psi} p(\psi)d\psi \tag{3.2a,b}$$

Thus $p_f(\psi)$ denotes the fraction of the sample that is finer than size ψ. Let x denote some percentage, say 50%, and ψ_x denote the grain size on the ψ scale such that x percent of the sample is finer. It then follows that

$$p_f(\psi_x) = \frac{x}{100} \tag{3.3}$$

The corresponding grain size in mm D_x is given from (3.1b) as

$$D_x = 2^{\psi_x} \tag{3.4}$$

A value $x = 50$ yields the median grain size D_{50}; the value $x = 90$ yields the value D_{90} such that 90 percent of the sample is finer, a value commonly used in the computation of the roughness associated with skin friction (grain roughness).

The arithmetic mean ψ_m and arithmetic standard deviation σ_m of the grain size distribution are given as

$$\psi_m = \int \psi p(\psi)d\psi \,, \quad \sigma^2 = \int (\psi - \psi_m)^2 p(\psi)d\psi \tag{3.5a,b}$$

The corresponding geometric mean D_g and geometric standard deviation σ_g are then given as

$$D_g = 2^{\psi_m} \,, \quad \sigma_g = 2^{\sigma} \tag{3.6a,b}$$

Sediment samples with values of σ_g in excess of 1.6 are said to be poorly sorted (Chapter 5, this volume). Poorly sorted sediment provides grist for the mill of the river as it sorts it spatially over the planform and in the vertical.

A grain size distribution is said to be unimodal if the density $p(\psi)$ displays a single peak and bimodal if it displays two peaks. The grain size densities and distributions associated with unimodal and bimodal distributions are illustrated in Figures 3.17a,b. Comparing Figures 3.11 and 3.17a,b, it is seen that the sediment samples from the sand-bed streams of the former diagram, i.e. those for which D_{50} is in the sand size are unimodal, and those from the gravel-bed streams of the former diagram, i.e. those for which D_{50} is in the gravel range, are bimodal, with peaks in the sand and gravel range and a paucity in the pea gravel range (2 – 8 mm). It is not accurate to say that the sediment in all sand-bed streams is unimodal and the sediment in all gravel-bed streams is bimodal, but this tendency is observed.

The simplest realistic analytical forms for the probability density and distribution of grain sizes is the log-normal form (normal distribution of the logarithm of grain size) i.e.

$$p(\psi) = \frac{1}{\sqrt{2\pi}\,\sigma} exp\left(-\frac{(\psi - \psi_m)^2}{2\sigma^2} \right)$$
$$p_f(\psi) = \frac{1}{\sqrt{2\pi}\,\sigma} \int_{-\infty}^{\psi} exp\left(-\frac{(\psi' - \psi_m)^2}{2\sigma^2} \right) d\psi' \tag{3.7a.b}$$

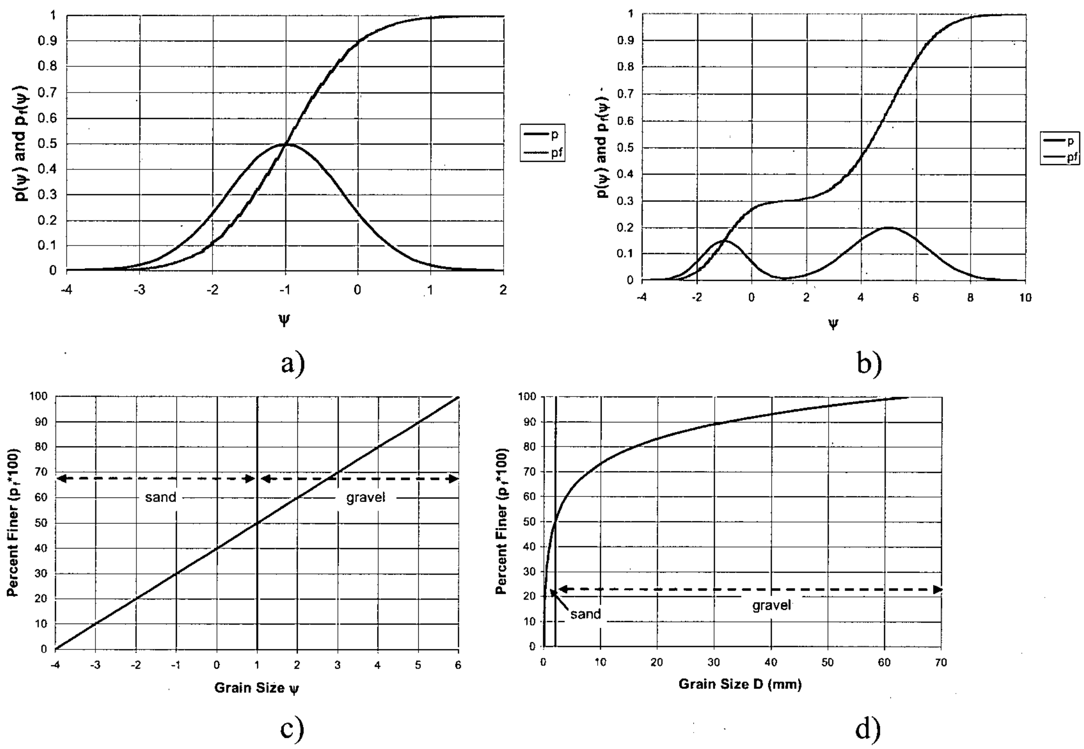


Figure 3.17 a) Diagram illustrating the probability density and distribution functions of a unimodal sediment sample. b) Diagram illustrating the probability density and distribution functions of a bimodal sediment sample. c) Plot of probability distribution function for a sand-gravel mix with constant content density as percent finer versus logarithmic grain size ψ. d) Plot of the same probability distribution function versus D in mm on a linear scale.

Eq. (3.7a) describes a symmetric, unimodal probability density that often provides a reasonable fit for samples from sand-bed streams, but rarely does so in the case of gravel-bed streams. (The size densities of gravel-bed streams with a bimodal mix of sand and gravel can sometimes be approximated as the weighted sum of two log-normal densities.)

In the case of a sediment sample that is log-normally distributed, it can be shown that the mean size ψ_m and the standard deviation σ are given by the relations

$$\psi_m = \frac{1}{2}(\psi_{84} + \Psi_{16}), \quad \sigma = \frac{1}{2}(\psi_{84} - \Psi_{16}) \tag{3.8a,b}$$

The corresponding geometric mean and geometric standard deviation are

$$D_g = \sqrt{D_{84} D_{16}}, \quad \sigma_g = \sqrt{\frac{D_{84}}{D_{16}}} \tag{3.9a,b}$$

It should be emphasized, however, that Eqs. (3.9a,b) are not generally accurate when the distribution cannot be approximated as log-normal, in which case D_g and σ_g must be computed from Eqs. (3.5) and (3.6).

The necessity of using a logarithmic scale when treating the grain size distributions of poorly sorted river sediments cannot be overemphasized. Consider a size distribution that is 1/2 sand (0.0625 mm – 2 mm) and 1/2 gravel (2 mm – 64 mm), uniformly distributed over all sizes. A plot of the distribution versus the logarithmic scale ψ (equivalent to a logarithmic scale for D) is given in Figure 3.17c; the corresponding plot using a linear scale for D is given in Figure 3.17d. Figure 3.17c clearly reflects the fact that half of the sample is sand and half is gravel, whereas in the case of Figure 3.17d the sand is squeezed into a tiny range on the left-hand size of the graph. The use of statistics based on D rather than any logarithmic scale for D (such as ψ) implies the computation of an arithmetic mean grain size D_m, given as

$$D_m = \int Dp(D)dD \tag{3.10}$$

rather than the geometric mean grain size D_g given from Eqs. (3.5a) and (3.6a). In the case of the distribution of Figures 3.17c and 3.17d, the two differ substantially; D_g is equal to 2 mm, reflecting the fact that the sample is half sand and half gravel, whereas D_m is 9.25 mm, reflecting a strong bias toward the coarse material

These comments notwithstanding, at least three bed-load transport relations for mixtures discussed below in Section 3.7, i.e. Ashida and Michiue (1972), Tsujimoto (1991; 1999) and Hunziker and Jaeggi (2002) define and use D_m rather than D_g.

3.3.2 Discretization of the Grain Size Distribution

While grain size density and distribution are continuous concepts, they must be discretized in order to handle data from rivers. Let the size range within which a sediment sample has content be divided into n intervals bounded by $n + 1$ grain sizes ψ_i, $i = 1..n+1$. The following definitions are made; for $i = 1..n$ ordered in increasing size,

$$\overline{\psi}_i = \frac{1}{2}(\psi_i + \psi_{i+1}), \quad p_i = p_f(\psi_{i+1}) - p_f(\psi_i), \quad \Delta\psi_i = \psi_{i+1} - \psi_i \tag{3.11a,b,c}$$

Note that by definition

$$\sum_{i=1}^{n} p_i = 1 \tag{3.12a}$$

The discretized versions of Eqs. (3.5a,b) and (3.10) are then

$$\psi_m = \sum_{i=1}^{n} \overline{\psi}_i p_i \, , \quad \sigma^2 = \sum_{i=1}^{n} (\overline{\psi}_i - \psi_m)^2 p_i \, , \quad D_m = \sum_{i=1}^{n} D_i p_i \qquad (3.12b,c,d)$$

The following notations are used to characterize sediment size distributions. Gravel-bed rivers often show some degree of armoring (coarsening) of the sediment at the surface of the bed compared to the substrate below, so it is useful to distinguish between the two. The fractions in the surface layer of the bed are denoted as F_i; the median size, geometric mean size, arithmetic standard deviation, geometric standard deviation and arithmetic mean size of the surface sediment are denoted as D_{50}, D_g, σ, σ_g and D_m, respectively. The fractions within the substrate at elevation z are denoted as $f_i(z)$. The fractions averaged over a relatively thick layer of substrate just below the surface layer are denoted as $\bar{f}_i$; the corresponding median size, geometric mean size, arithmetic standard deviation, geometric standard deviation and arithmetic mean size of the substrate sediment are denoted as D_{u50}, D_{ug}, σ_u, σ_{ug} and D_{um}, respectively. The fractions in the bed-load transport are denoted as f_{bi}.

3.3.3 Sampling of Bed Sediments

The subject of the sampling of river bed sediments is treated in depth in Chapter 5 of this volume as well as Bunte and Abt (2001), and so only a short summary is given here. There are two basic types of sediment samples in the field. The first of these is the bulk sample, according to which a large amount of sediment is removed in bulk from the bed. Church et al. (1987) provide rigorous criteria for accurate sampling. They indicate that each bulk sample should be sufficiently large such that the largest stone in the sample is not more than 1% of the total sample weight. They also provide guidelines for the areal distribution of bulk samples. A careful areal distribution of samples is often necessary because wherever the sediment is poorly sorted, the distribution itself is likely to vary from place to place.

The second kind of sample is the Wolman point count sample. Such a sample can be obtained by defining a grid on the bed and sampling those particles at each node of the grid (Wolman, 1954). Alternatively, the bed can be paced according to a conceptual grid, and 100 or more grains exposed on the surface may be sampled randomly near e.g. the toe of one's shoe (preferably with one's eyes shut). Such a sample is biased toward the coarse grains in two ways. Firstly, the method is usually appropriate only for gravel-sized grains; it is very difficult to pick up single sand grains. Secondly, even those grains that are sampled are systematically biased toward coarser sizes if analyzed in terms of percent finer by weight, as demonstrated in Kellerhals and Bray (1971).

Kellerhals and Bray (1971) have suggested a simple equivalency by which a Wolman sample analyzed in terms of percent finer by number of grains is a good approximation to a bulk sample of the same parent material analyzed by weight. This approximate conversion has generally stood the test of time with only minor modifications; see Chapter 5 of this volume, Diplas and Sutherland (1988) and Fripp and Diplas (1993) for more details. The equivalency only holds, however, when the bulk sample has been truncated so as to exclude sizes that are too small to sample by means of the Wolman technique.

Useful variations on these two techniques have been proposed. In the freeze-core technique, a hollow rod is pounded into the bed and liquid carbon dioxide is introduced into the rod. The evaporation of the carbon dioxide causes the sediment adjacent to the rod to freeze to it. The sample is obtained by hoisting the rod out. Freeze-core sampling has the advantage of obtaining a sample with minimal disturbance. It is however, biased toward the coarser sizes around the edge of the sample. Rood and Church (1994) describe a modified freeze-core technique based on a frozen barrel that helps overcome this disadvantage.

A second technique may be called the Klingeman surface sample (Klingeman et al., 1979). In this case a circle is placed over the bed surface. The circle should have a radius that is at least 10 times the largest stone exposed on the surface. This stone is then removed, and all the sediment is removed to the deepest level exposed by the stone. This method has the advantage of sampling not only the coarse grains on the bed surface, but also those finer grains, including sand, that would be exposed by the removal of the coarse grains. In addition, Klingeman samples can be obtained in deep gravel-bed rivers with the use of a cylindrical "cookie cutter" with a serrated bottom that can be worked into the bed by divers. The stilling of the flow in the cylinder helps prevent the loss of the finer part of the sample as it is collected by divers.

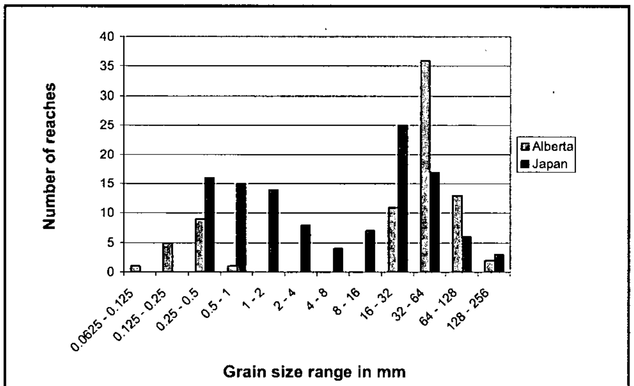


Figure 3.18 Plot of number of reaches for which characteristic grain size is within the specified grain size range for streams in Alberta, Canada and Japan.

In general the Wolman surface sample best serves to characterize the grain roughness offered by the bed surface, whereas the Klingeman surface sample best characterizes the material immediately available for transport under flow conditions sufficient to mobilize the larger surface grains. As a result, Klingeman samples are often used to characterize the grain size distribution of the active layer, i.e. the bed layer that exchanges directly with the bed-load, in gravel-bed streams.

3.4 DIMENSIONLESS BANK-FULL RELATIONS FOR GRAVEL-BED AND SAND-BED STREAMS

Alluvial rivers can be broadly divided into two types, i.e sand-bed streams, for which surface median size D_{50} falls in the range 0.0625 – 2 mm, and gravel-bed streams, for which $2 < D_{50} < 256$ mm. Here cobbles and gravel are grouped together for simplicity. The dividing line between the two is not arbitrary; streams with a characteristic size between 2 and 16 mm (pea gravel) are relatively rare. This is illustrated below using two sets of data. One set pertains to 78 river reaches in Alberta, Canada contained in Kellerhals et al. (1972). The other set is a combination of two sets pertaining to a total of 115 reaches in the Japanese archipelago (Yamamoto, 1994; Fujita et al., 1998; K. Fujita kindly provided the full data set). In Figure 3.18 the number of river reaches in each set with a characteristic grain size falling with each specified grain size range is plotted. The two sets are not completely comparable; whereas (surface) D_{50} is used in the Alberta data, the Japanese data are based on size D_{bulk60}, where the subscript "*bulk*" denotes bulk. The difference between the two is likely to be appreciable only for gravel-bed streams, for which surface median size D_{50} can be more than twice the substrate median size D_{u50}, and thus substantially larger than D_{bulk60}.

In the case of the Alberta streams the division between sand-bed and gravel-bed streams is complete; there are no streams in the set with values of D_{50} between 1 and 16 mm. In the case of the Japanese streams every size range is represented, but there is a clear paucity of streams with D_{bulk60} between 2 and 16 mm, with the lowest number of reaches in the range 4 – 8 mm.

Modeling of the transport of sediment mixtures in rivers requires some feel for how the rivers behave. Alluvial rivers tend to construct their channel geometries and floodplains in consistent ways. This geometry can be characterized in terms of bank-full characteristics, where bank-full conditions are attained when the river is just beginning to spill out of its channel and onto its floodplain. Bank-full conditions can be most easily defined in terms of a rating curve of stage ξ (water surface elevation) versus flow discharge Q. When the flow is confined within the channel, stage increases relatively rapidly with discharge. As stage increases the water spills out onto the floodplain, so that even substantial increases in discharge beyond bank-full discharge Q_{bf} yield much smaller increases in stage. A plot of ξ versus Q allows the determination of Q_{bf} as shown in Figure 3.19.

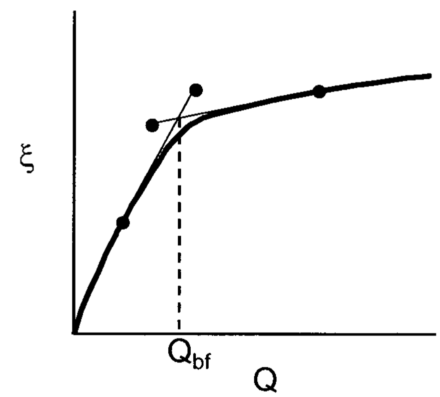


Figure 3.19 Diagram illustrating the definition of bank-full discharge in terms of the stage-discharge (ξ - Q) relation.

At any given point along the river an average down-channel bed slope S can be defined. Once bank-full discharge Q_{bf} is identified the bank-full channel width B_{bf} and average depth H_{bf} can be determined from cross-sectional shape. Bank-full flow velocity U_{bf} is given from continuity as

$$U_{bf} = \frac{Q_{bf}}{B_{bf} H_{bf}} \tag{3.13}$$

A characteristic bank-full boundary shear stress τ_{bbf} and shear velocity u_{*bf} can be estimated from the depth-slope product rule for normal (steady, uniform) flow in open channels;

$$\tau_{bbf} = \rho g H_{bf} S , \quad u_{*bf} = \sqrt{\frac{\tau_{bbf}}{\rho}} = \sqrt{g H_{bf} S} \tag{3.14a,b}$$

where ρ denotes water density. It is useful to define two dimensionless friction coefficients C_{fbf} and Cz_{bf} as

$$C_{fbf} = \frac{\tau_{bbf}}{\rho U_{bf}^2} = \frac{g H_{bf} S}{U_{bf}^2} , \quad Cz_{bf} = \frac{U_{bf}}{u_{*bf}} = C_{fbf}^{-1/2} \tag{3.15a,b}$$

The friction coefficient C_{fbf} is of the standard form used in the study of fluid mechanics, and is precisely equal to the corresponding D'arcy-Weisbach friction coefficient divided by 8. The parameter Cz_{bf} may be called a dimensionless Chezy resistance coefficient, because between Eqs. (3.14b) and (3.15b) it is found that

$$U_{bf} = Cz_{bf} \sqrt{g H_{bf} S} \tag{3.16}$$

i.e a form of the Chezy relation for flow velocity.

The friction coefficients C_{fbf} and Cz_{bf} are examples of dimensionless numbers. In the study of natural phenomena a dimensional number such as bank-full depth may vary greatly from site to site, whereas an appropriately defined dimensionless counterpart can allow the extraction of more universal characteristics. Alluvial rivers are no exception in this regard.

In order to implement a dimensionless characterization of the bank-full characteristics of alluvial streams, the following dimensionless parameters are defined;

$$\hat{Q} = \frac{Q_{bf}}{\sqrt{g D_{50}}\, D_{50}^2} , \quad \hat{B} = \frac{B_{bf}}{D_{50}} , \quad \hat{H} = \frac{H_{bf}}{D_{50}} , \quad Fr_{bf} = \frac{U_{bf}}{\sqrt{g H_{bf}}}$$
$$\tau_{bf50}^* = \frac{\tau_{bbf}}{\rho R g D_{50}} , \quad Re_{p50} = \frac{\sqrt{R g D_{50}}\, D_{50}}{\nu} , \quad R = \frac{\rho_s}{\rho} - 1 \tag{3.17a-g}$$

where ρ_s denotes the density of the sediment. That is, $\hat{Q}$ denotes dimensionless bank-full discharge, $\hat{B}$ denotes dimensionless bank-full width, $\hat{H}$ denotes dimensionless bank-full depth, Fr_{bf} denotes dimensionless bank-full Froude number, τ_{bf50}^* denotes the bank-full Shields number and Re_{p50} is a version of the particle Reynolds number introduced in Chapter 2, but here based on the surface median size D_{50}. Note that between Eqs. (3.14a), (3.16), and (3.17d,e) it is found that

$$C_{fbf} = Fr_{bf}^{-2} S \,, \quad Cz_{bf} = \frac{Fr_{bf}}{\sqrt{S}} \,, \quad \tau_{bf50}^{*} = \frac{H_{bf} S}{R D_{50}} \tag{3.18a,b,c}$$

Two simple limiting cases are considered so as to characterize alluvial rivers in a simple but clear way. One case consists of alluvial sand-bed streams (0.0625 mm < D_{50} < 2 mm) that are further restricted to have values of D_{50} not larger than 0.5 mm. Such streams are almost invariably suspension-dominated in terms of how the river bed interacts with the sediment it carries. Another limiting case consists of alluvial gravel-bed streams with D_{50} > 25 mm. (Here cobble-bed streams are included in the classification of gravel-bed streams for simplicity.) Such streams are almost invariably bed-load-dominated in terms of the interaction between river bed and sediment load. Most sand-bed streams transport much more mud (silt and clay) than sand, and many gravel-bed streams transport much more sand than gravel, but in both cases the finer fraction often interacts only weakly with the bed.

The restriction to these two limiting cases in terms of grain size does not mean that streams with values of D_{50} between 0.5 mm and 25 mm do not exist; their existence is demonstrated in Figure 3.18. Rather, the difference between the two limiting cases helps characterize the difference between bed-load-dominated and suspension-dominated rivers.

The data base for the relations presented here pertains to a) three sets of gravel-bed streams, one from Alberta, Canada, one from Wales, UK and one from Idaho, USA and b) a set of both single-channel and multiple-channel sand-bed streams from various locations. The three sets for gravel-bed streams are given in Parker et al. (2003). The sand-bed set was extracted from the much larger data base of Church and Rood (1983).

Figure 3.20 shows $\hat{H}$ versus $\hat{Q}$. The gravel-bed and sand-bed streams each form coherent and very similar trends in the case of depth. The following regressions are obtained;

$$\hat{H} = \begin{cases} 0.368\,\hat{Q}^{0.405} \,, \; gravel-bed \\ 3.01\,\hat{Q}^{0.321} \,, \; sand-bed \end{cases} \tag{3.19}$$

In Figure 3.21 $\hat{B}$ is plotted versus $\hat{Q}$. Again each data set defines a coherent trend, but there is a somewhat greater discrimination between the sand-bed and gravel-bed case in the case of width. The regressions are

$$\hat{B} = \begin{cases} 4.87\,\hat{Q}^{0.461} \,, \; gravel-bed \\ 0.274\,\hat{Q}^{0.565} \,, \; sand-bed \end{cases} \tag{3.20}$$

In Figure 3.22 S is plotted against $\hat{Q}$. Here the scatter is much larger, and the discrimination between sand-bed and gravel-bed streams stronger. There is a reason for the scatter in slope. Rivers can construct their own cross-sectional geometry in relatively short geomorphic time. Changing the slope of the long profile of a river requires much more time, however. The characteristic time scale is so large that it can be on the order of the tectonism (uplift or subsidence) that ultimately drives landscape evolution. As a result, there is a general trend for S to decrease with $\hat{Q}$, but not a precise one. The regression relations are

$$S = \begin{cases} 0.0976\hat{Q}^{-0.341}, & gravel-bed \\ 6.42\hat{Q}^{-0.397}, & sand-bed \end{cases} \tag{3.21}$$

Figure 3.23 shows bank-full Shields number τ_{bf50}^* versus $\hat{Q}$. Again, there is a strong discrimination between sand-bed and gravel-bed streams, but little variation with $\hat{Q}$ The trends can be reasonably approximated in terms of average values of τ_{bf50}^*;

$$\tau_{bf50}^* \approx \begin{cases} 0.049, & gravel-bed \\ 1.86, & sand-bed \end{cases} \tag{3.22}$$

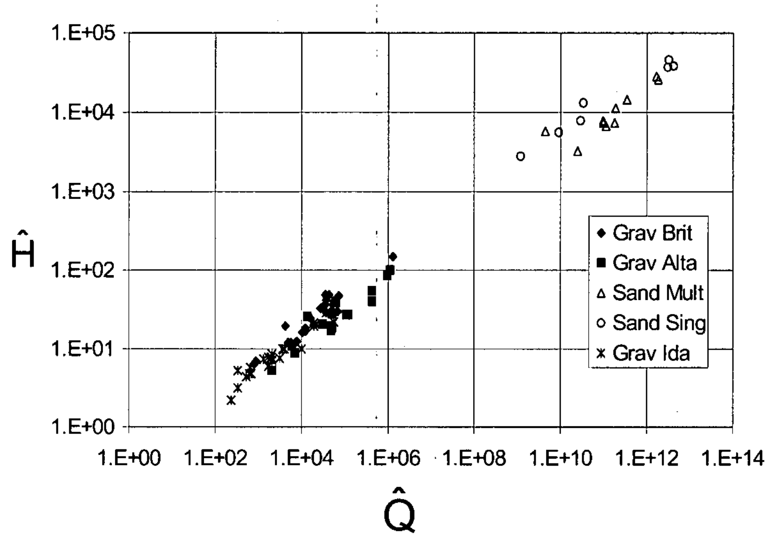


Figure 3.20 Dimensionless bank-full depth $\hat{H}$ versus dimensionless bank-full discharge $\hat{Q}$.

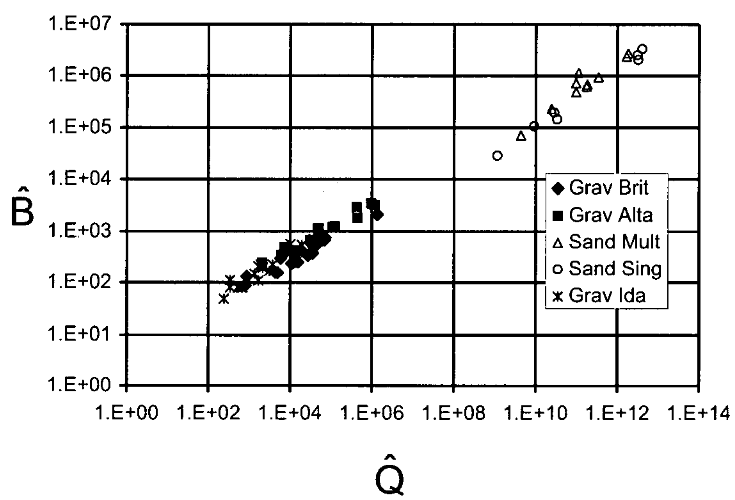


Figure 3.21 Dimensionless bank-full width $\hat{B}$ versus dimensionless bank-full discharge $\hat{Q}$.

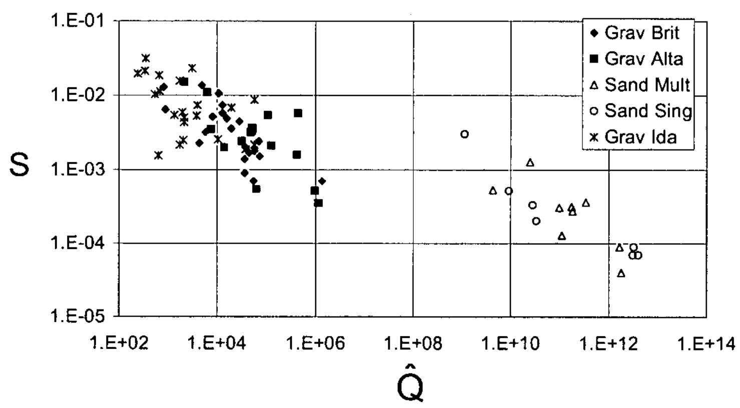


Figure 3.22 Channel bed slope S versus dimensionless bank-full discharge $\hat{Q}$.

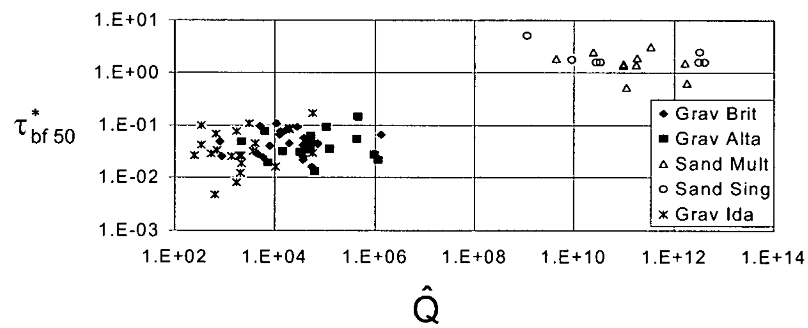


Figure 3.23 Dimensionless Shields number $\tau_{bf50}{}^*$ based on bank-full flow and D_{50} versus dimensionless bank-full discharge $\hat{Q}$.

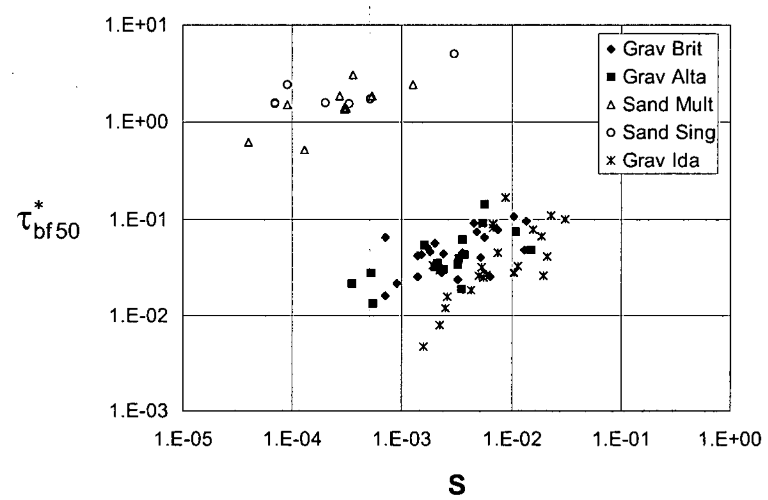


Figure 3.24 Dimensionless Shields number τ_{bf50}^* based on bank-full flow and D_{50} versus channel bed slope S.

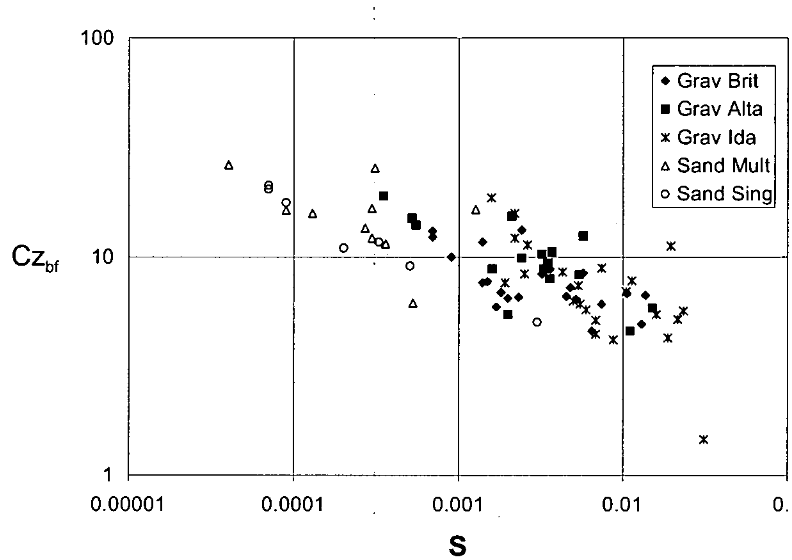


Figure 3.25 Dimensionless Chezy friction coefficient Cz_{bf} versus channel bed slope S.

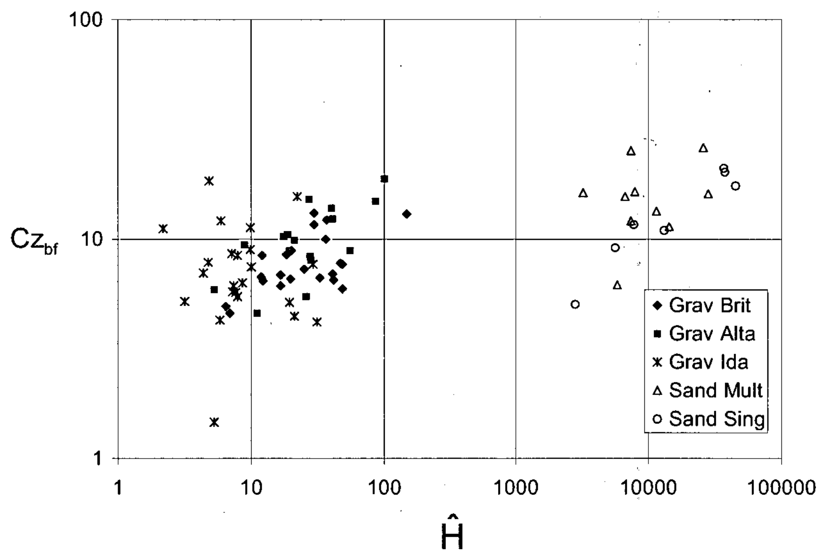


Figure 3.26 Dimensionless Chezy friction coefficient Cz_{bf} versus dimensionless depth $\hat{H}$.

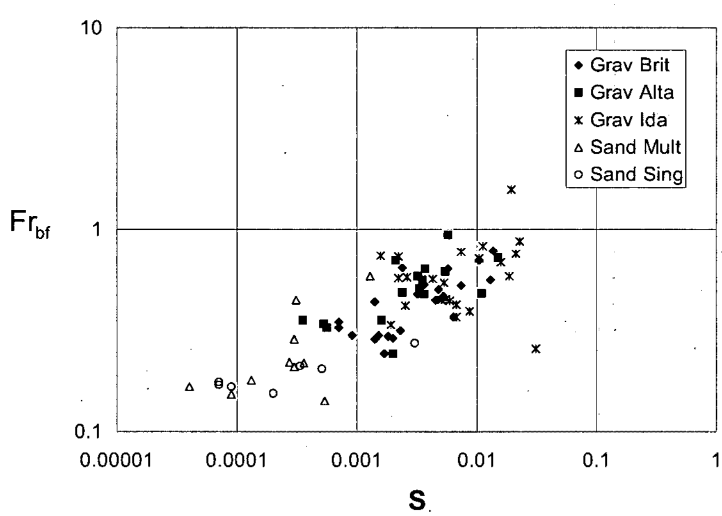


Figure 3.27 Froude number at bank-full flow Fr_{bf} versus channel bed slope S.

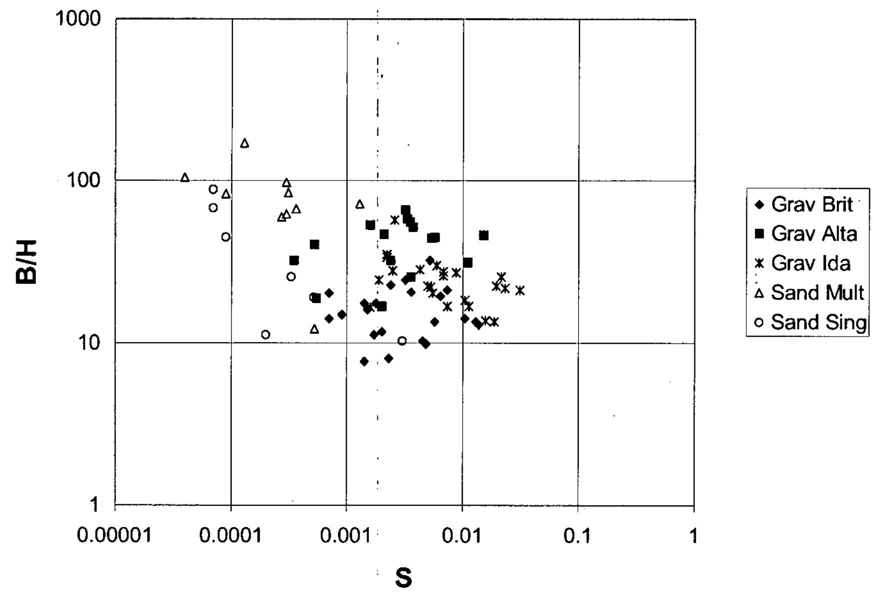


Figure 3.28 Bank-full width-depth ratio *B/H* versus channel bed slope *S*.

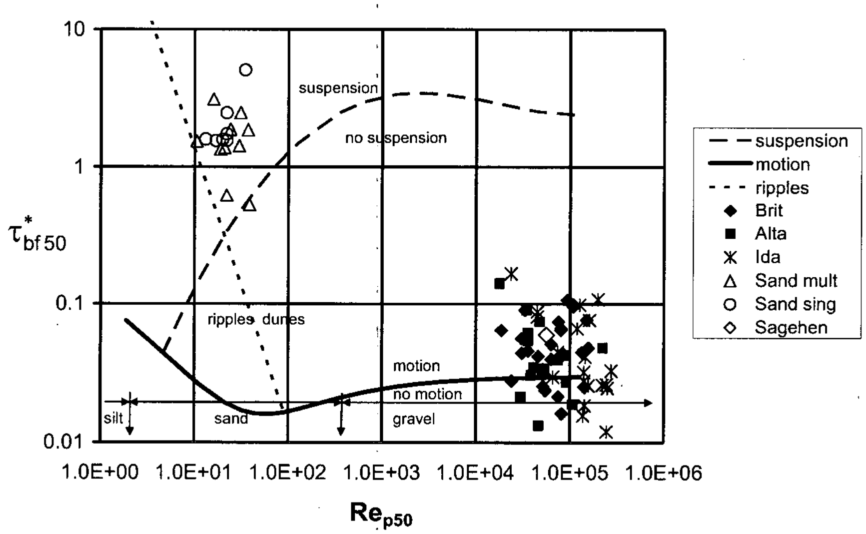


Figure 3.29 Dimensionless Shields stress based on bank-full flow τ_{bf50}^* versus particle Reynolds Re_{p50} number based on D_{50}. Also included is a point from Sagehen Creek, California, USA.

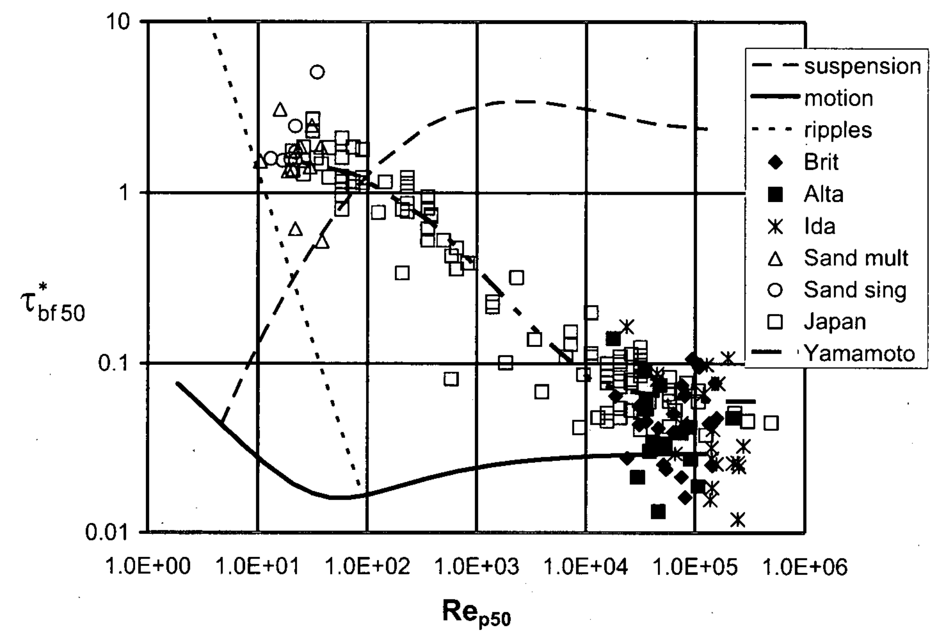


Figure 3.30 Extended version of Figure 3.29 including data from Japanese streams and the empirical regime relation of Yamamoto (1994).

Figure 3.23 shows a considerable amount of scatter. There are at least two reasons for this. The fine component of the load (mud in the case of sand-bed streams and sand in the case of gravel-bed streams) may either not be present in the bed (sand-bed streams) or may interact only passively with the bed (sand simply filling the pores of gravel-bed streams). This finer material is, however, available to build up the floodplain. As result, bank-full depth H_{bf} in particular can vary in ways that are not captured with the use of a single bed surface median size D_{50}. In addition, some gravel-bed streams contain relict gravel on their beds that was emplaced during a regime of higher flows. In such streams a finer gravel may move over the bed without completely covering the relict material. As a result the median size D_{50} may be too large to reflect the present mobility of the stream. These caveats notwithstanding, the estimates of Eq. (3.22) are useful for characterizing the two limiting cases. A bank-full Shields number on the order of 1.86, i.e. the average value for the sand-bed streams in Figure 3.23, describes a suspension-dominated river, whereas a bank-full Shields number on the order of 0.049, i.e. the average value for the gravel-bed streams in Figure 3.23, describes a bed-load-dominated system, as illustrated in Figure 2.26.

Figure 3.24 shows a plot of τ_{bf50}^* versus S. Again the sand-bed and gravel-bed streams plot in different regimes, but in each case τ_{bf50}^* shows a weak tendency to increase with increasing slope S.

Figure 3.25 shows the dimensionless Chezy number Cz_{bf} versus S. Except for one outlier the values of Cz_{bf} range between 4 and 26, and Cz_{bf} decreases noticeably with increasing S. There is little discrimination between sand-bed streams and gravel-bed streams in terms of the trend, but values for sand-bed streams, ranging from 9 to 26 excluding one outlier, are generally somewhat higher than for gravel-bed streams, which range from 4 to 19 excluding one outlier. Thus sand-bed streams tend to have somewhat lower bank-full friction coefficients C_{fbf} than gravel-bed streams (0.0015 – 0.012 versus 0.003 – 0.06). Figure 3.26 shows Cz_{bf} plotted against $\hat{H}$. The scatter is large, and the two types plot in very different regions. The fact that the values of Cz_{bf} are not that greatly different between the two cases even with vastly different values of $\hat{H}$ indicates that grain roughness, which is often dominant for gravel-bed streams, may be relatively unimportant in most sand-bed streams, with bedforms taking over that role.

Figure 3.27 shows a plot of Fr_{bf} versus S. With the exception of one point, all the bank-full flows are in the Froude-subcritical regime. This does not mean that supercritical flow does not occur in rivers. It does, however, tend to be restricted to floods in very steep rivers with a step-pool topography, a class of stream that is not represented in Figure 3.27. Within the scatter of the data, the two stream types define a common trend, but with sand-bed streams usually having lower bank-full Froude numbers. More specifically, sand-bed streams have values of Fr_{bf} ranging from 0.14 to 0.58 and gravel-bed stream having values ranging from 0.24 – 0.93 (excluding one supercritical outlier).

Figure 3.28 shows the bank-full width-depth ratio (aspect ratio) B_{bf}/H_{bf} versus bed slope S. In general the aspect ratio tends to be between 10 and 100, with the sand-bed streams tending toward somewhat larger values than the gravel-bed streams.

Figure 3.29 shows the bank-full Shields number τ_{bf50}^* against particle Reynolds number Re_{p50}, which is a surrogate for grain size D_{50}. A slightly different version of the diagram was presented as Figure 2.12 of Chapter 2, where the basis for the various regimes was explained. The only essential difference between the two figures is that Brownlie's (1981) relation for the onset of motion is used in Figure 2.26, whereas a modified version, in which the predicted critical Shields number is halved, is used in Figure 3.29 (and also Figure 3.30). (This modified relation is presented and explained below in Section 3.7.1). The strong tendency for the size D_{50} to move as bed-load in gravel-bed streams and as suspended load in sand-bed streams is clear. In addition, at bank-full stage the Shields numbers of sand-bed rivers are typically about 50 times the critical Shields number at the threshold of motion, whereas the corresponding value for the gravel-bed streams is only about 1.6. These differences provide the basis for the exposition of grain size-specific sediment transport relations for heterogeneous sediment given below. Also included in Figure 3.29 is a single point for Sagehen Creek, California, USA (Andrews and Erman, 1986). Sagehen Creek is explained in more detail in Section 3.11.3.

Figure 3.30 addresses the issue of streams with values of D_{50} between 0.5 mm and 25 mm. The added data are from the two sets of Japanese streams described above in regard to Figure 3.18. As noted above, D_{bulk60} rather than surface median size D_{50} was used to characterize the bed material of the Japanese streams. In addition, self-formed bank-full discharge is not as clearly defined in the heavily engineered Japanese streams as in streams in other parts of the world, and as a result a mean annual peak flood flow was used as the basis for the computation of Shields number in the diagram. This notwithstanding, the plot shows a concentration of sand-bed and gravel-bed streams within and adjacent to the two limiting cases described here, along with a lesser but still substantial number of transitional streams. The solid line in the figure is due to Yamamoto (1994). It should be remembered that such transitional streams are not unique to Japan; see Kleinhans (2002) for a description of such streams in Europe.

A final discriminator between sand-bed and gravel-bed streams is embodied in Figure 2.11. It is seen in that figure that gravel-bed rivers tend to have grain size distributions that are substantially wider than sand-bed streams. This fact, combined with the fact that in Figure 3.29 the gravel-bed streams tend to cluster close to the threshold condition at bank-full conditions whereas the sand-bed streams plot well above it, renders grain sorting of heterogeneous sediment rather more intense in gravel-bed streams than sand-bed streams. The difference is, of course, relative; sand-bed rivers also sort their sediment.

3.5 THE ACTIVE LAYER CONCEPT

3.5.1 The Role of Fluctuations in Bed Elevation during Sediment Transport

The transport of bed material load in a river is always accompanied by fluctuations in bed elevation. Fluctuations occur at a variety of scales, including the scour and fill of river bends, pool-riffles and bank-attached bars through a flood hydrograph, as well as the migration of free bars, dunes and ripples and their interaction. At the finest scale, even in the absence of clearly defined bedforms, bed elevation fluctuations are observed at the scale of the surface size D_{90} of the bed material. That is, coarse clusters form and break up, the removal of a coarse grain creates a hole in which finer grains are captured, coarse grains are buried by local scour of the finer grains around them etc. Fluctuations in bed elevation are typically linked to fluctuations in the rate of sediment transport. In the case of dunes in a bed-load-dominated regime, for example, the probability density of bed-load fluctuations can often be accurately estimated from the probability density of bed elevation through considerations of bedform migration (Hamamori, 1962; Hubbell, 1987; Ribberink, 1987; Kuhnle and Southard, 1988; Gomez et al., 1989).

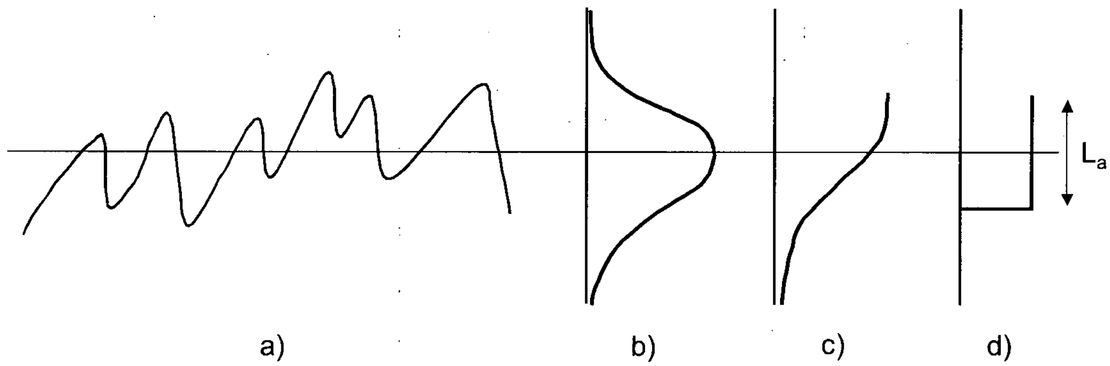


Figure 3.31 Definition diagram showing a) the spatial variation of bed elevation at a given time or temporal variation of bed elevation at a given location;
b) the probability density of bed elevation;
c) the probability of entrainment per unit time of a grain as a function of elevation in the bed; and
d) the approximation of c) embodied in the active layer approximation.

These bed fluctuations are an interesting feature of the transport of uniform or well sorted sediments, but are essential to the understanding of the transport of sediment mixtures. If the possibility of leaching of fine grains through the bed sediment by groundwater flow is neglected for the sake of argument, in order for a grain in the bed to be entrained into motion it must be exposed at least momentarily at the bed surface. The higher the elevation of the grain, the higher is the probability per unit time that it is entrained. Deeply buried grains have minimal probability of entrainment because the probability that the bed will locally be at that elevation must decline with depth. Figure 3.31 schematizes a) the instantaneous bed profile, b) the associated probability density of bed elevation and c) the probability per unit time of entrainment of a grain as a function of elevation.

The simplest reasonable approximation of the curve c) is as a step function, according to which the probability of erosion of a grain per unit time is a constant value in an "exchange", "active" or "surface" layer of thickness L_a near the bed surface, and is vanishing below this layer. That is, all the bed fluctuations are assumed to be concentrated in a well-mixed layer of finite thickness L_a. This approximation, which is shown as d) in Figure 3.31, is the essence of the active layer formulation for the Exner equation of the conservation of bed sediment mass for mixtures. It was first introduced in a landmark paper by Hirano (1971), and is outlined below. The extension to continuous variation in the vertical direction is briefly introduced in Section 3.15.2.

3.5.2 The Formulation of Hirano

Consider the bed of Figure 3.32. Let the fractions p_i in the size distribution in the active or surface layer be denoted as F_i; here it is assumed that the fractions have been averaged over fluctuations. Note that F_i might be functions of time t, streamwise coordinate s and transverse coordinate n, but may not be functions of the upward normal coordinate z because the surface layer is assumed to be perfectly mixed by the fluctuations. The size fractions in the substrate are denoted as f_i, where in general f_i can be functions of s, n and z, so defining the stratigraphy of the deposit, but cannot be functions of t because they are assumed to be below the level of bed fluctuations.

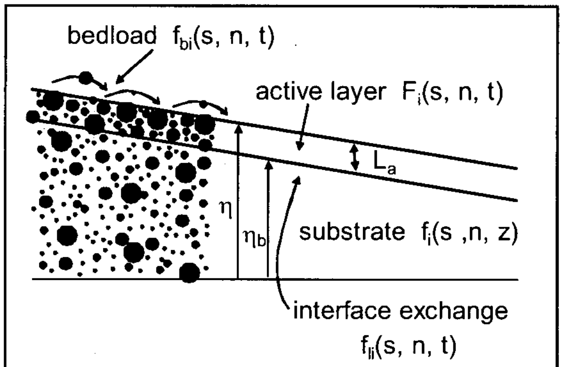


Figure 3.32 Definition diagram for the active layer concept.

Now consider one-dimensional transport of bed-load in the s direction. Let q_i denote the volume rate of bed-load transport of sediment in the *ith* grain size range per unit width normal to the flow. In the case of 1-D bed-load transport of sediment mixtures, Eq. (**2.XX**) generalizes to

$$(1-\lambda_p)\left[f_{Ii}\frac{\partial \eta_b}{\partial t}+\frac{\partial}{\partial t}(L_a F_i)\right]=-\frac{\partial q_i}{\partial s} \tag{3.23}$$

In the above relation f_{Ii} denotes the size fractions of the material exchanged between the surface layer and the substrate as the bed aggrades or degrades. In addition, η_b denotes the elevation of the bottom of the surface layer, so that bed elevation η is given as

$$\eta = \eta_b + L_a \tag{3.24}$$

Note that η and η_b correspond to averages over bed elevation fluctuations. Eq. (3.23) may be summed over all grain sizes, yielding in conjunction with Eq. (3.24) the 1-D version of Eq. (**2.XX**) in the absence of suspended load;

$$(1-\lambda_p)\frac{\partial \eta}{\partial t} = -\frac{\partial q_T}{\partial s} \tag{3.25}$$

where

$$q_T = \sum_{i=1}^{n} q_i \tag{3.26}$$

The four equations given above yield the following relation for the time evolution of the active layer;

$$(1-\lambda_p)\left[\frac{\partial}{\partial t}(L_a F_i) - f_{Ii}\frac{\partial L_a}{\partial t}\right] = -\left(\frac{\partial q_i}{\partial s} - f_{Ii}\frac{\partial q_T}{\partial s}\right) \tag{3.27}$$

Denoting the fractions in the bed-load as f_{bi}, it is seen from Eq. (3.26) that

$$f_{bi} = \frac{q_i}{\sum_{i=1}^{n} q_i} \tag{3.28}$$

A full derivation of Eq. (3.23) and the associated forms (3.25) and (3.27) can be found in Parker and Sutherland (1990) and Parker et al. (2000). Once appropriate forms for q_i, L_a and f_{Ii} are specified, Eq. (3.25) can be used to compute the time change in bed elevation due to net deposition or erosion, and Eq. (3.27) can be used to compute the time change in the composition in the surface layer of the bed.

3.5.3 Active Layer Thickness and Interfacial Exchange Fractions

There is a degree of arbitrariness in the specification of the active surface layer thickness L_a. In the absence of bedforms, L_a can be thought to scale with a characteristic large size of the surface such as D_{90} or D_σ, where D_σ is defined as

$$D_\sigma = D_g \sigma_g \tag{3.29}$$

Note that D_σ corresponds to D_{84} for a log-normal distribution. Thus e.g.

$$L_a = n_a D_{90} \tag{3.30}$$

where n_a is an order-one parameter that requires calibration in the absence of a probability distribution of bed fluctuations. The Klingeman sampling method discussed above implicitly assumes that n_a is unity. When bedforms such as dunes and bars are present, and when the time scales of interest are large enough for the bed above the troughs to be thoroughly mixed by these bedforms, L_a must scale with bedform height.

In the case of meander bends, L_a must scale with some measure of the amplitude of scour and fill, and the time scales must be restricted to those larger than one corresponding to the passage of enough floods to completely rework the sediment within this amplitude. A compendium of expressions for L_a used by various researchers in numerical models of bed elevation variation and sorting due to the transport of mixtures can be found in Kelsey (1996).

The interfacial exchange fractions f_{Ii} describe the mean size distribution of the sediment that is exchanged between the surface layer and the substrate as the bed aggrades or degrades. When the bed degrades, substrate is transferred to the active layer, so that

$$f_{Ii} = f_i(z)\big|_{z=\eta_b} \quad for \quad \frac{\partial \eta_b}{\partial t} < 0 \tag{3.31}$$

In the original formulation of Hirano (1971), surface material was transferred to the substrate during bed aggradation. Subsequent research has suggested that the material transferred is a weighted mixture of bed-load and surface material, so that

$$f_{Ii} = aF_i + (1-a)f_{bi} \quad for \quad \frac{\partial \eta_b}{\partial t} > 0 \tag{3.32}$$

This form was first suggested by Hoey and Ferguson (1994); Toro-Escobar et al. (1996) used a set of large-scale experiments on downstream fining of gravel-sand mixtures to evaluate a for at least one case.

3.5.4 Further Generalizations and Alternate Formulations

Eq. (3.23) is easily generalized to include a) channel width variation in a 1-D formulation, b) transverse as well as streamwise variation in a 2-D formulation, c) suspended sediment as well as bed-load sediment and d) abrasion. All these cases are discussed later in this chapter. Abrasion may be included in a variety of ways. Here it is assumed that the product of abrasion is silt or fine sand that then moves as throughput load. As a result, abrasion is assumed to represent a net loss of bed material. Where A_i denotes the net loss per unit time per unit bed area of clast volume in the *ith* grain size range due to abrasion, Eq. (3.23) generalizes to

$$(1-\lambda_p)\left[f_{Ii}\frac{\partial \eta_b}{\partial t} + \frac{\partial}{\partial t}(L_a F_i)\right] = -\frac{\partial q_i}{\partial s} - A_i \tag{3.33}$$

The issue of abrasion will be treated in more detail below in Section 3.9.

The use of Eq. (3.23) or some close variant thereof has increasingly become the standard in the implementation of the active layer formulation. Some researchers, however, have used *ad hoc* formulations that are similar in nature but cannot be expressed in the compact analytical formulation given above. Examples of these *ad hoc* formulations can be found in Borah et al. (1982), Park and Jain (1987), Copeland and Thomas (1992) and Belleudy and SOGREAH (2000). In many such treatments the active layer is implemented only to the extent necessary to describe the evolution of a static armor as the sediment supply is cut off.

As will be shown in Section 3.11, Eq. (3.27) can be used to describe the evolution of bed armoring. When the supply of sediment to a river with a mix of sediment sizes is cut off, the bed coarsens to eventually form a static armor, i.e. a surface layer containing material so coarse that it can no longer be removed and the bed can no longer degrade. The same formulation can also be used to describe a mobile armor, in which case a coarse surface layer is maintained even when all sizes are mobile. It will be demonstrated that there is a smooth progression from the unarmored state to a mobile armor, and then to a static armor as river stage decreases.

As can be seen by comparing cases c) and d) in Figure 3.31, the active layer formulation is the simplest formulation capable of describing the change in bed composition due to the selective transport of sediment mixtures. Recently progress has been made by Parker et al. (2000) in moving from the simplified case d) to the real case c). This work is described briefly in Section 3.15 below.

3.5.5 Entrainment Formulation

Before closing this chapter, an alternative active layer formulation for the Exner equation of sediment conservation of mixtures deserves mention. Bed-load particles typically roll, slide or saltate intermittently without being substantially supported by turbulence. Einstein (1950) introduced the concepts of a pickup rate and a step length for bed-load particles. Tsujimoto and Motohashi (1990) and Tsujimoto (1991, 1999) have pursued these concepts. Here the pickup rate is described in terms of a bed-load volume entrainment rate per unit time per unit bed area for the *ith* grain size range E_{bi}. The probability density that a grain in size range i moves a distance s in one step is denoted as $P_{si}(s)$. The mean step length L_{si} for the *ith* grain size range is thus given as

$$L_{si} = \int_0^{\infty} sP_{si}(s)ds \tag{3.34}$$

The volume rate of deposition of particles in the *ith* size range from the bed-load per unit time per unit bed area is given as D_{bi}, where

$$D_{bi} = \int_0^{\infty} E_{bi}(s-s')P_{si}(s')ds' \tag{3.35}$$

The entrainment form of Eq. (3.23) is thus

$$(1-\lambda_p)\left[f_{Ii}\frac{\partial \eta_b}{\partial t} + \frac{\partial}{\partial t}(L_a F_i) \right] = D_{bi} - E_{bi} = \int_0^{\infty} E_{bi}(s-s')P_{si}(s')ds' - E_{bi} \tag{3.36}$$

The bed-load transport rate q_i can be computed as

$$q_i = \int_0^\infty E_{bi}(s-s')\int_{s'}^\infty P_{si}(s'')ds''ds' \tag{3.37}$$

With a little algebra it can be demonstrated between Eqs. (3.35) and (3.37) that

$$D_{bi} - E_{bi} = -\frac{\partial q_i}{\partial x} \tag{3.38}$$

so demonstrating the equivalency between Eqs. (3.23) and (3.36).

This equivalency applies, however, only to the treatment of sediment conservation. In the transport formulation of Eq. (3.23) it is necessary to specify q_i as a function of the flow and surface layer characteristics; in the entrainment formulation of Eq. (3.36) it is necessary to specify E_{bi} and P_{si} as functions of the flow and surface layer characteristics. At small time and length scales the predictions of the two methods may be different. At scales that are large compared to the step length and associated step time, the predictions will be nearly the same if the bed-load and entrainment formulations are related by Eq. (3.37).

The above model can be simplified by assuming the step length L_{si} to be specified deterministically rather than in terms of a probability function. The versions of Eqs. (3.35), (3.36) and (3.37) simplified in this manner are, respectively,

$$D_{bi} = E_{bi}(s - L_{si}) \tag{3.39}$$

$$(1-\lambda_p)\left[f_{Ii}\frac{\partial \eta_b}{\partial t} + \frac{\partial}{\partial t}(L_a F_i)\right] = D_{bi} - E_{bi} \tag{3.40}$$

$$q_i = \int_0^{L_{si}} E_{bi}(s-s')ds' \tag{3.41}$$

3.6 GENERAL FORMULATION FOR BED-LOAD TRANSPORT OF MIXTURES.

3.6.1 Surface-based formulation

If material within a given size range is not present in the bed surface then it cannot be entrained into the bed-load. To account for this it is appropriate to define a volume bed-load transport rate q_{Ui} per unit time, per unit width and per unit fraction content in the surface layer, and a corresponding bed-load entrainment rate E_{Ubi} such that

$$q_{Ui} = \frac{q_i}{F_i}, \quad E_{Ubi} = \frac{E_{bi}}{F_i} \tag{3.42a,b}$$

Thus, for example, even if a given model predicts that $q_{Ui} > 0$, implying that the flow is competent to move material in the *ith* grain size range, if $F_i = 0$ then that size range is unavailable for participation in bed-load transport. The model thus must predict a value of q_i of zero. Such a treatment defines a "surface-based" formulation for bed-load transport. A "substrate-based" formulation will also be defined below.

3.6.2 Dimensional Analysis for Bed-load Transport of Mixtures

In general the unit bed-load transport rate q_{Ui} can be expected to be a function of not more than two hydraulic parameters, here denoted as X_1 and X_2, and also water density ρ, sediment material density ρ_s, water viscosity ν, gravitational acceleration g, grain sizes D_i and other parameters based on the first, second, third... moments of the surface grain size distribution, here denotes as m_1, m_2, m_3... (Parker and Anderson, 1977). Thus

$$q_{Ui} = \frac{q_i}{F_i} = fn(X_1, X_2, \rho_s, \rho, \nu, g, D_i, m_1, m_2 ...) \tag{3.43}$$

Here the moment series is truncated at second moment, m_1 is equated with the surface size D_g (based on the first moment of F_i) and m_2 is equated with the surface arithmetic standard deviation σ (square root of second moment of F_i). In a theory with the highest local accuracy X_1 and X_2 must be parameters that are most closely tied to bed-load. In a formulation to be applied to locally quasi-equilibrium flows at a macroscopic scale, however, the precise choice of these parameters is less critical. They can be chosen from, e.g. depth-averaged flow velocity U, flow depth h, water discharge per unit width q_w, bed or energy slope S, boundary shear stress τ_b etc. Customarily one of the hydraulic parameters plays a primary role in sediment transport and the other one (or other ones) play a secondary role. Here it is assumed that X_1 is the primary hydraulic parameter. In addition, many researchers have used D_{50} rather than D_g as the parameter of choice for characteristic surface grain size.

Some researchers, e.g. Einstein (1950), have included more than two hydraulic parameters their formulation of Eq. (3.43). For the case of locally quasi-equilibrium transport, however, the constraints of fluid mass and momentum balance as well as a formulation for hydraulic resistance allow the ultimate elimination of the extra hydraulic parameters.

Eq. (3.43) truncated at the second moment constitutes a relation between ten dimensioned parameters. The principles of dimensional analysis allow the reduction of this relation to an equivalent dimensionless one involving seven parameters. Defining

$$R = \frac{\rho_s}{\rho} - 1, \quad q_i^* = \frac{q_i}{F_i\sqrt{RgD_i}\,D_i}, \quad Re_{pg} = \frac{\sqrt{RgD_g}\,D_g}{\nu} \tag{3.44a,b,c}$$

then Eq. (3.43) can be recast as

$$q_i^* = T_b\left(\hat{X}_1, \hat{X}_2, \frac{D_i}{D_g}, \sigma, Re_{pg}, R\right) \tag{3.45a}$$

In the above relation T_b denotes a dimensionless bed-load transport function, $\hat{X}_1$ and $\hat{X}_2$ are dimensionless versions of X_1 and X_2, q_i^* denotes a grain size specific Einstein number, R denotes the submerged specific gravity of the sediment (near 1.65 for the most common natural sediments in rivers) and Re_{pg} denotes an explicit particle Reynolds number. Note that $\hat{X}_1$ and $\hat{X}_2$ may contain the parameter D_i and thus be grain-size specific.

Many but not all researchers have assumed the existence of a critical or threshold value of the primary dimensionless hydraulic parameter $\hat{X}_{1c}$, which may in turn depend on D_i/D_g, σ, Re_p and R, below which sediment transport vanishes. In this way (3.45a) is amended to

$$q_i^* = T_b\left(\hat{X}_1 - \hat{X}_{1c}, \hat{X}_2, \frac{D_i}{D_g}, \sigma, Re_{pg}, R\right) \tag{3.45b}$$

Nearly all dimensionless formulations for the bed-load transport of sediment mixtures can be cast into the form of Eq. (3.45) (but sometimes with extra dimensionless hydraulic parameters). Researchers such as Fernandez Luque and van Beek (1976) have studied bed-load transport rates for a variety of values of R and found no discernible independent effect as long as R is incorporated into the primary dimensionless hydraulic parameter (e.g. the Shields number). As a result it is dropped here. Although there are many possible choices for $\hat{X}_1$ and $\hat{X}_2$, for the sake of illustration $\hat{X}_2$ is dropped and $\hat{X}_1$ is set equal to a Shields number τ_{si}^* based on the shear stress associated with skin friction τ_{bs} and grain size D_i;

$$\tau_{si}^* = \frac{\tau_{bs}}{\rho R g D_i} = \frac{u_{*s}^2}{R g D_i} \tag{3.46}$$

where

$$u_{*s} = \sqrt{\frac{\tau_{bs}}{\rho}} \tag{3.47}$$

denotes the shear velocity associated with skin friction. The (partial) justification for the use of the Shields number is that it has become the standard primary dimensionless hydraulic parameter in many recent bed-load formulations. The (partial) justification for dropping the second dimensionless hydraulic parameter refers to the fact that the removal of the form drag from the boundary shear stress used in Eq. (3.46) eliminates other parameters that would enter into the bed-load transport relation through the relation for hydraulic resistance. (See Chapter 2 for a discussion of these relations, and the decomposition of boundary shear stress into skin friction and form drag components.) With these assumptions Eq. (3.45a) becomes

$$q_i^* = T_b\left(\tau_{si}^*, \frac{D_i}{D_g}, \sigma, Re_{pg}\right) \tag{3.48}$$

The flow is hydraulically rough during events that transport gravel in gravel-bed streams and many laboratory flumes. For such flows the particle Reynolds number Re_{pg} can be dropped. In the case of flow in sand-bed streams, however, it generally cannot be dropped. The reader should also be reminded that D_g can be replaced with D_{50} in the above formulation with no loss of generality.

A form equivalent to Eq. (3.48) can be obtained by dividing both sides of the equation by $(\tau_{si}^*)^{3/2}$, in which case it reduces to

$$W_i^* = \hat{T}_b\left(\tau_{si}^*, \frac{D_i}{D_g}, \sigma, Re_{pg}\right) \tag{3.49}$$

where

$$W_i^* = \frac{Rgq_i}{F_i u_{*s}^3} = \frac{q_i^*}{\left(\tau_{si}^*\right)^{3/2}}, \quad \hat{T}_b = \frac{T_b}{\left(\tau_{si}^*\right)^{3/2}} \tag{3.50a,b}$$

The advantage of Eq. 3.49 is that it places all the effect of variation of grain sizes D_i and D_g on the right-hand side of the equation, so simplifying the job of identifying selective transport.

3.6.3 Critical or Reference Condition for the Onset of Significant Transport

Eqs. (3.48) and (3.49) provides a basis for studying not only bed-load transport itself, but also the beginning of transport of sediment mixtures. Before proceeding with this, however, one must wrestle with the meaning of "beginning of transport." In Chapter 2, the transport equation (2.95) of Meyer-Peter and Müller (1948) contains a critical condition for the onset of bed-load transport, whereas the Einstein (1950) relation (2.99) does not. This leads one to ask whether or not there really is a threshold condition for the onset of motion.

The answer is yes and no. Fortunately, however, this answer is not a complicated as one might think. In a classical set of experiments, Paintal (1971) ran flows over an erodible bed at conditions that were well below established critical conditions for the onset of bed-load transport. After weeks or months of patient waiting, some sediment was invariably collected at the downsteam end of the flume. In addition, this data could be organized into a sensible transport relation satisfying the following relation at very low transport rates;

$$q^* = 6.5x10^{18}\left(\tau^*\right)^{16}, \quad W^* = 6.5x10^{18}\left(\tau^*\right)^{14.5} \qquad (3.51a,b)$$

where τ^* and q^* are defined in Eqs. (2.56) and (2.91) and and W^* is obtained by dividing q^* by $(\tau^*)^{3/2}$. The implication is that there is no "absolute" threshold of motion in the statistical sense.

This notwithstanding, Paintal's work allows for the definition of an "effective" threshold of motion, below which the sediment transport rate is so low that the resulting morphodynamic change of the bed is negligible over most or all time periods of interest. The definition is made meaningful by the high exponent in Eq. (3.51), which guarantees that in the regime of very low bed-load transport rates large changes in q^* lead to only small changes in τ^*. Both the "absolute" and "effective" approaches are pursued here in order to better summarize the available data.

In the "absolute" approach, q_i^* is set equal to zero in Eq. (3.48) or W_i^* is set equal to zero in Eq. (3.49), resulting in the following relation for the critical Shields number τ_{sci}^* for the *ith* grain size;

$$\tau^*_{sci} = F_c\left(\frac{D_i}{D_g}, \sigma, Re_{pg}\right) \qquad (3.52)$$

(Here the subscript "*sci*" denotes "skin, critical, *i*th grain size). In the "effective" approach, flow conditions are determined for a very low but measurable reference value of bed-load transport. Parker et al. (1982a), for example suggested the reference dimensionless transport rate

$$W_r^* = 0.002 \qquad (3.53)$$

based on field data from Oak Creek, Oregon, USA. Setting W_i^* equal to W_r^* in Eq. (3.49) and solving for the associated reference Shields number τ_{ssri}^*, it is found that

$$\tau^*_{ssri} = F_r\left(\frac{D_i}{D_g}, W_r^*, \sigma, Re_{pg}\right) \qquad (3.54)$$

(Here the subscript "*ssri*" denotes "skin, surface-based, reference, *i*th grain size). Eqs. (3.52) and (3.54) are very similar. The latter equation has the advantage of referring to a small but measurable transport rate. It is very hard to accurately measure zero sediment transport rate. Based on the high exponent in Eq. (3.52b) of Paintal (1971), it can be expected that the values of τ_{ssri}^* depend only weakly on the choice of W_r^* as long as it is sufficiently small.

Eqs. (3.52) or (3.54) can be further reduced by evaluating it for $D_i = D_g$ and dividing the result into the original equation, yielding the respective forms

$$\frac{\tau^*_{sci}}{\tau^*_{scg}} = \frac{F_c\left(\frac{D_i}{D_g}, \sigma, Re_{pg}\right)}{F_c\left(1, \sigma, Re_{pg}\right)}, \quad \frac{\tau^*_{ssri}}{\tau^*_{ssrg}} = \frac{F_r\left(\frac{D_i}{D_g}, \sigma, Re_{pg}\right)}{F_r\left(1, \sigma, Re_{pg}\right)} \qquad (3.55a,b)$$

(The parameter W_r^* is suppressed in Eq. (3.55b) because in any given formulation its value must be specified and held constant subsequently.) It is commonly assumed that the critical or reference Shields number τ_{scg}^* or τ_{ssrg}^* (or equivalent forms using the surface size D_{50} instead of D_g) depends only on Re_{pg}, and the ratios on the left-hand sides of Eqs. (3.55a,b) depend only on D_i/D_g (or D_i/D_{50});

$$\frac{\tau^*_{sci}}{\tau^*_{scg}(Re_{pg})} = F_{hc}\left(\frac{D_i}{D_g}\right), \quad \frac{\tau^*_{ssri}}{\tau^*_{ssrg}(Re_{pg})} = F_{hr}\left(\frac{D_i}{D_g}\right) \qquad (3.56a,b)$$

where the functions F_{hc} and F_{hr} above differ from those in Eq. (3.55a,b).

3.6.4 Similarity Hypothesis

The bed-load transport rate q_i^* in Eq. (3.48) or alternatively W_i^* in Eq. (3.49) is assumed to be a function of, among other parameters, the ratio D_i/D_g The shape of the bed-load curve defined as q_i^* versus τ_{si}^*, or alternatively W_i^* versus τ_{si}^* may thus differ from grain size to grain size in a mixture. It may be, however, that the curve for each value of D_i/D_g can be collapsed into a single curve, greatly simplifying the analysis. Similarity analysis can be used to test this hypothesis.

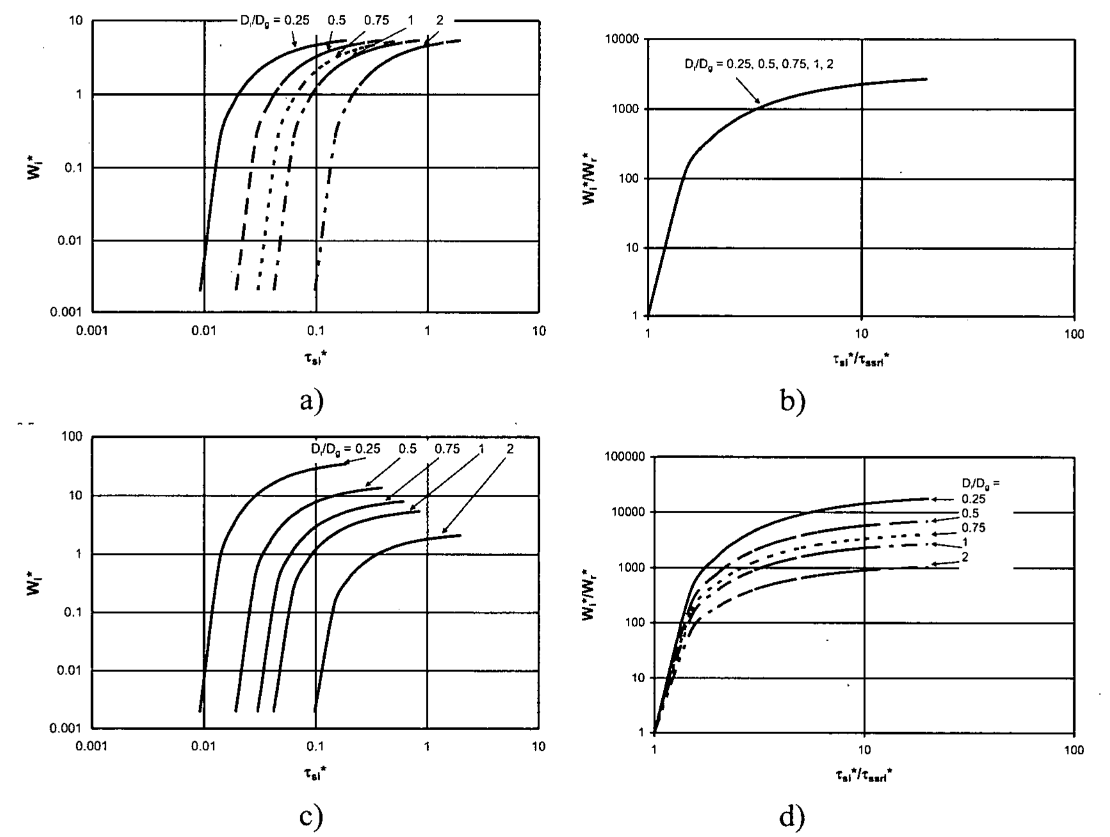


Figure 3.33 Plots illustrating the use of similarity.
a) Plot of W_i^* versus τ_{si}^* for a case for which similarity collapse is realized.
b) Similarity plot of the data of the figure to the left which results in a perfect collapse.
c) Plot of W_i^* versus τ_{si}^* for a case for which similarity collapse is not realized.
d) Similarity plot of the data of the figure to the left does not results in a collapse.

Here a similarity analysis is pursued in the context of Eq. (3.49) as an example. In Figures 3.33a and 3.33c W_i^* is plotted against τ_{si}^* for $n = 5$ values of D_i/D_g based on two sets of synthetic data. The solid lines shown in the figures can be taken to be fits to data points. A standard value W_r^* of 0.002 used to define the reference parameters τ_{ssri}^* in accordance with Eq. (3.54). The ratio W_i^*/W_r^* is then plotted against $\tau_{si}^*/\tau_{ssri}^*$, so defining a total of n curves, one for each value of i. Note that by definition every curve passes through the point $(W_i^*/W_r^*, \tau_{si}^*/\tau_{ssri}^*) = (1, 1)$. If the curves in fact coincide for all values of $\tau_{si}^*/\tau_{ssri}^*$ and every value of i, a similarity collapse is realized according to which

$$\frac{W_i^*}{W_r^*} = G_{sim}\left(\frac{\tau_{si}^*}{\tau_{ssri}^*}\right) \qquad (3.57)$$

where G_{sim} is a similarity collapse function which is independent of grain size. The synthetic data of Figure 3.33a do in fact yield the similarity collapse of Figure 3.33b.

The synthetic data of Figure 3.33c, however, do not collapse into a single line, as shown in Figure 3.33d.

Figures 3.33a and 3.33b thus show a case for which a similarity collapse to a common function is realized; Figures 3.33c and 3.33d show one for which it is not realized. Even in the event that similarity is realized, the parameters D_i/D_g, σ and Re_{pg} do not necessarily become unimportant; rather, it follows that τ_{ssri}^* itself may be a function of these parameters. A further similarity collapse, if successful, allows this relation to be reduced to the form

$$\frac{\tau_{ssri}^*}{\tau_{ssrg}^*(Re_{pg},\sigma)} = F_{hr}\left(\frac{D_i}{D_g}\right) \qquad (3.58)$$

i.e. a hiding function similar to Eq. (3.56b).

Parker et al. (1982a), Parker and Klingeman (1982), Parker (1990a), Wilcock and McArdell (1993), Wilcock (1997a) and Wilcock and Crowe (2003) have pursued approximate similarity collapses of the above type based on both surface and substrate. They have invariably found that a better approximation to a collapse of the data is realized using the parameter W_i^* than q_{bi}^*, largely because W_i^* does not contain grain size D_i in its definition by Eq. (3.50a).

3.6.4 Hiding Functions

Equations (3.55), (3.56) and (3.58) may be termed hiding functions. The reason for this relates to the seminal work of Egiazaroff (1965), who derived a relation of the above form from considerations of the forces acting on grains exposed on a bed containing a mixture of grain sizes. In Egiazaroff's simple but cogent model, larger grains are harder to move because they are heavier. Larger grains are, on the other hand, easier to move because they tend to protrude more into the flow, so feeling a higher drag. (Hence the terminology "hiding," in that the finer grains are sheltered from the full brunt of the flow by the protrusion of the coarser grains.) The net result of these two effects is a modest bias toward lesser mobility for coarser grains. The reduced mobility of coarser grains in a mixture turns out, then, to be much more subdued than what would be expected based on weight alone. Egiazaroff's version of (3.56), along with others, are introduced in the Section 3.7.

The dimensioned values of the critical (reference) boundary shear stresses based on skin friction (and surface content in the case of reference values) τ_{bsci} and τ_{bscg} (τ_{bssri} and τ_{bssrg}) associated with sizes D_i and D_g, respectively, are given from the relations

$$\tau_{bsci} = \rho R g D_i \tau_{sci}^*, \quad \tau_{bscg} = \rho R g D_g \tau_{scg}^*$$
$$\tau_{bssri} = \rho R g D_i \tau_{ssri}^*, \quad \tau_{bssrg} = \rho R g D_g \tau_{ssrg}^* \qquad (3.59a,b,c,d)$$

Between Eqs. (3.56) and (3.59) it is found that

$$\frac{\tau_{bsci}}{\tau_{bscg}} = F_{rhc}\left(\frac{D_i}{D_g}\right) \equiv \frac{D_i}{D_g} F_{hc}\left(\frac{D_i}{D_g}\right)$$
$$\frac{\tau_{bssri}}{\tau_{bssrg}} = F_{rhr}\left(\frac{D_i}{D_c}\right) \equiv \frac{D_i}{D_g} F_{hr}\left(\frac{D_i}{D_g}\right) \qquad (3.60a,b)$$

The above equations may be termed reduced hiding functions.

3.6.5 Size-independence and Equal-threshold Limiting Cases

Two limiting cases are of interest here. In one limit F_{hc} (or F_{hr}) is equal to unity, in which case Eqs. (3.56a,b), and (3.60a,b) devolve to

$$\frac{\tau^*_{sci}}{\tau^*_{scg}(Re_{pg})} = 1, \quad \frac{\tau^*_{ssri}}{\tau^*_{ssrg}(Re_{pg})} = 1, \quad \frac{\tau_{bsci}}{\tau_{bscg}} = \frac{D_i}{D_g}, \quad \frac{\tau_{bssri}}{\tau_{bssrg}} = \frac{D_i}{D_g} \qquad (3.61a,b,c,d)$$

This case corresponds to the absence of hiding. Each grain has a critical (reference) Shields number that is the same, regardless of size. A grain of given size D within a mixture has exactly the same mobility as it would have if the bed were composed entirely of size D. Thus each grain acts independently of its neighbors of differing size. The dimensioned critical (reference) shear stress needed to move a grain of size D within a mixture increases linearly with size D. If this size-independence (hiding-free) scenario were to hold, the initiation of (significant) transport of sediment mixtures would be highly selective based on grain size.

In the second limiting case F_{hc} (F_{hr}) is equated to $(D_i/D_g)^{-1}$, in which case Eqs. (3.56a,b) and (3.58a,b) devolve to

$$\frac{\tau^*_{sci}}{\tau^*_{scg}(Re_{pg})} = \left(\frac{D_i}{D_g}\right)^{-1}, \quad \frac{\tau^*_{ssri}}{\tau^*_{ssrg}(Re_{pg})} = \left(\frac{D_i}{D_g}\right)^{-1}, \quad \frac{\tau_{bsci}}{\tau_{bscg}} = 1, \quad \frac{\tau_{bssri}}{\tau_{bssrg}} = 1 \qquad (3.62a,b,c,d)$$

In this limiting case the effect of the mixture has been to equalize the threshold for (significant) motion, so that all grains are mobilized at the same absolute boundary shear stress.

In the next chapter it will be shown that sediment mixtures behave somewhere in between the size-independence and equal-threshold scenarios, but are biased more toward the latter than the former.

3.6.6 Substrate-based Formulation

A surface-based formulation is necessary in order to develop a local predictor of bed-load transport. Gross, overall predictions can be made, however, using a substrate-based formulation. Let $\bar{f}_i$ denote the volume fraction of material the ith grain size range averaged over a relatively thick layer of substrate, proceeding downward from the surface-substrate interface. The substrate-based forms corresponding to Eqs. (3.44b), (3.48), (3.49), (3.50a), (3.56) and (3.60) are

$$q_{ui}^* = \frac{q_i}{\bar{f}_i \sqrt{RgD_i}\, D_i} \tag{3.63}$$

$$q_{ui}^* = T_{ub}\left(\tau_{si}^*, \frac{D_i}{D_{ug}}, \sigma_u, Re_{pug}\right) \tag{3.64}$$

$$W_{ui}^* = \hat{T}_{ub}\left(\tau_{si}^*, \frac{D_i}{D_{ug}}, \sigma_u, Re_{pug}\right) \tag{3.65}$$

$$W_{ui}^* = \frac{Rgq_i}{\bar{f}_i u_{*s}^3} \tag{3.646}$$

$$\frac{\tau_{suci}^*}{\tau_{sucg}^*(Re_{pug})} = F_{uhc}\left(\frac{D_i}{D_{ug}}\right), \quad \frac{\tau_{suri}^*}{\tau_{surg}^*(Re_{pug})} = F_{uhr}\left(\frac{D_i}{D_{ug}}\right) \tag{3.67a,b}$$

$$\frac{\tau_{bsuci}}{\tau_{bsucg}} = F_{urhc}\left(\frac{D_i}{D_{ug}}\right) \equiv \frac{D_i}{D_{ug}} F_{uhc}\left(\frac{D_i}{D_{ug}}\right)$$

$$\frac{\tau_{bsuri}}{\tau_{bsurg}} = F_{urhr}\left(\frac{D_i}{D_{ug}}\right) \equiv \frac{D_i}{D_{ug}} F_{ur}\left(\frac{D_i}{D_{ug}}\right) \tag{3.68a,b}$$

where the subscript "u" everywhere denotes "under", i.e. substrate (as "s" has already been used for surface) and the parameter Re_{pug} is obtained from Eq. (3.44c) with the transformation $D_g \rightarrow D_{ug}$, where D_{ug} (D_{u50}) refers to substrate values based on $\bar{f}_i$. It is useful to remind the reader that D_g (D_{50}) refers to surface mean (median) sizes based on F_i. The same limiting cases of grain-independent and equal-threshold behavior can be defined based on a substrate formulation with the use of Eqs. (3.67) and (3.68).

3.6.7 Surface-based Formulation for Entrainment

A parallel development is possible for the entrainment formulation. Here the case of deterministic step lengths L_{si} in a surface-based formulation is considered for simplicity. In analogy to Eq. (3.44b), the dimensionless entrainment rate E_i^* and step length L_{si}^* are defined as

$$E_i^* = \frac{E_i}{\sqrt{RgD_i}}, \quad L_{si}^* = \frac{L_{si}}{D_i} \tag{3.69a,b}$$

The analogs of Eq. (3.48) are

$$E_i^* = T_{be}\left(\tau_{si}^*, \frac{D_i}{D_g}, \sigma, Re_{pg}\right), \quad L_{si}^* = T_{bl}\left(\tau_{si}^*, \frac{D_i}{D_g}, \sigma, Re_{pg}\right) \qquad (3.70a,b)$$

Eq. (3.70a) can be used to develop threshold (reference) conditions for the onset of (significant) entrainment into bed-load that are analogous to Eqs. (3.56) and (3.60).

3.7 RELATIONS FOR HIDING AND BED-LOAD TRANSPORT OF MIXTURES

3.7.1 Relations for Threshold of Motion and Hiding

The classical relation for the threshold of motion of uniform sediment is that of Shields (1936). In terms of the notation presented above, the relation predicts the critical Shields number τ_{scg}^* (or τ_{sc50}^*) as a function of explicit particle Reynolds number Re_{pg} or Re_{p50}. Brownlie (1981) fitted a convenient analytical function to this curve. In general, however, the Shields curve tends to overpredict the critical Shields number. For example, in the limit of hydraulically rough flows ($Re_{pg} \rightarrow \infty$) the predicted value of τ_{scg}^* is near 0.06. This criterion incorrectly indicates, however, that most gravel-bed streams would be unable to move a surface mean or median size particle even at bank-full flow, as demonstrated below. Neill (1968) has suggested a revised value of 0.03, which appears to have stood the test of time (e.g. in the case of Oak Creek, Oregon, California as analysed by Milhous, 1973 and Parker and Klingeman, 1982; and in the case of the Nahal Eshtemoa, Israel, as analyzed by Powell et al., 2001). Adjusting the Brownlie relation by multiplying the right-hand side by one-half to obtain this limit, the following curve is obtained;

$$\tau_{scg}^* = \frac{1}{2}\left[0.22\ Re_{pg}^{-0.6} + 0.06 \cdot 10^{(-7.7 Re_{pg}^{-0.6})}\right] \qquad (3.71)$$

The appropriate grain size to use in Eq. (3.71) is a surface value D_g or D_{50}. In the case of field gravel-bed rivers in particular, the bed tends to be armored at low flow, so that the corresponding substrate D_{ug} or D_{u50} can usually be expected to be below the corresponding surface value, by a multiplicative factor ranging from 0.25 to 1 (e.g. Dietrich et al., 1989). As a result the value of τ_{sucg}^* based on D_{ug} tends to be higher than τ_{scg}^* by a factor of 1 to 4.

Buffington and Montgomery (1997) conducted a review of eight decades of incipient motion data, with special reference to gravel-bed rivers. Their data base includes both experimental and field data. Their analysis was done in terms of D_{50} rather than D_g. They went to some effort to ensure the removal of form drag from most of the estimates of shear stress used in their treatment. In addition, they performed a service to the community in publishing their entire data set. They found that the data generally followed the overall shape of the Shields curve. Eq. (3.71) forms an approximate lower bound for the data for $Re_{pg} > 100$ ($D_g > 0.85$ mm for $R = 1.65$ and $\nu = 1\text{x}10^{-6}$ m^2/s). A subset of their data base is compared with Eq. (3.71) in Figure 3.34. Also included in the figure are a) the original form of the Brownlie fit to the Shields curve and b) points based on bank-full flow and surface D_{50} (measured at low flow) for the three sets of gravel-bed streams introduced in Section 3.3 above. Most (but not all) of these streams can be expected to be competent to move the surface D_{50} size at bank-full flow.

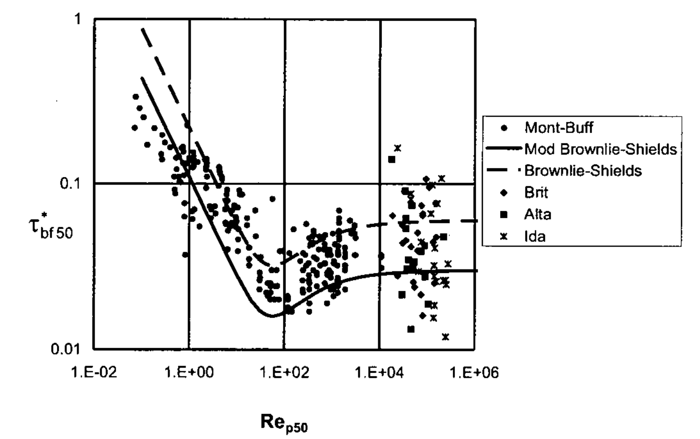


Figure 3.34 Plot of critical Shields number versus particle Reynolds number showing a) the Brownlie (1981) fit to the original Shields (1936) curve, b) the modified Brownlie fit of Eq. (3.71), c) the data of Buffington and Montgomery (1997) pertaining to τ_{cv50m}^* and d) the gravel-bed rivers of Figure 3.29.

The large scatter in Figure 3.34 is a problem, as noted by Buffington and Montgomery (1997). This notwithstanding, Eq. (3.71) would appear to be an appropriate estimator of at least a lower bound on τ_{scg}^* or the corresponding τ_{sc50}^* based on D_{50} in streams with values of D_g or D_{50} in excess of 1 mm. The original form the the Brownlie fit to the Shields curve is seen to overpredict the critical Shields number for the great majority of the data from Buffington and Montgomery (1997), and to render most of the gravel-bed streams therein incapable of transporting their mean or median surface size at bank-full flow.

Several researchers have presented derivations of the Shields diagram from basic principles. In the case of uniform sediment, the work of Ikeda (1982) and Wiberg and Smith (1987) stand out. The latter work also provides an extension to sediment mixtures, and thus implicitly determines a hiding function similar to that of Egiazaroff (1965).

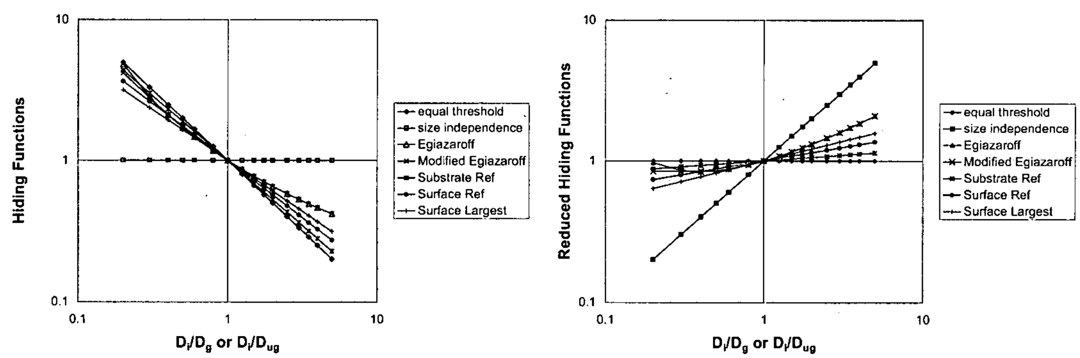
The first researcher to suggest a form for a hiding function for sediment mixtures was Einstein (1950). This work is remarkable in that it provides a complete, physically based implementation of the dimensional analysis presented above. Unfortunately the work was so far ahead of its time that little data was available to test the hiding function. Further analysis (e.g. Misri et al., 1984) has shown that the Einstein hiding function is a poor approximation of the data.

The first hiding function which was found to be a reasonable approximation of at least some data for heterogeneous sediments is the surface-based relation of Egiazaroff (1965). Egiazaroff provides a simplified derivation from basic principles so as to include both the effect of increasing grain weight in reducing mobility, and increasing protrusion of larger grains in increasing mobility, within a mixture.

$$\frac{\tau^*_{sci}}{\tau^*_{scg}} = F_{hc}\left(\frac{D_i}{D_g}\right) = \left[\frac{log(19)}{log\left(19\frac{D_i}{D_g}\right)}\right]^2$$

$$\frac{\tau_{bsci}}{\tau_{bscg}} = F_{rhc}\left(\frac{D_i}{D_g}\right) = \frac{D_i}{D_g}\left[\frac{log(19)}{log\left(19\frac{D_i}{D_g}\right)}\right]^2 \qquad (3.72a,b)$$

(In point of fact Egiazaroff used D_m, defined by Eq. (3.10), rather than D_g, so perpetuating a misconception that has continued to this day, i.e. that D_m rather than D_g is the appropriate size with which to characterize sediment mixtures.) The Egiazaroff hiding function is illustrated in Figure 3.35a, along with the limiting cases of size-independence (no hiding) and equal-threshold. The corresponding reduced hiding function is shown in Figure 3.35b, along with the limiting cases.



a) b)

Figure 3.35 Plots of a) hiding function obtained from Egiazaroff relation, the modified Egiazaroff relation, the condition of size-independence, the condition of equal-threshold, and the power relations of Eqs. (3.74a,b) using $\gamma_{subref} = 0.81$, $\gamma_{surfref} = 0.90$ and $\gamma_{surflarg} = 0.72$; and b) reduced hiding functions corresponding to a) above.

Figure 3.35b is of particular interest. The Egiazaroff hiding function clearly plots between the case of size-independence and equal-threshold. It is clearly closer, however, to the latter case, indicating that the structure of sediment mixtures works in the direction of equalizing the threshold shear stress required for the motion of all grains. This equalization cannot extend, however, all the way to very coarse, rare grains, and as a result the largest deviation from equal-threshold is for the coarsest grains in a mix.

Ashida and Michiue (1972) noted one curious feature in Figure 3.35b; sizes such that $D_i/D_g < 0.04$ become progressively harder to move with decreasing grain size. With this in mind, they suggested the following *ad-hoc* modification;

$$\frac{\tau_{sci}^*}{\tau_{scg}^*} = F_{hc}\left(\frac{D_i}{D_g}\right) = 0.843\left(\frac{D_i}{D_g}\right)^{-1} \; for \frac{D_i}{D_g} \leq 0.4$$
$$\frac{\tau_{bsci}}{\tau_{bscg}} = F_{rhc}\left(\frac{D_i}{D_g}\right) = 0.843 \; for \frac{D_i}{D_g} \leq 0.4 \qquad (3.73a,b)$$

This modified form has been used by many subsequent researchers.

Parker et al. (1982a) and Parker and Klingeman (1982) introduced the concept of power relations for hiding functions. In particular, they deduced the following surface-based forms for reference (rather than critical) conditions using D_{50};

$$\frac{\tau_{ssri}^*}{\tau_{ssr50}^*} = F_{hr}\left(\frac{D_i}{D_{50}}\right) = \left(\frac{D_i}{D_{50}}\right)^{-\gamma}$$
$$\frac{\tau_{bssri}}{\tau_{bssr50}} = F_{rhr}\left(\frac{D_i}{D_{50}}\right) = \left(\frac{D_i}{D_{50}}\right)^{1-\gamma} \qquad (3.74a,b)$$

as well as corresponding substrate-based forms. Here a value of γ of 0 corresponds to size-independence and a value of 1 corresponds to equal-threshold conditions.

Parker et al. (1982a) found a substrate-based value of γ of 0.982 for Oak Creek, Oregon, USA, i.e. very near equal-threshold conditions. Parker (1990a) deduced a surface-based value for the same stream of 0.905. Parker and Klingeman (1982) interpreted the difference between these two numbers in terms of a mobile-bed armor, as discussed in Section 3.10.

Values of γ have been investigated in a number of rivers and laboratory flumes. Buffington and Montgomery (1997) and Powell (1998) provide summaries of these relations. Computations have proceeded using the reference concentration method, in which a measured bed-load data are used to interpolate or extrapolate values of reference Shields number, and also by determining the coarsest grain captured in a bed-load sample for a given flow. Discussion of the difference between the two methods can be found in Komar (1987), Wilcock (1988) and Shih and Komar (1990). The reported values of γ are summarized for field streams in Table 3.1.

Table 3.1. Values of γ Measured for Various Gravel-bed Streams

STREAM	AUTHORS	D_{50}	γ
SURFACE-BASED REFERENCE METHOD			
Oak Creek, Oregon, USA	Parker (1990a)	54	0.90
Allt Dubhaig, Scotland	Ashworth and Ferguson (1989)	50	0.65
Goodwin Creek, Mississippi, USA	Kuhnle (1992)	11.7	0.81
Allt Dubhaig, Scotland	Wathen et al. (1995)	21	0.90
Sunwapta River, Canada	Ashworth et al. (1992)	24	0.79
AVERAGED SURFACE-BASED REFERENCE			0.81
SUBSTRATE-BASED REFERENCE METHOD			
Oak Creek, Oregon, USA	Parker et al. (1982a)	20	0.98
Goodwin Creek, Mississippi, USA	Kuhnle (1992)	8.3	0.81
AVERAGED SUBSTRATE-BASED REFERENCE			0.90
SURFACE-BASED LARGEST GRAIN METHOD			
Sage Hen Creek, California, USA	Andrews (1983) and Andrews and Erman (1986)	58	1.07
Oak Creek, Oregon, USA	Komar (1987) and Komar and Carling (1991)	63	0.43 – 0.64
Great Egglesthorpe Beck, UK	Komar (1987) and Komar and Carling (1991)	62	0.64 = - 0.82
Sunwapta River, Canada	Ashworth et al. (1992)	21	0.69
AVERAGED SURFACE BASED LARGEST GRAIN			0.72

Table 3.1 can be summarized as follows. Substrate-based values of γ based on the reference method average to γ_{subref} = 0.90, and are closest to the equal-threshold condition. Surface-based values based on the reference method average to $\gamma_{surfref}$ = 0.81, and surface-based values using the method of largest clast average to $\gamma_{surflarg}$ = 0.72. The resulting hiding functions are shown in Figure 3.34. In all cases the trend is far more toward equal-threshold conditions rather than size-independence conditions. In all cases,

however, there is at least a residual tendency toward selecting the finer sizes in mobilizing sediment mixtures. Surface-based values of the exponent γ are smaller than substrate-based values.

As pointed out above, a simple power form for the hiding function cannot in general be correct. In particular, both the hiding function and the reduced hiding function can be expected to be concave-upward. On the one hand rare, large clasts must be rendered difficult to move, causing the hiding function to curve upward as relative grain size increases. On the other hand the influence of grain size on mobility can be expected to diminish as relative grain size decreases, causing the hiding function to curve upward with decreasing grain size. The hiding functions of Egiazaroff (1965) and Proffitt and Sutherland (1983) have this property; in the former case it can be readily seen in Figures 3.35a and 3.35b. Misri et al. (1984) have demonstrated the same behavior for their experimental data. Wilcock and Southard (1988) demonstrated it for their own data, as well as the experimental data of Day (1980) and Parker et al. (1982b) and the field data for Oak Creek due to Milhous (1973). The hiding function of Wilcock and Crowe (2003) also shows this property, as is discussed below in Section 3.7.9.

3.7.2 Calculation of Boundary Shear Stress and Other Flow Parameters

Bed-load transport is driven by the hydraulics of the flow. As noted in Section 3.6.2, at least one hydraulic parameter, such as boundary shear stress τ_b or depth-averaged flow velocity U invariably appears in bed-load transport relations. Boundary shear stress is often quantified in terms of shear velocity u_*, where

$$u_* = \sqrt{\frac{\tau_b}{\rho}} \tag{3.75a}$$

Depth- or cross-sectionally averaged flow velocity U is related to shear velocity in terms of a dimensionless friction coefficient C_f, or an equivalent dimensionless Chezy coefficient Cz, where

$$Cz = \frac{U}{u_*}, \quad C_f = \frac{\tau_b}{\rho U^2} = Cz^{-2} \tag{3.75b,c}$$

Forms for these parameters were introduced for bank-full flow as Eqs. (3.15a,b) in Section 3.4.

The boundary shear stress acting on the bed of a river can be a mixture of skin friction τ_{bs} and form drag τ_{bf}, as discussed in Chapter 2. In the case of flow over a hydraulic rough granular bed in the absence of form drag friction relations of the following type are often used;

$$Cz = 2.5 ln\left(11\frac{H}{k_s}\right), \quad Cz = 8.1\left(\frac{H}{k_s}\right)^{1/6} \tag{3.75d,e}$$

where H denotes flow depth and k_s denotes roughness height. Eqs. (3.75d) and (3.75e) are similar; the former is a logarithmic form due to Keulegan (1938) and the latter is a Manning-Strickler form due to Parker (1991a). Many variations on these forms can be found in literature. Roughness height k_s is often related to the surface size D_{90} as follows;

$$k_s = n_k D_{90} \tag{3.75f}$$

where n_k has been estimated to range between 2 and 3.5 for granular beds (Kamphuis, 1974; Hey, 1979).

Many predictive relations for bed-load transport require boundary shear stress as an input parameter. The simplest formulation for calculating boundary shear stress, or shear velocity is based on the assumption of 1D normal (steady, uniform equilibrium) flow in a wide rectangular channel;

$$\tau_b = \rho gHS\,, \quad u_* = \sqrt{gHS} \tag{3.76a,b}$$

where H and S denote flow depth and bed slope. Where flow velocity is required for a sediment transport calculation, it can then be computed from Eqs (3.75) and (3.76).

Two questions arise at this point. Is form drag negligible in gravel-bed rivers? Can the flow field be accurately computed from the assumption of 1D normal flow? The latter query is approached first. Many gravel-bed rivers are small and steep, with very flashy hydrographs. For such streams Eq. (3.76) may be inadequate to model boundary shear stress. The next level of complication is the use of the 1D shallow-water St. Venant equations to predict the flow field. The 1D equations of momentum balance takes the form

$$\frac{\partial H}{\partial t} + \frac{\partial UH}{\partial s} = 0\,, \quad \frac{\partial U}{\partial t} + U\frac{\partial U}{\partial s} = -g\frac{\partial H}{\partial s} + gS - \frac{C_f U^2}{H} \tag{3.76c,d}$$

Thes equations, coupled with the resistance formulations of Eqs. (3.75d,e) allow for the computation of τ_b or u_*, U, H and other hydraulic parameters that might serve as inputs to sediment transport equations as functions of streamwise distance s and time t. In some cases Eqs. (3.76c,d) can be simplified to their backwater forms by neglecting the time derivatives. In other cases even a 1D unstready, nonuniform approach may be insufficient, and the local input parameters to a sediment transport equation may require estimation with a 2D model. A case in point is a resolution of the 2D sediment transport field in a river bend. The issue is discussed in more detail in Section 3.13.2.

As for the former question, form drag in sand-bed streams is of sufficient importance to merit extensive attention, as seen in Chapter 2. A number of methods are available to extract out only the term τ_{bs} due to skin friction from the total boundary shear stress τ_s for such streams.

As noted in Section 3.6.2, it is explicitly or implicitly assumed in most shear stress-based formulations of bed-load transport that only the portion of the shear stress due to skin friction actually drives sediment transport, so that τ_{bs} rather than τ_b should appear as input to the computation. The problem with gravel-bed streams, however, is that once obvious effects such as debris jams and major channel irregularities have been discounted, the residual form drag due to e.g. bars has only been poorly quantified to date. Parker and Peterson (1980) have argued that form drag associated with bars in gravel-bed rivers is negligible at flows high enough to transport significant gravel loads. Hey (1989) has argued otherwise, and Millar (1999) has presented further evidence suggesting that form drag can be significant in some gravel-bed streams. A generally-validated predictive method allowing a boundary shear stress decomposition into skin friction and form drag, however, is no yet available.

The reader is thus offered two caveats concerning the transport relations presented below.

- While the indicated input parameter in the text is τ_{bs}, in point of fact the user will most often have to equate this to τ_b because the information for a shear stress decomposition is lacking.
- In addition, much of the data analysis used to estimate boundary shear stress and other parameters in developing the relations presented below is based on the assumption of normal flow, which in fact may not been an accurate approximation to the actual flows in question. This is particularly true of the field data.

The scatter seen between the predictions of the various relations must be viewed in light of these two sources of error.

3.7.3 Relation of Einstein

Considerations of dimensional analysis yielded bed-load transport relations of the type of Eqs. (3.48) and (3.49). The conversion of these forms into predictive relations has typically required the folding of parameters together by means of an explicit or implicit similarity hypothesis. Einstein (1950) was the first to execute such an analysis for the bed-load transport of mixtures. The relation cannot be considered appropriate for the purposes of calculation due to the gross inaccuracies in the hiding function. As a result the relation is not covered in detail here. (The form for a single grain size is given in Chapter 2.) This notwithstanding, subsequent researchers have owed a debt to Einstein for pointing the path toward the progress that has been realized to date.

3.7.4 Relation of Ashida and Michiue

The relation of Ashida and Michiue (1972) is the first bed-load transport relation for mixtures with a thorough test against against data. The data pertain exclusively to experiments. Although the authors did not specify their relation as surface-based because the concept did not exist at the time, it is here treated as such.

In Eq. (3.49) the parameters Re_{pg} and σ are dropped, D_m is used rather than D_g (so that $g \rightarrow m$ in the subscripts) and the dependence on D_i/D_m is folded into a hiding relation for critical stress. The relation thus takes the form

$$q_i^* = 17\left(\tau_{si}^* - \tau_{sci}^*\right)\left(\sqrt{\tau_{si}^*} - \sqrt{\tau_{sci}^*}\right) \tag{3.77a}$$

where

$$\frac{\tau_{sci}^*}{\tau_{scm}^*} = F_{hc}\left(\frac{D_i}{D_m}\right) = \begin{cases} 0.843\left(\dfrac{D_i}{D_m}\right)^{-1} & for\dfrac{D_i}{D_m} \le 0.4 \\ \left[\dfrac{log(19)}{log\left(19\dfrac{D_i}{D_m}\right)}\right]^2 & for\dfrac{D_i}{D_m} > 0.4 \end{cases} \tag{3.77b}$$

i.e. the modified Egiazaroff relation. Note that in the above relation D_m denotes a mean surface grain size calculated in accordance with the arithmetic rule of Eq. (3.10) rather than the geometric rule of Eqs. (3.5a) and (3.6a). This treatment of grain statistics appears to be a legacy of Egiazaroff (1965), who likely did not perceive clearly the difference between D_g and D_m. Ashida and Michiue recommend the following value for $\tau_{scm}{}^*$;

$$\tau_{scm}^* = 0.05 \tag{3.77c}$$

Shear stress is based on skin friction. Ashida and Michiue provide their own method for removing form drag. The data base used to develop the relation consists mostly of experiments with a sand bed, but experiments using pea gravel were also a significant component. The relation, however, is difficult to apply to many natural gravel-bed streams due to the high value of $\tau_{scm}{}^*$. In particular, the average value of the bank-full Shields number $\tau_{bf50}{}^*$ based on surface median size in the gravel-bed streams of Figure 3.23 is only 0.049.

Calculations with the relation of Ashida and Michiue proceed as follows. The grain sizes and fractions (D_i, F_i) of the surface layer, submerged specific gravity of the sediment R and shear velocity associated with skin friction u_{*s} must be specified. The surface mean grain size D_m is computed with Eq. (3.12d) (in which $p_i \rightarrow F_i$), the Shields numbers τ_{si}^* are computed with Eqs. (3.46) and (3.47), and the critical Shields numbers τ_{sci}^* are computed from Eqs. (3.77b,c). The Einstein numbers q_i^* are then computed from Eq. (3.77a), and the volume transport rates per unit width q_i from Eq. (3.44b). The total bed-load transport rate per unit width q_T and fraction bed-load in the ith grain size range f_{bi} are then computed from Eqs. (3.26) and (3.28).

3.7.5 Substrate-based Relation of Parker, Klingeman and McLean and Derivative Formulations

The substrate-based relation of Parker et al (1982a) is based solely on field data, mostly from Oak Creek (Milhous, 1973) but also from the Elbow River, Canada (Hollingshead, 1971) and several other streams. The shear stresses were computed from depth-slope products, and it was assumed that form drag at gravel-transporting flows was negligible. This assumption was made based on visual observation of the channel of Oak Creek at low flow, which is not particular sinuous and contains only very subdued bars. In retrospect, however, the assumption may not be entirely accurate. The relations are developed with the aid of an approximate substrate-based similarity collapse similar to the one introduced in Section 3.6.4.

The relation applies only to gravel transport. A bulk sample of substrate in a relatively thick layer immediately below the surface layer is used to characterize the fractions $\bar{f}_i$ All sand must be extracted out of the substrate size distribution, and the resulting gravel distribution renormalized so that $\bar{f}_i$ sums to unity before applying the relation.

The relevant characteristic grain size in the relation is substrate median size D_{u50}. It does not contain a critical shear stress, but rather uses a reference value W_r^* of 0.002 in order to determine reference Shields numbers τ_{suri}^*. The hiding relation was found to be

$$\frac{\tau_{suri}^*}{\tau_{sur50}^*} = F_{uhr}\left(\frac{D_i}{D_{u50}}\right) = \left(\frac{D_i}{D_{u50}}\right)^{-0.98} \tag{3.78a}$$

where

$$\tau_{sur50}^* = 0.0876 \tag{3.78b}$$

The transport relation is obtained from an approximate similarity collapse of the data. Thus Re_{pg} and σ are dropped from Eq. (3.49), and the parameter D_i/D_{u50} is folded into the reference Shields numbers, resulting in the relation

$$W_{ui}^* = \frac{Rgq_i}{\bar{f}_i u_{*s}^3} = G_u(\phi), \quad \phi = \frac{\tau_{si}^*}{\tau_{suri}^*} \tag{3.78c,d}$$

where

$$G_u(\phi) = \begin{cases} 0.0025\,exp\left[14.2(\phi-1)-9.28(\phi-1)^2\right] for \quad 0.95 < \phi < 1.65 \\ 11.2\left(1-\dfrac{0.822}{\phi}\right)^{4.5} \quad for \quad \phi > 1.65 \end{cases} \tag{3.78e}$$

The alternative for $\phi > 1.65$ in Eq. (3.76d) is based on the Parker (1978b) approximation of the Einstein (1950) relation for uniform sediment.

Calculations with the above relation proceed as follows. The grain sizes and fractions (D_i, $\bar{f}_i$) of the substrate layer, submerged specific gravity of the sediment R and shear velocity associated with skin friction u_{*s} must be specified. The substrate median grain size D_{u50} is computed from by interpolation from the fractions finer. The Shields numbers τ_{si}^* are computed with Eqs. (3.46) and (3.47), and the reference Shields numbers τ_{suri}^* are computed from Eqs. (3.78a,b). The values of W_{ui}^* and q_i are then obtained from Eqs. (3.78c,d,e). The total bed-load transport rate per unit width q_T and fraction bed-load in the ith grain size range f_{bi} are then computed from Eqs. (3.26) and (3.28).

Eqs. (3.78a) and (3.78b) engender a remarkable simplification that merits note. Replacing the exponent – 0.98 in Eq. (3.74a) with – 1, corresponding to the equal-threshold condition and substituting into Eq. (3.78c), it is found that grain size D_i exactly cancels out, resulting in the relation

$$\phi = \frac{\tau_{si}^*}{\tau_{suri}^*} = \frac{\tau_{su50}^*}{\tau_{sur50}^*} \tag{3.78f}$$

$$\tau_{su50}^* = \frac{\tau_{bs}}{\rho R g D_{u50}} \tag{3.78g}$$

As a result, (3.78c) becomes

$$q_i = \bar{f}_i \frac{u_{*s}^3}{Rg} G_u\left(\frac{\tau_{su50}^*}{\tau_{sur50}^*}\right) \tag{3.78h}$$

Since G_u has been rendered independent of D_i, it is quickly verified from Eqs. (3.28) and (3.78g) that

$$f_{bi} = \bar{f}_i \tag{3.78i}$$

That is, all sizes in the substrate are represented in the same proportion in the bed-load. This defines an extreme case of substrate-based equal mobility.

Parker et al. (1982a) went on to demonstrate that perfect substrate-based equal mobility is not in fact satisfied because the similarity collapse of Eq. (3.78c) is not perfect. Lower flood flows are biased toward finer gravel, and higher flood flows are biased toward coarser gravel. This notwithstanding, substrate-based equal mobility is approximately satisfied in terms of the annual yield of gravel.

Parker et al. (1982a) extended their treatment to include deviation from perfect similarity. The resulting substrate-based transport relation contains three gravel size ranges, and correctly predicts the tendency for median bed-load gravel size to increase with increasing stage. Parker and Klingeman (1982) extended this three-size treatment to a surface-based model. Diplas (1987) further refined the work with a detailed analysis of deviation from similarity, resulting in a model that can clearly define the degree of transport selectivity in Oak Creek. Bakke et al. (1999) have used the basic model of Parker and Klingeman (1982) to develop a modified predictor allowing for efficient site-specific calibration.

3.7.6 Surface-based Relation of Parker

A substrate-based bed-load transport relation can be used for gross predictions of sediment transport. In a local sense, however, it is surface material that directly exchanges sediment with the bed-load. As a result, it is not obvious how to implement the active layer formulation of Section 3.5 with a substrate-based bed-load formulation. This renders numerical modeling of bed level variation and sorting difficult. In addition, it will be demonstrated in Section 3.10 that the grain size distribution of the surface layer varies dynamically with flow conditions.

With this in mind, Parker (1990a) reanalyzed the Oak Creek data to determine a surface-based bed-load transport formula. Again, all sand must be excluded from the surface grain size distribution and the fractions F_i renormalized to sum to unity before applying the model. The reasons for the exclusion of sand are a) during flood flows capable of moving the gravel the sand may be suspended and carried as throughput load, with little interaction with the bed other than a passive filling of gravel pores, and b) many rivers (although not Oak Creek) are strongly bimodal, with a paucity of pea gravel, so defining a natural cutoff size for gravel. The model takes the form

$$W_i^* = \frac{Rgq_i}{F_i u_{*s}^3} = 0.00218G(\phi) \qquad (3.79a)$$

where

$$\phi = \omega\phi_{sgo}\left(\frac{D_i}{D_g}\right)^{-0.0951}, \quad \phi_{sgo} = \frac{\tau_{sg}^*}{\tau_{ssrg}^*}, \quad \tau_{sg}^* = \frac{\tau_{bs}}{\rho R g D_g}, \quad \tau_{ssrg}^* = 0.0386$$

$$G(\phi) = \begin{cases} 5474\left(1 - \dfrac{0.853}{\phi}\right)^{4.5} & for\ \phi > 1.59 \\ exp\left[14.2(\phi - 1) - 9.28(\phi - 1)^2\right] & for\ 1 \le \phi \le 1.59 \\ \phi^{14.2} & for\ \phi < 1 \end{cases} \qquad (3.79b\text{-}g)$$

$$\omega = 1 + \frac{\sigma}{\sigma_O(\phi_{sgo})}\left[\omega_O(\phi_{sgo}) - 1\right]$$

Finally the functions $\sigma_O(\phi_{sgo})$ and $\omega_O(\phi_{sgo})$ are specified in Figure 3.36. Tables for these functions are given in Parker (1990b), along with a DOS implementation of the above method, ACRONYM1.

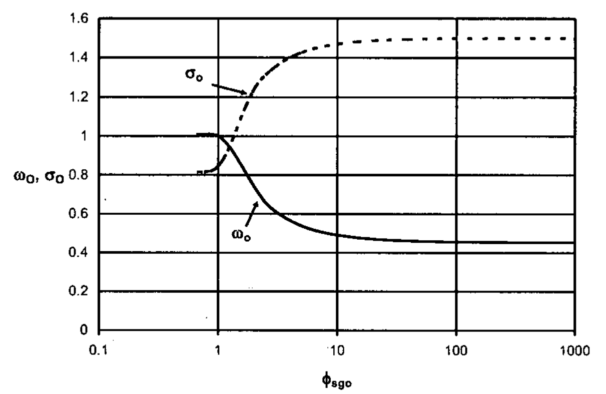


Figure 3.36 Plots of the functions $\sigma_O(\phi_{sgo})$ and $\omega_O(\phi_{sgo})$ for the Parker (1990a) relation.

Observations of the state of the bed surface of Oak Creek during floods transporting bed-load were not possible (Milhous, 1973). As a result, the above equation is not based on direct measurements of the composition of the surface layer during floods. Rather, the variation in F_i as a function of stage was inferred in the derivation of the relation. When applied to Oak Creek with a varying gravel bed-load transport rate and a constant gravel bed-load grain size distribution, the model predicts a tendency for the surface layer to become finer with increasing stage, eventually approaching the composition of the substrate. That is, the model predicts that at very high stages the bed should be unarmored. This is exactly what is observed in some ephemeral streams subject to violent floods such as the Nahal Eshtemoa (Powell et al., 2001). The issue is explored in more detail in Section 3.11.3. Some debate about this result remains, however, because in point of fact the gravel bed-load grain size distribution becomes coarser with stage in Oak Creek.

Calculations with the above relation proceed as follows. The grain sizes and fractions (D_i, F_i) of the surface layer (from which the sand has been excluded), submerged specific gravity of the sediment R and shear velocity associated with skin friction u_{*s} must be specified. The surface geometric grain size D_g and arithmetic standard deviation σ are computed from Eqs. (3.6a), (3.12b) and (3.12c) with the transformation $p_i \rightarrow F_i$. The Shields number τ_{sg}^* are computed with Eqs. (3.79d) and (3.47). The values of W_i^* and q_i are then obtained from Eqs. (3.79a) with the aid of Eqs.

(3.79b,e,f,g). The total bed-load transport rate per unit width q_T and fraction bed-load in the *i*th grain size range f_{bi} are then computed from Eqs. (3.26) and (3.28).

3.7.7 Surface-based Entrainment Relation of Tsujimoto

In a bed-load entrainment model of type specified in Eqs. (3.39) – (3.41) it is necessary to specify expressions for E_i and L_{si} along the lines of Eqs. (3.70a,b). Tsujimoto and Motohashi (1990) and Tsujimoto (1991, 1999) have developed such forms;

$$E_i^* = 0.02\tau_{si}^*\left(1-0.7\frac{\tau_{sci}^*}{\tau_{si}^*}\right)^3 \qquad (3.80a)$$

$$\frac{\tau_{sci}^*}{\tau_{scm}^*} = F_{hc}\left(\frac{D_i}{D_m}\right) = \begin{cases} 0.843\left(\dfrac{D_i}{D_m}\right)^{-1} & for\ \dfrac{D_i}{D_m} \le 0.4 \\ \left[\dfrac{log(19)}{log\left(19\dfrac{D_i}{D_m}\right)}\right]^2 & for\ \dfrac{D_i}{D_m} > 0.4 \end{cases} \qquad (3.80b,c)$$

$$L_{si}^* = L_{so}^* \qquad (3.80d)$$

In the above relations the arithmetic mean grain size D_m is specified by the arithmetic rule of Eq. (3.10) rather than the geometric rule of Eqs. (3.5a) and (3.6a). The hiding function is the same one as used by Ashida and Michiue (1972), i.e. the modified Egiazaroff (1965) relation. The critical Shields number τ_{scm}^* is in general a function of Re_{pm} that appears to be specified in Nakagawa et al. (1982), but takes the value 0.05 in the limit of large Re_{pm}, i.e. the same limit as Ashida and Michiue (1972). In addition, Tsujimoto (1990) rather vaguely specifies L_{so}^* as "almost constant" among grain sizes and taking a value between 10 and 30, i.e. "smaller…than the value for uniform size material (80 – 250)."

In the case of bed-load transport that can be approximated as quasi-uniform at the scale of the step length, Eq. (3.41), the definitions of Eqs. (3.70a,b) and the above relations yield the following expression for bed-load transport rate;

$$q_i^* = E_i^* L_{si}^* = 0.02 L_{so}^* \tau_{si}^*\left(1-0.7\frac{\tau_{sci}^*}{\tau_{si}^*}\right)^3 \qquad (3.80e)$$

The main reason for including this relation is the illustration of a bed-load transport relation obtained from considerations of entrainment into bed-load. The equation itself is not of sufficient generality to recommend it as a general method for calculating bed-load transport in gravel-bed streams.

3.7.8 Surface-based Relation of Hunziker and Jaeggi

The surface-based relation of Hunziker and Jaeggi (2002) represents a generalization of the relation of Meyer-Peter and Müller (1948). It was developed in order to obtain a description of both static and mobile armoring in rivers. The experiments on mobile armoring reported in Suzuki and Kato (1991) and Suzuki and Hano (1992) were used to help develop and verify the model. The formulation is expressed as

$$q_i^* = 5\left(\frac{D_i}{D_m}\right)^{-3/2}\left[\left(\frac{D_i}{D_m}\right)^{-\alpha}\left(\tau_{sm}^* - \tau_{scm}^*\right)\right]^{1.5}$$

$$\tau_{sm}^* = \frac{\tau_{bs}}{\rho R g D_m}, \quad \tau_{scm}^* = \tau_{scmo}^*\left(\frac{D_{um}}{D_m}\right)^{0.33}, \quad \tau_{scmo}^* = 0.05 \qquad (3.81a\text{-}e)$$

$$\alpha = 0.011\left(\tau_{sm}^*\right)^{-1.5} - 0.3$$

where D_m and D_{um} refer to mean surface and substrate sizes, respectively, computed from the arithmetic rule of Eq. (3.10) rather than the geometric rule of Eqs. (3.5a) and (3.6a).

Calculations with the relation of Ashida and Michiue proceed as follows. The grain sizes and fractions (D_i, F_i, $\bar{f}_i$) of the surface and immediate substrate layers, submerged specific gravity of the sediment R and shear velocity associated with skin friction u_{*s} must be specified. The surface and substrate mean grain sizes D_m, respectively are computed from Eq. (3.12d) with the respective transformations $p_i \rightarrow F_i$ and $p_i \rightarrow \bar{f}_i$. The Shields number $\tau_{sm}{}^*$ is computed with Eqs. (3.81b) and (3.47), and the Einstein numbers $q_i{}^*$ are then computed from Eq. (3.81a) with the aid of Eqs. (3.81c,d,e). The volume transport rates per unit width q_i are obtained from Eq. (3.44b). The total bed-load transport rate per unit width q_T and fraction bed-load in the ith grain size range f_{bi} are then computed from Eqs. (3.26) and (3.28).

3.7.9 Two-fraction Relation of Wilcock and Kenworthy

A unique set of experiments on the transport of sand-gravel mixtures in a recirculating flume (Wilcock et al., 2001) has allowed for a quantification of the interplay between the sand and gravel components of a mixture undergoing bed-load transport. The experiments, in which sand content in the bulk material varies from 6.2% to 34%, reveal a degree of interaction that was not foreseen by e.g. Parker (1990a), in whose relation the sand is excluded from the surface grain size distribution before computing the gravel bed-load transport.

Consider a sediment mixture undergoing bed-load transport in, for example, a sediment feed flume. Now increase the feed rate of a range of the finest grain sizes undergoing bed-load transport without changing the feed rate of the coarser sizes. The increased feed of finer sizes has the effect of lowering D_{50}, and so increases the Shields number τ_{s50}^*, given as

$$\tau_{s50}^* = \frac{\tau_{sb}}{\rho R g D_{50}} \tag{3.82}$$

The result is an increased mobility of all sizes. The model of Parker (1990a) can capture this effect when fine gravel is added, but it is unable to capture it when sand is added because the sand is explicitly excluded from the grain size distribution.

Wilcock et al. (2001) have demonstrated that the addition of sand results in an effect that is stronger than that embodied in the increase of τ_{s50}^* through decreased D_{50}. In particular, the addition of sand can dramatically lower the reference Shield stress for gravel. This effect was first described in Wilcock (1998a). (Recall that a reference Shields number is a surrogate for critical Shields number).

Wilcock and Kenworthy (2002) captured this effect in terms of a two-fraction model such that grain size D_1 characterizes the sand and size D_2 characterizes the gravel. The model was developed with both the laboratory data reported in Wilcock et al. (2001) and field data from the East Fork River, Wyoming, USA (Emmett et al., 1980), Goodwin Creek, Mississippi, USA (Kuhne, 1992), Jacoby Creek, California, USA (Lisle, 1989) and Oak Creek, Oregon, USA (Milhous, 1973). Their model is presented in both surface-based and substrate-based form. Only the surface-based form is presented here; the reader is referred to the original reference for the substrate-based form.

$$W_i^* = \frac{Rgq_i}{F_i u_{*s}^3} = G(\phi), \quad \phi = \frac{\tau_{si}^*}{\tau_{ssri}^*} = \frac{\tau_{bs}}{\tau_{bssri}}$$
$$G = \begin{cases} 0.002\phi^{7.5} & for\ \phi < \phi' \\ A\left(1 - \dfrac{\chi}{\phi^{0.25}}\right)^{4.5} & for\ \phi \geq \phi' \end{cases} \tag{3.83a-d}$$
$$\tau_{ssri}^* = \tau_{ssri,max}^* - \frac{\tau_{ssri,max}^* - \tau_{ssri,sand}^*}{1 + exp(-kF_1)}$$

Recall here that $i = 1$ corresponds to sand and $i = 2$ corresponds to gravel; thus F_1 and F_2 correspond to the content of sand and gravel, respectively, in the surface layer. in the surface layer. The form of G has a steep dependence on ϕ for low stage, in the manner of Paintal (1971), and incorporates a modified form of the Parker (1978b) approximation to the Einstein (1950) relation for higher stage. In the above relations,

$$A = \begin{cases} 70, & laboratory \\ 115, & field \end{cases}, \quad \chi = \begin{cases} 0.908, & laboratory \\ 0.923, & field \end{cases}, \quad \phi' = \begin{cases} 1.19, & laboratory \\ 1.27, & field \end{cases}$$

$$\tau^*_{ssr1,max} = \tau^*_{ssr2,max}\frac{D_2}{D_1}, \quad \tau^*_{ssr2,max} = 0.061$$
$$\tau^*_{ssr1,sand} = 0.065, \quad \tau^*_{ssr2,sand} = 0.011, \quad k = 20 \tag{3.83e-l}$$

It is Eq. (3.83d) that plays the key role of increasing the mobility of gravel as sand content is increased.

Note that in Eqs. (3.83e-g) the constants in the relations differ between laboratory and field. There is a reason why the same underlying sediment transport relation might be expressed somewhat differently in the field as compared to the laboratory, even though the underlying physics is identical. This issue is discussed in more detail in Section 3.7.15.

In order to apply the above formulation, it is necessary to specify the characteristic grain sizes D_1 for the sand portion and D_2 for the gravel portion of the surface layer, the fractions F_1 and F_2 of sand and gravel, respectively in the surface layer, the submerged specific gravity of the sediment R and shear velocity associated with skin friction u_{*s}. The Shields numbers τ_{si}^* are computed with Eqs. (3.46) and (3.47), and the parameters τ_{ssri}^* are evaluated from Eq. (3.83d) with the aid of Eqs. (3.83e-l). The parameters W_i^* and q_i are obtained from Eqs. (3.83a,b,c). The total bed-load transport rate per unit width q_T and fraction bed-load in the ith grain size range f_{bi} are then computed from Eqs. (3.26) and (3.28).

3.7.10 Surface-based Relation of Wilcock and Crowe

The surface-based relation of Wilcock and Crowe (2003) generalizes the two-grain method of Wilcock and Kenworthy (2002) to an arbitrary number of grain size ranges of both gravel and sand. That is, not only is the sand not excluded from the method, but it plays an important role in determining the gravel transport rate. A reference value W_r^* of 0.002 was used to determine the reference stresses. The relation can be stated as

$$W_i^* = \frac{Rgq_i}{F_i u_{*s}^3} = G(\phi)$$

$$G = \begin{cases} 0.002\phi^{7.5} & for\ \phi < 1.35 \\ 14\left(1 - \dfrac{0.894}{\phi^{0.5}}\right)^{4.5} & for\ \phi \geq 1.35 \end{cases}$$

$$\phi = \frac{\tau_{sg}^*}{\tau_{ssrg}^*}\left(\frac{D_i}{D_g}\right)^{-b} \qquad (3.84a\text{-}e)$$

$$\tau_{ssrg}^* = 0.021 + 0.015\,exp(-14F_s)$$

$$b = \frac{0.69}{1 + exp(1.5 - D_i / D_g)}$$

where τ_{sg}^* is given by Eq. (3.79d) and F_s denotes the fraction of the material of the surface layer that is sand.

The essential role of sand is to depress the reference Shields number τ_{ssrg}^* via Eq. (3.84d). This in turn increases the mobility of all sizes, including gravel. The experiments of Wilcock et al. (2001), which were used to develop the above relation, clearly show that the addition of sand to a sand-gravel mix in a sediment-recirculating flume can increase the transport rate of gravel, in some cases substantially. Cui et al. (2003b) have confirmed this effect in an experimental study of sediment pulses in gravel-bed rivers using a sediment-feed flume.

The surface-based relation of Wilcock and Crowe (2003) has not yet been tested against field data. A notable aspect of the experiments used to develop the relation is the fact that the surface size distribution was measured immediately after a flow event, before substantial reworking could take place. In this sense, the relation is truly a surface-based relation. In point of fact the armor layer showed little variability in grain size distribution with stage over the range of the experiments.

Calculations with the above relation proceed as follows. The grain sizes and fractions (D_i, F_i) of the surface layer, submerged specific gravity of the sediment R and shear velocity associated with skin friction u_{*s} must be specified. The surface geometric mean size D_g is computed from the fractions finer in the surface material and τ_{sg}^* is evaluated from Eqs. (3.82) (but with $D_{50} \rightarrow D_g$ therein) and (3.47). The fraction F_s of the surface material that is sand is computed from the fractions F_i. The values of W_i^* and q_i are then obtained from Eqs.(3.84a) with the aid of Eqs. (3.84b,c,d,e). The total bed-load transport rate per unit width q_T and fraction bed-load in the ith grain size range f_{bi} are then computed from Eqs. (3.26) and (3.28).

3.7.11 Relation of Wu, Wang and Jia

The bed-load transport relation of Wu et al. (2000) was developed using data from one set of experiments using poorly sorted sand (Samaga et al., 1986), three sets of experiments using poorly sorted gravel (Liu, 1986; Kuhnle, 1993 and Wilcock and McArdell, 1993) and five gravel-bed streams in the United States (Williams and Rosgen, 1989). The model appears to be substrate-based, but the authors nowhere make a distinction between surface and substrate. The reference stress method was used to develop a hiding function. The relation can be expressed in the form

$$W_{ui}^* = \frac{Rgq_i}{\bar{f}_i u_{*s}^3} = 0.0053\frac{1}{\left(\tau_{si}^*\right)^{3/2}}\left(\frac{\tau_{si}^*}{\tau_{suri}^*} - 1\right)^{2.2}$$

$$\tau_{suri}^* = \tau_{suro}^*\left(\frac{p_{ei}}{p_{hi}}\right)^{-0.6} \quad , \quad \tau_{suro}^* = 0.03 \qquad (3.85a\text{-}e)$$

$$p_{ei} = \sum_{j=1}^{N}\bar{f}_j\frac{D_i}{D_i + D_j} , \quad p_{hi} = \sum_{j=1}^{N}\bar{f}_j\frac{D_j}{D_i + D_j}$$

The authors also suggested a framework for removing form drag from the boundary shear stress based on adjusted Manning's n, but they do not specify how to implement it.

Wu et al. attempted to verify their bed-load relation in two ways. First, they compared the predictions of their relation in the limiting case of uniform sediment against 1859 sets of data from the compendium of Brownlie (1981), obtaining excellent agreement. The paper does not state, however, how many of the data refer to gravel. Second, they compared predictions for mixtures against laboratory and field data, all of which pertain to sand-bed streams. Again, excellent agreement is reported. The method awaits an independent test against a field gravel-bed stream.

Calculations with the above relation proceed as follows. The grain sizes and fractions (D_i, $\bar{f}_i$) of the substrate layer, submerged specific gravity of the sediment R and shear velocity associated with skin friction u_{*s} must be specified. The parameters p_{ei} and p_{hi} are computed from Eqs. (3.85d,e). The values of τ_{suri}^* are computed from Eqs. (3.85b,c). The values of W_i^* and q_i are then obtained from Eqs.(3.85a).

3.7.12 Relation of Powell, Reid and Laronne

The bed-load relation of Powell et al. (2001, 2003)) is solely based on field data from the Nahal Eshtemoa, an ephemeral stream in Israel subject to occasional violent floods. The streambed is virtually unarmored when the channel is dry. As a result it is not possible to use the data to discriminate between a surface-based and a substrate-based model. This notwithstanding, the model is treated as a surface-based formulation here.

The transport relation is based on the Parker (1978b) approximation to the Einstein (1950) relation. It is assumed that all material below 2 mm is removed and the grain size distribution renormalized so that it sums to unity before applying the model, which takes the form

$$W_i^* = \frac{Rgq_i}{F_i u_{*s}^3} = 11.2\left(1 - \frac{1}{\phi}\right)^{4.5} \quad , \quad \phi = \frac{\tau_{si}^*}{\tau_{sci}^*}$$

$$\frac{\tau_{sci}^*}{\tau_{sc50}^*} = F_{hc}\left(\frac{D_i}{D_{50}}\right) = \left(\frac{D_i}{D_{50}}\right)^{-0.74} \quad , \quad \tau_{sc50}^* = \frac{\tau_{bsc}}{\rho RgD_{50}} = 0.03 \qquad (3.86\text{a-d})$$

Eq. (3.86b) can be reduced with Eq. (3.86c) to yield

$$\phi = \frac{\tau_{s50}^*}{\tau_{sc50}^*}\left(\frac{D_i}{D_{50}}\right)^{-0.26} \qquad (3.86\text{e})$$

While the model was not verified with data under conditions of mobile-bed armoring, it appears to have all the characteristics necessary to predict it.

Calculations with the above relation proceed as follows. The grain sizes and fractions (D_i, F_i) of the surface layer (from which the sand has been excluded), submerged specific gravity of the sediment R and shear velocity associated with skin friction u_{*s} must be specified. The surface median size D_{50} is computed from the fractions finer in the surface material. The Shields numbers τ_{si}^* are computed with Eqs. (3.46) and (3.47). The values of W_i^* and q_i are then computed from Eq. (3.86a) with the aid of Eqs. (3.86b,c,d). The total bed-load transport rate per unit width q_T and fraction bed-load in the ith grain size range f_{bi} are then computed from Eqs. (3.26) and (3.28).

3.7.13 Relation of Ackers and White Extended with Proffitt and Sutherland's Hiding Function

The total bed material load predictor of Ackers and White (1973) has already been introduced in Chapter 2. It is based on a characteristic grain size D of the bed material, and is not designed to compute the grain size distribution of the transported sediment. In point of fact very little of the data used to develop this relation was in the range of gravel-bed rivers. This notwithstanding, it has been found to be a good predictor of bed material load in both the laboratory and the field (Brownlie, 1981). Several efforts have been made to provide it with a hiding function that would allow generalization to sediment mixtures, including those of Day (1980), Ackers and White (1980), White and Day (1982) and Proffitt and Sutherland (1983). These reformulations were made with gravel-bed rivers specifically in mind. The hiding function due to Proffitt and Sutherland is presented here.

The reader is referred back to Eqs. (2.242a-l). The original relation of Ackers and White can be written as

$$q^* = C\frac{U}{\sqrt{RgD}}\left(\frac{U}{u_*}\right)^n \left(\frac{F_{gr}}{A} - 1\right)^m \qquad (3.87\text{a})$$

where the parameter F_{gr} is a parameter specified as Eq. (2.242b) and requiring known values of u_* u_{*s}, R and D_{50} for its computation. In the above form the Einstein number q^* is related to the transport parameter G_{gr} of the original relation as

$$G_{gr} = \left(\frac{U}{\sqrt{RgD}}\right)^{-1}\left(\frac{U}{u_*}\right)^{-n} q^* \tag{3.87b}$$

In Eq. (3.87a) F_{gr} is the primary dimensionless parameter driving sediment transport and A is the value of F_{gr} at the threshold of motion. These parameters are defined in Eqs. (2.242a-l); the parameter F_{gr} contains an exponent n. The parameters A, C, n and m are all dependent on a dimensionless grain size D_{gr}, where in terms of the notation of this chapter

$$D_{gr} = Re_{p50}^{2/3} = \left(\frac{\sqrt{RgD_{50}}\,D_{50}}{\nu}\right)^{2/3} \tag{3.87c}$$

The generalization to mixtures is here treated as surface-based; it proceeds as follows. Eq. (3.87a) is amended to

$$q_{bmi}^* = C_i \frac{U}{\sqrt{RgD_i}}\left(\frac{U}{u_*}\right)^{n_i}\left(\frac{F_{gri}}{A_{ai}} - 1\right)^{m_i} \tag{3.87d}$$

where

$$q_{bmi}^* = \frac{q_{bmi}}{F_i\sqrt{RgD_i}\,D_i}, \quad u_* = \sqrt{\frac{\tau_b}{\rho}} \tag{3.87e,f}$$

In the above relations τ_b denotes boundary shear stress at the bed and u_* denotes shear velocity (total values, not skin friction only), and q_{bmi} denotes the total volume bed material transport rate (bed-load plus bed material suspended load) per unit width per unit time. The parameters F_{gri}, A_i, C_i, n_i and m_i are all computed as in the original relation, but with the transformation $D_{50} \rightarrow D_i$. The adjusted value A_{ai} embodying the hiding function is given as

$$\frac{A_{ai}}{A_i} = \begin{cases} \dfrac{1}{1.3} \; for \; \dfrac{D_i}{D_u} > 3.7 \\ \dfrac{1}{0.53\,log(D_i/D_u) + 1} \; for \; 0.075 < \dfrac{D_i}{D_u} < 3.7 \\ \dfrac{1}{0.4} \; for \; \dfrac{D_i}{D_u} < 0.075 \end{cases} \tag{3.87g}$$

In addition, D_u is computed from the relation

$$\frac{D_u}{D_{50}} = f_u(\tau_{50}^*), \quad \tau_{50}^* = \frac{\tau_b}{\sqrt{RgD_{50}}} \tag{3.87h,i}$$

given graphically in Figure 3.37a

The original relation of Ackers and White (1973) was developed using the same data base as was used for the hydraulic resistance relation of White, Paris and Bettess (1980). It thus may be inferred that the relations should be used a pair, and that this also holds for the extension to mixtures.

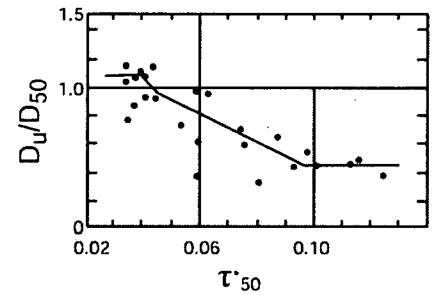


Figure 3.37 Plot of D_u/D_{50} as a function of τ_{50}^* for the hiding function of Proffitt and Sutherland (1983) as applied to the sediment transport relation of Ackers and White (1973).

In applying the above relation the grain sizes and surface layer fractions (D_i, F_i), cross-sectionally averaged flow velocity U, shear velocites u_* and u_{*s} the submerged specific gravity of the sediment R and the kinematic viscosity of water ν must be specified. The surface median size D_{50} is computed from the grain size distribution of the surface layer, and τ_{50}^* and D_u are computed from Eqs. (3.87f,h,i). The parameters n_i, m_i, F_{gri}, A_i and C_i are all computed from the relations in Chapter 2, but with the transformation $D_{50} \rightarrow D_i$. The values of A_{ai} are computed from Eq. (3.87g). The values of q_{bmi}^* and q_{bmi} are then computed from Eqs. (3.87d,e).

3.7.14 Other Bed-load Transport Relations for Mixtures

The relations given above represent only a sample of those available in the literature that describe the bed-load transport of sediment mixtures. Some others are listed below.

Proffitt and Sutherland (1983) generalized the Paintal (1971) transport relation to mixtures by developing a hiding relation, and used it to study the development of static armor. Misri et al. (1984) developed a new relation for bed-load transport for uniform material, and generalized it to mixtures using their own set of experimental data. The analysis clearly illustrates the failure of the Einstein (1950) hiding function. The only reason their relation is not presented in detail here is because the data used to develop the hiding function for mixtures are all restricted to the range of very coarse sand and pea gravel. Samaga et al. (1986) extended and corrected the model of Misri et al. (1984), this time including data from several rivers.

The Yang (1973) total bed material transport relation presented in Chapter 2 was developed for the prediction of sediment transport in sand-bed streams, and uses only a single sediment size. Yang (1984) extended this relation for gravel, again using only a single sediment size. Yang and Wan (1991) further extend these relations to allow for grain-size specific calculations of bed material transport of sediment mixtures, including gravel. These methods are summarized in Yang (1996).

Bridge and Bennett (1992) developed a Bagnold-type stream power formulation for the bed-load transport of mixtures. The model is notable in that it pays attention to differences in shape and density as well as size. Belleudy and SOGREAH (2000) adapted the bed material load predictor of Engelund and Hansen (1967) to mixtures in order to study bed-load transport. Their treatment of hiding had not yet been published at the time of writing of this chapter. Kleinhans and van Rijn (2002) generalized the bed-load transport relations of Meyer-Peter and Müller (1948) and van Rijn (1984) to mixtures. The generalization incorporates a stochastic sub-model in order to increase the accuracy of predictions near the threshold of motion. In addition to the hiding function of Egiazaroff (1965), the model also contains an empirical "hindrance" factor to account for the difficulty of movement of finer grains over and through a bed of coarser grains.

One relation that does not specifically pertain to mixtures merits mention here. Smart and Jaeggi (1983) and Smart (1984) have developed a bed-load transport relation specifically designed for channels with steep slopes, i.e. in excess of 3%. The data used to develop the relation were also used to show that the Meyer-Peter and Müller (1948) relation, for example, seriously underestimates the bed-load transport rate at such slopes. Their predictor yields only transport rates and not size distributions. This notwithstanding, many of the experiments used to develop it were performed with poorly sorted sediment. The issue of grain size distribution is of interest because Solari and Parker (2000) have documented and explained a reversal in mobility, with coarse grains rendered more mobile than fine grains in a mixture, at slopes exceeding about 2%.

Carson and Griffiths (1987) summarize several bed-load transport formulations and apply them to gravel-bed streams in New Zealand. Useful data on gravel transport for several streams in that country are presented. The treatment does not, however, focus on grain-size specific transport.

3.7.15 Sample Applications of Bed-load Relations

The results of sample calculations applied to a hypothetical gravel-bed river are presented here in order to illustrate the predictions of several of the relations presented above. The grain size distributions of the surface and substrate are presented in Figure 3.38a. The geometric mean size D_g, arithmetic mean size D_m, median size D_{50}, geometric standard deviation σ_g and sand fraction F_s of the surface material are given by the respective values 22.3 mm, 46.0 mm, 36.6 mm, 4.93 and 0.16; the corresponding values for the substrate D_{ug}, D_{um}, D_{u50}, σ_{ug} and F_{us} are, respectively, 10.9 mm, 33.1 mm, 21.0 mm, 5.22 and 0.28. Also shown in Figure 3.38a is the renormalized grain size distribution of the surface with the sand removed, resulting in the respective values of D_g, D_{50} and σ_g of 40.7 mm, 45.3 mm and 2.36.

Calculations are performed for the relations of Ashida and Michiue (1972), Parker (1990a), Powell et al. (2001), Hunziker and Jaeggi (2002) and Wilcock and Crowe (2003), all of which are applied as surface-based relations. In applying the relations of Parker (1990a) and Powell et al. (2001) the sand has been excluded from the surface grain size distribution, and only the bed-load transport rates of the gravel sizes are calculated. In the other cases, bed-load transport rates of sand are predicted as well.

The hydraulic parameter entering into the calculations is the boundary shear stress due to skin friction τ_{bs}, or alternatively the shear velocity due to skin friction u_{*s} defined by Eq. (3.47). The range of values of u_{*s} considered is 0.15 ~ 0.40 m/s, corresponding to a range of Shields numbers τ_{s50}^* based on surface median grain size of the surface material (sand included) of 0.038 ~ 0.270, where according to Eqs. (3.82) and (3.47)

$$\tau_{s50}^* = \frac{u_{*s}^2}{RgD_{50}} \tag{3.88}$$

Each model is used to compute a) the total volume gravel bed-load transport rate per unit width q_G (summed over all gravel sizes; sand excluded), b) the geometric mean size of the gravel portion of the bed-load D_{Gg} and c) the geometric standard deviation of the gravel portion of the bed-load σ_{Gg}. In addition, in all cases except the Parker (1990a) and Powell et al. (2001) relations, which exclude sand from the calculation, the fraction f_{bG} of the bed-load consisting of gravel is computed.

The results are shown in Figures 3.38b~e. In Figure 3.38b it is seen that the predictions for q_G fall well within an order of magnitude at all but the lowest shear velocities. The relations of Ashida and Michiue (1972) and Hunziker and Jaeggi (2002) predict vanishing transport rate for values of u_{*s} below a value between 0.175 and 0.20 m/s due to the presence of relatively high critical Shields numbers in the formulations. At the highest transport rates the difference between the predicted values of q_G is less than a factor of two.

The predictions for D_{Gg} in Figure 3.38c are also quite similar. In all cases the gravel bed-load becomes coarser with increasing friction velocity, and the degree of coarsening levels off at the highest values of friction velocity. The relations of Hunziker and Jaeggi (2002) and Powell et al. (2001) show the strongest tendency for the gravel bed-load to coarsen with friction velocity, and the relation of Wilcock and Crowe (2003) shows the least tendency. Figure 3.38d indicates that the predicted values of σ_{Gg} nearly all fall between 2 and 3, with a tendency for σ_{Gg} to decrease with increasing friction velocity through most or all of the calculated range of u_{*s} for all relations except Ashida and Michiue (1972).

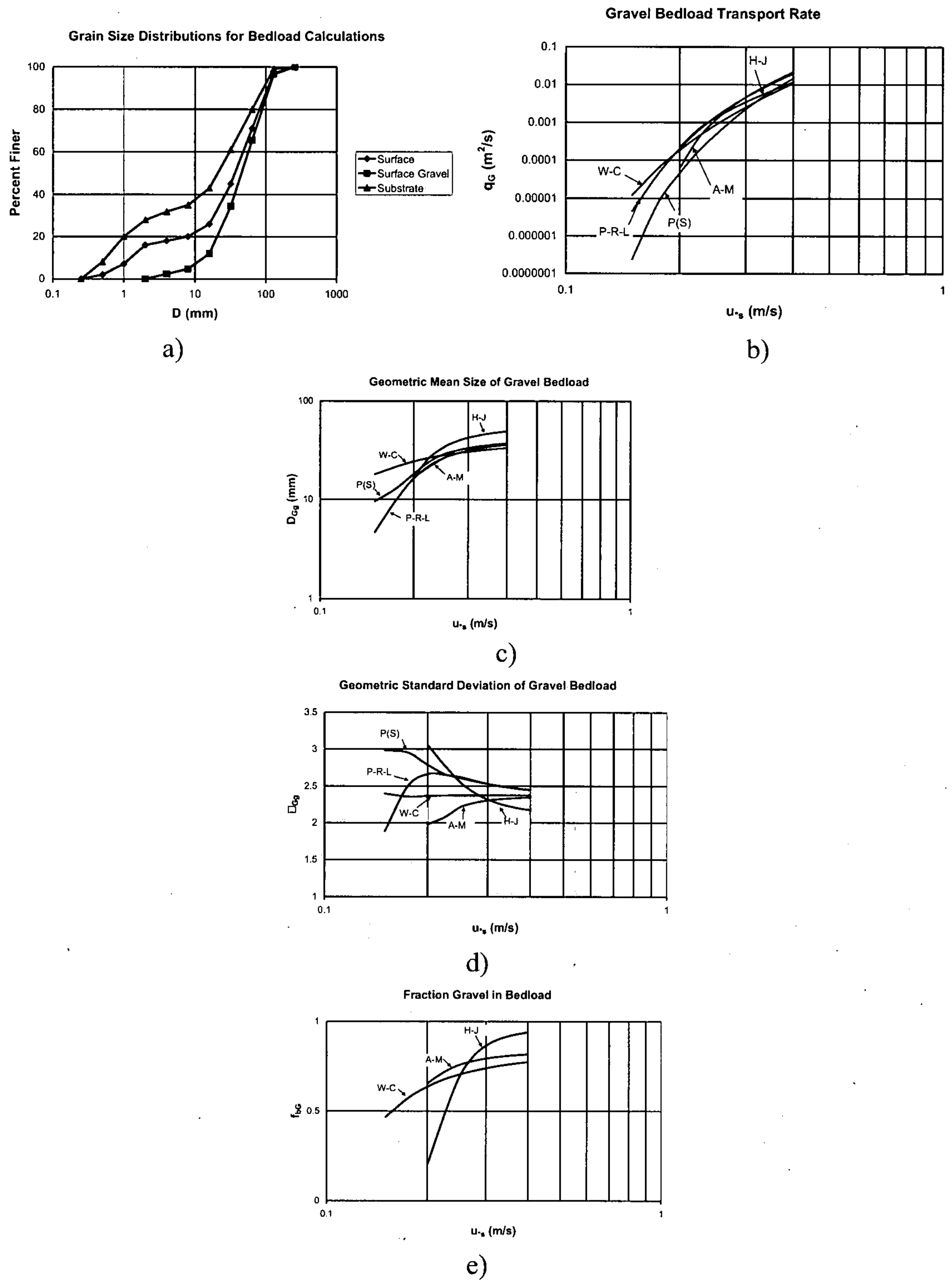


Figure 3.38 Predictions of bedload transport using the relations of Ashida and Michiue (1972) (A-M), Parker (1990a) (P(S)), Powell et al. (2001) (P-R-L), Hunziker and Jaeggi (2002) (H-J) and Wilcock and Crowe (2003) (W-C). a) Grain size distributions for bedload calculations, b) total volume gravel bedload transport rate, c) geometric mean size of gravel bedload, d) geometric standard deviation of gravel bedload, and e) fraction of gravel in bedload (the rest being sand).

The most variation among the predictions is in the relation between fraction gravel in the bed-load f_{bG} and u_{*s} of Figure 3.38e. This is likely because the tendency for sand in gravel-bed streams to go into suspension rather easily makes the prediction of the bed-load transport of sand rather inaccurate. Note in this regard that the fraction of sand in the bed-load is given as $1 - f_{bG}$. This comment notwithstanding, for values of u_{*s} above 0.25 m/s the bed-load transport is predicted to be predominantly gravel for all four relations in the figure.

Some further discussion of Figure 3.38b is warranted. It is encouraging to see that the predictions of the relations of Ashida and Michiue (1972), Hunziker and Jaeggi (2002) and Wilcock and Crowe (2003), all of which are based on laboratory data, are for the most part bracketed by the field-based relation of Powell et al. (2001) as an upper bound and the field-based relation of Parker (1990a) as a lower bound. This lends confidence to the concept of applying the results of laboratory studies of gravel transport to field-scale rivers.

These comments notwithstanding, the predictions of the Parker (1990a) relation and that of Powell et al. (2001), both of which are based on field data, do show substantial differences. Some of the possible reasons for these differences, as well as avenues for reducing them in the future, are discussed in Section 3.7.18.

3.7.16 Topographic Variability, Patchiness and Partial Transport

Rivers are not flumes; they are considerably more complex. Flumes are valuable tools for the study of sediment transport, but results based on flume data are not directly transferable to the field without accounting for the spatial and temporal variability characteristic of the field. A vivid example of this is provided by the bed material load (bed-load plus suspended load) predictor of Brownlie (1981). Brownlie found that his regression relation developed for laboratory data was modestly but consistently in discrepancy with his regression for field data. As a result the prediction for load is multiplied by a factor of 1.000 in applying the relation to flume data and a factor of 1.268 in applying the relation to the field.

The reason for this is not hard to decipher. The explanation provided here is adapted from the work of Paola and Seal (1995), Paola (1996) and Paola et al. (1999). Sediment transport predictors are invariably nonlinear in their primary driving parameter, e.g. Shields number. That is, a doubling of Shields number produces more than a doubling of the load. This effect is particularly strong at low transport rates.

To see this, consider a natural channel, with bars, bends and other elements of channel complexity. Local skin friction can be expected to vary spatially according to some probability distribution. The same holds true for local mean grain size, and thus for the Shields number based on skin friction itself. The more complex the channel is, the higher will be the standard deviations of these fluctuations. In a nonlinear transport relation, zones of high Shields number will magnify the transport rate far more than zones of low Shields number depress it. The result is to elevate the overall transport rate. In addition, if the transport relation is grain size-specific and renders finer surface grains more mobile than coarser surface grains, the effect of nonlinearity can also act to bias the load toward the fine grains, especially in the case of relatively low boundary shear stress.

To see this, it is useful to begin with the case of uniform sediment. Consider a bed-load transport relation of the generic form

$$q = \sqrt{RgD}D\left[\frac{\tau_{bs}}{\rho RgD} - \tau_{sc}^*\right]^{n_L} \tag{3.89a}$$

where τ_{sc}^* denotes a critical Shields number and the exponent n_L is expected to be greater than unity. In most applications of flume-derived sediment transport relations to the field, the parameters actually put into the equation are the spatial averages, i.e. in this case $\overline{\tau}_{bs}$ and $\overline{D}$ (the spatial averaging in the case of grain size being performed on the ψ scale rather than directly on D). Because of the nonlinear dependencies in Eqs. (3.89a) and (3.1b) the input of these averaged parameters does not yield $\overline{q}$. Instead,

$$\overline{q} = \overline{\sqrt{RgD}D\left[\frac{\tau_{bs}}{\rho RgD} - \tau_{sc}^*\right]^{n_L}} = C_{comp}\sqrt{Rg\overline{D}}\,\overline{D}\left[\frac{\overline{\tau}_{bs}}{\rho Rg\overline{D}} - \tau_{sc}^*\right]^{n_L} \tag{3.89b}$$

where the overbar denotes averaging over a reach containing morphologic complexity and C_{comp} is a dimensionless complexity coefficient. Abbreviating the functional relation of Eq. (3.89b), the above relation can be summarized as

$$\overline{q} = C_{comp}q\left(\overline{\tau}_{bs},\overline{D}\right) \tag{3.89c}$$

where $q(x, y)$ denotes the functional relation, and $C_{comp} > 1$ is a dimensionless parameter that amplifies the sediment load.

Paola and Seal (1995), Paola (1996) and Paola et al. (1999) describe a way to implement the above calculation using probability densities for τ_{bs} and D. They find that C takes the value of 1 in a straight flume with no bedforms and no local sorting. This value increases with increasing complexity, becoming as large as 3 – 4 in braided streams. The above analysis provides a conceptual explanation for the multiplicative factor 1.268 in the Brownlie (1981) relation; it is none other than the complexity coefficient C. The fact that it is not larger than 1.268 is likely related to the fact that sediment transport measurements in natural streams are usually taken along the straightest reaches with the least variation possible, e.g. in a straight reach rather than at the apex of a bend. Brownlie (1981) himself was cognizant of this nonlinear amplification effect and explained the factor in terms of it.

The above framework receives further verification in terms of the flume experiments of Onishi et al. (1972). Onishi et al. studied sediment transport in two flumes, one straight and the other with meandering sidewalls, but with an average down-channel bed slope that was identical to that of the straight flume. For the same water discharge and sediment size, the sediment transport rate was measurably larger in the meandering flume.

Paola and Seal (1995) have extended the above analysis to sediment mixtures. Consider a generic model transport relation of the form

$$q_i = \sqrt{RgD_i}D_iF_i\left[\frac{\tau_{bs}}{\rho RgD_i} - \tau^*_{scg}\left(\frac{D_i}{D_g}\right)^{-m}\right]^{n_L} \quad (3.90a)$$

where it is again expected that $n_L > 1$. Note that the above equation represents a direct generalization of Eq. (3.89a) to mixtures, with the term containing the exponent m characterizing a hiding function. Again, the parameters actually input in field applications are usually the spatial averages $\overline{\tau}_{bs}$, $\overline{F}_i$ and $\overline{D}_g$. Again,

$$\overline{q}_i = \overline{\sqrt{RgD_i}D_iF_i\left[\frac{\tau_{bs}}{\rho RgD_i} - \tau^*_{scg}\left(\frac{D_i}{D_g}\right)^{-m}\right]^{n_L}} = C_{comp,i}\sqrt{RgD_i}D_i\overline{F}_i\left[\frac{\overline{\tau}_{bs}}{\rho RgD_i} - \tau^*_{scg}\left(\frac{D_i}{\overline{D}_g}\right)^{-m}\right]^{n_L} \quad (3.90b)$$

The above relation can be summarized as

$$\overline{q}_i = C_{comp,i}q_i\left(\overline{\tau}_{bs}, \overline{D}_g, \overline{F}_i\right) \quad (3.90c)$$

where $q_i(x,y,z)$ denotes the functional relation for bed-load transport and $C_{comp,i}$ are dimensionless grain size-specific complexity coefficients. Thus

$$\overline{q}_T = \sum_{i=1}^{n} C_{comp,i}q_i(\overline{\tau}_{bs}, \overline{D}_g, \overline{F}_i) > \sum_{i=1}^{n} q_i(\overline{\tau}_{bs}, \overline{D}_g, \overline{F}_i) = q_T(\overline{\tau}_{bs}, \overline{D}_g, \overline{F}_i) \quad (3.90d)$$

so that the total bed-load transport is amplified. In addition, the morphologically averaged grain size fractions $\overline{f}_{bi}$ of the bed-load differ from the ones that would be obtained using averaged parameters as input,

$$\overline{f}_{bi} = \frac{\overline{q}_i}{\overline{q}_T} \neq \frac{q_i(\overline{\tau}_{bs}, \overline{D}_g, \overline{F}_i)}{q_T(\overline{\tau}_{bs}, \overline{D}_g, \overline{F}_i)} \quad (3.90e)$$

and this bias is typically in the direction of a finer bed-load size distribution.

Paola and Seal (1995) found a notable enhancement of downstream fining in the North Fork Toutle River, Washington, USA due to the presence of "patches" and "lanes" of sediment mixtures with differing mean sizes. Two of these "patches" are visible in Figure 3.7. Paola (1996) outlines an algorithm for the adjustment of any sediment transport relation to account for channel complexity. In order to implement it, however, the probability distributions of spatial variation in boundary shear stress and grain size distribution must be known, measured or inferred.

The two-grain relation of Wilcock and Kenworthy (2002) is reconsidered in light of the above. Recall that the bed-load transport rates in field streams used by them to develop their relation tended to be consistently higher than in the laboratory by a factor that varied with transport rate but was close to 1.64. This difference is most likely not an expression of a fundamental difference in the physics of field streams compared to laboratory flumes, but rather an expression of the fact that field streams are more complex than flumes.

A second issue of particular interest for gravel-bed streams is partial transport. Partial transport may be defined as a condition in which a portion of the grains on the bed surface are actively transported, while the balance of the surface grains remain entirely immobile (Wilcock and McArdell, 1993). A case of particular interest is when the immobile grains are coarser than a threshold size.

The following thought experiment illustrates one of the dilemmas of partial transport. A flume is supplied with a modest, constant feed of heterogeneous sediment and allowed to develop to a macroscopic mobile-bed equilibrium, here called case A. At this equilibrium all sizes fed in must exit the flume at the same macroscopic rate. Now cut off the supply of the very coarsest grains from the feed, and, if necessary, slightly increase the feed rate of the remaining load so as to prevent bed degradation. Since the bed does not degrade, some of the coarsest grains will remain at least partially exposed on the bed. These exposed grains must, however, attain a configuration (by partial burial, the formation of stone clusters etc.) so as to eventually render them completely immobile. All the finer sizes continue to move through the system, so resulting in case B.

Now the hydraulic conditions have barely changed, but in case A the largest stones are mobile, whereas in case B they are not. At present there is no sediment transport relation that contains enough physics to discriminate between the two cases.

In recent years, however, there has been an increasing interest in partial transport, resulting in a data base that may help resolve this issue in the future (Wilcock and McArdell, 1993, 1997; Hassan and Church, 2000). Figure 3.39 illustrates three plots of the ratio of unit bed-load transport rate q_i/F_i versus grain size D_i, one from Oak Creek, Oregon, USA (from Wilcock, 1997a), one for the experiments of Wilcock and McArdell (1997), and one from the Nahal Eshtemoa, Israel (Powell et al., 2001). Recalling that the fractions in the bed-load f_{bi} are related to the fractional transport rates q_i according to Eq.

(3.28), it is easily shown that if the ratio q_i/F_i is constant for all grain sizes D_i for a given flow, then

$$f_{bi} = F_i \tag{3.91}$$

so that the grain size distribution of the bed-load is identical to that of the bed surface. That is, a condition of perfect surface-based equal mobility prevails. A deviation from this constancy denotes size-selective transport. If q_i/F_i drops to zero for any grain size range, partial transport prevails.

Figure 3.39a from Oak Creek reveals partial transport with an absence of the coarsest grains in the bed-load for the lowest flow in the diagram, size-selective transport biased toward the finer grains at somewhat higher flows, and near-equal mobility, or rather a slight bias toward the coarser grains at the highest flows, which transport the bulk of the sediment. Figure 3.39b reveals a much stronger tendency toward partial transport at the lower stages of the experiments of Wilcock and McArdell (1997) in a sediment-recirculating flume, with all sizes in motion and near-equal mobility only at the highest stage in the diagram. In the case of the Nahal Eshtemoa, Figure 3.39c shows possible partial transport at the two lowest stages, size-selective transport at the two next-highest stages and near-equal mobility at the seven higher stages.

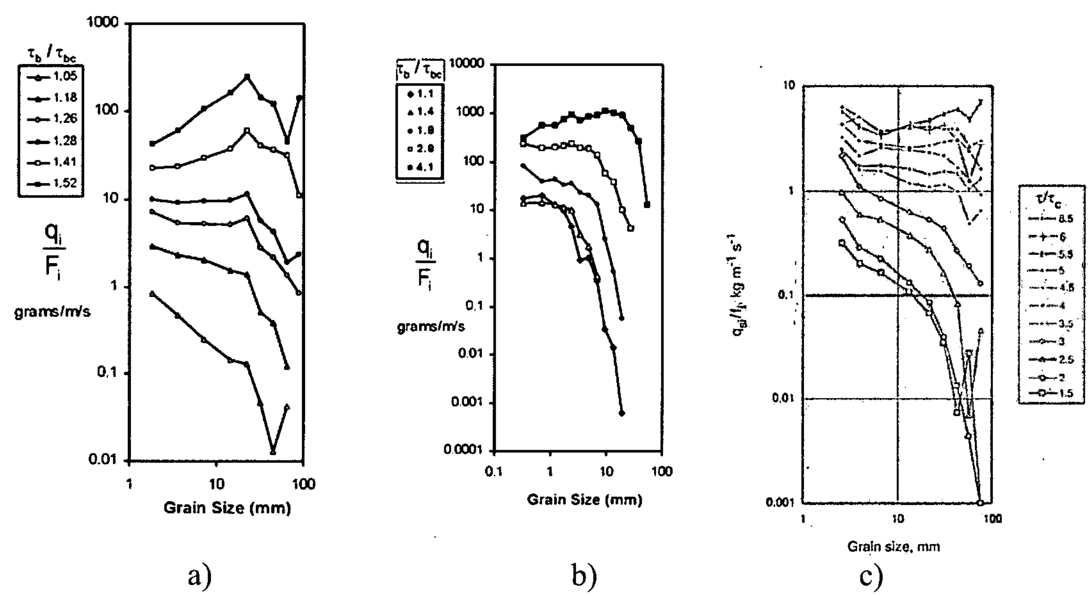


Figure 3.39 Plots of q_i/F_i versus D_i for a) Oak Creek field data as presented by Wilcock (1997a); b) experiments of Wilcock and McArdell (1997); and c) Nahal Eshtemoa field data of Powell et al. (2001).

The issue of partial transport becomes particularly important when the diversion of floodwater from a gravel-bed river is considered. The loss of floodwater may impose a perennial condition of partial transport, with the coarser grains no longer participating in the load. As a result, the bed may no longer be reorganized and renewed by floods, and habitat may degrade, as in the case of the Trinity River below Lewiston Dam (Kondolf and Wilcock, 1996).

3.7.17 Surface-based versus Substrate-based

A common objection to the use of surface-based formulations is that they require a knowledge of the composition of the surface, or active layer at any given time in order to compute the bed-load transport rate. The issue is important because the composition of the surface is free to respond to changes in the flow. Direct information on the composition of the surface is usually available, however, only at low flow when the bed can be sampled. So it would appear that there is no obvious way to know what surface grain size distribution to use in the model.

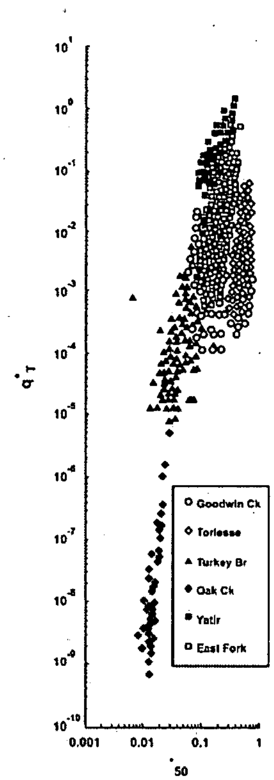


Figure 3.40 Dimensionless Einstein number based on total bedload transport rate q_T^* versus Shields stress τ_{50}^* for six streams: Goodwin Creek, Mississippi, USA, East Fork River, Wyoming, USA, Oak Creek, Oregon, USA, Nahal Yatir, Israel, Turkey Brook, England; UK and Torlesse Stream, New Zealand. From Reid et al., (1995).

The above dilemma is easily resolved. Surface-based models are designed to be implemented in a numerical simulation of the flow and sediment transport. The low-flow composition of the surface is input as an initial condition. The calculation proceeds by solving a) the grain size-specific Exner equation of sediment continuity, b) a surface-based bed-load transport formula and c) an appropriate predictor of the flow, e.g. the St. Venant shallow water equations through a flood hydrograph. In this way the composition of the surface layer is computed along with other parameters such as bed elevation, bed-load transport rate, and bed-load grain size distribution, at every time step of the calculation. The issue is described in more detail in Section 3.9.

In some cases, however, it may not be feasible to implement a full numerical calculation; one may simply wish to estimate the bed-load yield and grain size distribution over one hydrograph or for a given flow duration curve. In such cases, a substrate-based formulation may be appropriate in that it requires a parameter, i.e. the grain size distribution of the substrate, which can be measured at low flow and which is unlikely to change too much in engineering time.

3.7.18 Comparison of Relations against Field Data: Future Developments

There have not been many comprehensive independent tests of predictive relations for bed-load transport of heterogeneous sediments against data, and in particular field data. Two attempts are outlined in Gomez and Church (1989) and van der Scheer et al. (2001). The results are not particularly encouraging. Gomez and Church state "No formula performs consistently well." In the case of van der Scheer et al., various formulas were compared with three experimental sets, each using a mix of sand and pea gravel and with well-developed dunes, as well as the data set due to Day (1980). The first three sets are likely to be outside the range of applicability of most relations developed for heterogeneous gravel-bed streams. Not surprisingly, most of the relations performed poorly; the Ackers and White (1973) relation with the Proffitt and Sutherland (1983) hiding correction performed the best.

In Figure 3.40 Reid et al. (1995) have plotted the Einstein number q_T^* based on total bed-load transport rate summed over all grain sizes and on D_{50} versus the Shields number τ_{50}^* based on average boundary shear stress and D_{50} for six rivers; Goodwin Creek, Mississippi, USA, East Fork River, Wyoming, USA, Oak Creek, Oregon, USA, Nahal Yatir, Israel, Turkey Brook, England, UK and Torlesse Stream, New Zealand. The parameter D_{50} was measured at low flow. The data from Oak Creek, Turkey Brook and Nahal Yatir appear to collapse into a single curve. The data from the East Fork, Goodwin Creek and Torlesse Stream are shifted to the right of this curve, and clearly do not collapse into a single curve. This same shift to the right can be seen in the data of Ashworth and Ferguson (1989) from three streams in Scotland and Norway. Reid et al. note, "Transport efficiency is shown to vary considerably for each stream and from one stream to another, suggesting that it may not be possible to incorporate it easily into bed-load equations in order to improve levels of prediction."

Their conclusion may be overly pessimistic. They themselves point out that Oak Creek, Turkey Brook and the Nahal Yatir define a relatively consistent relation, a point amplified upon by Almedeij and Diplas (2003). This issue is explored in more detail in Section 3.10. In addition, Wilcock and Kenworthy (2002) have developed a consistent relation for Oak Creek, Goodwin Creek and the East Fork River upon having accounted for the effect of sand content in the bed. A proper accounting of the relevant physics is thus likely to bring most of the disparities into concordance before the next time ASCE Manual No. 54 is revised. Considerations that might help bring about this concordance are given below.

1. As noted in Section 3.7.2, most transport relations for gravel-bed streams gloss over the issue of form drag (as opposed to sand-bed streams). Form drag may be more important than previously thought (Hey, 1989; Millar, 1999). Form drag associated with channel bars and bends may vary with channel width, slope, standard deviation of the parent sediment etc. The presence of large, immobile colluvial boulders in streams may contribute to form drag. A form drag predictor for gravel-bed streams needs to be developed.

2. As described in Section 3.7.16, channels with the same mean morphological characteristics may transport sediment differently due to differing levels of complexity. The methodology discussed in that section needs to be implemented for more field streams.

3. As noted in Section 3.7.16, gravel-bed streams with strong tendencies toward partial transport may behave differently from streams with only size-selective transport. Predictive methods specifically including partial transport need to be developed.

4. As illustrated by the relations of Wilcock and Kenworthy (2002) in Section 3.7.9 and Wilcock and Crowe (2003) in Section 3.7.10, variation in the sand content can in some cases dramatically affect the transport of gravel. The recent efforts to quantify this effect need to be redoubled.

5. If the composition of the surface layer changes with stage, the interaction of this variation with the bed-load transport may be intense. The few attempts to quantify this effect in the field (e.g. Andrews and Erman, 1986) need to be augmented.

6. Finally, as noted in Section 3.7.2, the fluid mechanics used to calculate primary parameters controlling bed-load transport, such as boundary shear stress, is often much too primitive. In many cases boundary shear stress τ_b is estimated from the simple depth-slope product rule for to steady, uniform (normal) flow in a wide, rectangular channel;

$$\tau_b = \rho g H S \tag{3.92}$$

where S denotes mean bed slope and H denotes mean depth. The technology presently exists to perform the computations needed to obtain more precise measurements of boundary shear stress, including the effects of hydrograph variation, spatial variation, secondary flow, convergences and divergences etc. This technology needs to be applied more consistently to the issue of bed-load transport in gravel-bed rivers.

3.8 FIELD DATA

Since ASCE Manual No. 54, "Sedimentation Engineering," was first published in 1975, a major expansion of the data base for the transport of heterogeneous sediments in rivers has taken place. This data base serves two roles. Firstly, it allows the engineer working on with a problem a particular stream to identify a similar stream for which the transport rate and grain size distribution have been measured in order to determine appropriate countermeasures. Secondly, it is an essential key to future advances in predictive technology. With this in mind, a partial accounting of this data base is provided in Table 3.2 below.

Wilcock (2001) has outlined a practical method for estimating sediment transport rates in gravel-bed streams. The importance of interaction between field-based and experimental research has been emphasized by Wilcock (2000). Kuhnle et al. (1989) and Kuhnle (1996) have pointed out the need to consider systematic temporal variation in flow and sediment transport rates, an effect that is likely to be more important in the field than in the laboratory.

In addition to the streams of Table 3.2, a research group in Colorado centered around K. Bundt (Bundt et al., 2004) has collected a substantial set of data for bedload transport in small gravel-bed streams, mostly in Colorado. When this database becomes public is should provide a most useful addition to the database represented by Table 3.2.

Table 3.2: Streams for which gravel/sand transport rate and grain size distribution have been measured; S denotes slope and D_{u50} denotes substrate or bulk median size.

STREAM	*LOCATION*	*S*	D_{u50}, mm	*DATA SOURCE*
Allt Dubhaig	Scotland, UK	0.0040 – 0.021	23-98	Ashworth and Ferguson (1989)
Bambi Creek	Alaska, USA	0.0082	14.7	Sidle (1988); Smith et al. (1993); Lisle (1995)
Carl Beck	England, UK	0.039	73	Carling and Reader (1982), Carling (1989)
Clearwater River	Idaho, USA	0.00048	18	Emmett (1976)
Rio Cordon	Italy	0.17	90*	Lenzi et al. (2000)
East Fork River	Wyoming, USA	0.0007	6.4	Emmett et al. (1980)
Elbow River	Alberta, Canada	0.00745	28	Hollingshead (1971)
Nahal Eshtemoa	Israel	0.0075	18	Powell et al. (2001)
Feshie River	Scotland, UK	0.0086 – 0.0094	52 – 63	Ashworth and Ferguson (1989)
Goodwin Creek	Mississippi, USA	0.0033	14.2	Kuhnle (1992)
Great Eggleshope Beck	England, UK	0.010	67.7	Carling and Reader (1982), Carling (1989)
Harris Creek	British Columbia, Canada	0.013	20	Hassan and Church (2001)
Jacoby Creek	California, USA	0.0063	20.6	Lisle (1989)
Las Vegas Wash	Nevada, USA	0.003 – 0.004	5.2	Duan and Chen (2003)
Lyngsdalselva	Norway	0.020 – 0.028	69	Ashworth and Ferguson (1989)
North Casper Creek	California, USA	0.013	23.7	Lisle (1989)
Oak Creek	Oregon, USA	0.01	20	Milhous (1973)
Nahal Og	Palestinian West Bank	0.014	15	Hassan and Egozi (2001)
Ohau River	New Zealand	0.0065	19.2	Thompson (1985)
Redwood Creek 1	California, USA	0.014	9.1	Lisle and Madej (1992)
Redwood Creek 2	California, USA	0.026	18.1	Lisle and Madej (1992)
Snake River	Idaho, USA	0.0011	27	Emmett (1976)
Tanana River	Alaska, USA	0.0008	20.3	Burrows et. al. (1981), Burrows and Harrold (1983)
Toklat River	Alaska, USA	0.018	28.5	pers. comm. to Lisle (1995)
Tom McDonald Creek	California, USA	0.0060	10.8	Smith (1990)
Torlesse Stream	New Zealand	0.067	15*	Hayward (1980)
Turkey Brook	England, UK	0.0086	16	Reid et al. (1985), Reid and Frostick (1986)
Virginio Creek	Italy	0.008	13	Tacconi and Billi (1987)
Nahal Yatir	Israel	0.0088	10	Reid et al. (1995)

*Denotes surface rather than substrate size.

3.9 ABRASION

In addition to sorting their sediment through selective transport, rivers can also modify their grains through abrasion. Gravels and sands that have been in a river for a sufficiently long time tend to be rounded as a consequence of abrasion. This effect is illustrated in Figure 3.13.

As noted in Section 3.1, many rivers show a clear pattern of downstream fining of characteristic grain size. An example is given in Figure 3.10. This decrease in characteristic grain size may be due to selective transport of finer grains, abrasion, a tendency for tributaries farther down in the drainage network to deliver finer sediment or some other cause. In order to help resolve this issue it is necessary to have some understanding of fluvial abrasion.

The issue can be of considerable engineering importance. Large amounts of fresh, and in many cases relatively weak sediment can enter river systems from natural or human-induced landslides (Figure 3.12) or from the disposal of waste sediment from e.g. a mine (Figure 3.16). This sediment often consists of a mixture of lithologies, each of which has a different resistance to wear. In addition, the sediment may be highly fractured and thus far easier to abrade than material that has been in the river system for some time. In this sense one may think of the gravel in rivers at points far downstream of the source area as the very tough residual of an input that has had all the weaker members ground out of it. Thus if abrasion plays a significant role in the reorganization of inputs of fresh sediment, the gravel bed-load transport rates at distances of 10's or 100's of km downstream of the source area may be considerably less than if abrasion had been neglected, because most of the gravel may be ground into sand and silt.

Mine waste in particular may contain such elements as copper, lead and cadmium, which in bioavailable form can lead to serious damage to riparian ecosystems. One step in the process by which these elements become bioavailable is the grinding of the stones that contain them into silt. The large ratio of surface area to volume of silt-sized grains as compared to e.g. gravel facilitates the desorption of toxic elements into the water column. In addition, elevated concentrations of suspended silt in rivers can damage stream habitat by clogging fish gills, reducing visibility, and drowning near-bank and floodplain habitat in mud.

3.9.1 Quantification of Abrasion

The focus here is on the abrasion of gravel. The most common sand lithology in rivers, i.e. quartz, is highly resistant to abrasion, and the process by which sand grains become rounded is evidently a very slow one. Maunsell and Partners (1982) have demonstrated the very subdued tendency for sand to abrade as compared to gravel.

In most cases the process of breakdown of a single clast (stone) consists of an initial period during which it may shatter, followed by a much longer period during which it is gradually worn down by abrasion, producing silt and some sand as byproducts. There are several ways by which abrasion is accomplished.

1. In the case of rivers in cold regions, *in situ* freeze-thaw processes can play a role in abrasion.

2. In the case of meandering gravel-bed rivers with well-developed floodplains, channel migration can result in river gravels being stored under finer material in the floodplain for extended periods of time. This can result in the formation of a thin weathering rind. When the clast in question is re-introduced into the channel by migration or avulsion, the rind may be quickly shed, resulting on a one-time abrasion of the clast (Bradley, 1970).

3. As gravel clasts are carried downstream as bed-load, frequent collisions with other clasts in the bed result in a gradual wear, the main byproduct being silt (Shaw and Kellerhals, 1982). The exposition below focuses on this type of abrasion.

Abrasion by gradual wear due to fluvial transport is quantified in terms of an abrasion coefficient. The abrasion coefficient defined as the fractional volume loss (or equivalently mass loss) per unit distance traveled α_v is

$$\alpha_v = -\frac{1}{V_p}\frac{dV_p}{ds} \tag{3.93a}$$

where V_p denotes particle volume and s denotes distance of travel. The corresponding coefficient based on grain size D is

$$\alpha_d = -\frac{1}{D}\frac{dD}{ds} \tag{3.93b}$$

Approximating grain shape as spherical so that $V_p \sim D^3$, it is found that

$$\alpha_v = 3\alpha_d \tag{3.94}$$

Substituting Eq. (3.1) into Eq. (3.93b),

$$\frac{d\psi}{ds} = -\frac{\alpha_d}{ln(2)} \tag{3.95}$$

For the case of an abrasion coefficient that varies with neither clast size nor downstream distance, Eqs. (3.94) and (3.95) can be solved to yield the results

$$D = D_u\, exp(-\alpha_d s), \quad \psi = \psi_u - \frac{\alpha_d}{ln(2)}s \tag{3.96a,b}$$

where D_u and ψ_u denote upstream values.

Eqs. (3.96a,b) are alternate expressions of Sternberg's law for grain size change in the downstream direction. The downstream variation in grain size in many rivers often approximates the exponential relation (3.96a), but this in and of itself is no guarantee that abrasion is the cause. A very similar pattern of downstream fining can be driven mainly or exclusively by selective transport of finer grains, as discussed in Section 3.12.

It is in general very difficult to measure abrasion directly in the field. As a result, researchers have resorted to rotating tumbling mills such as the Los Angeles abrasion mill, concrete mixers and circular flumes to quantify abrasion. The characteristics of the device are used to compute an equivalent distance traveled, and the resulting diminution in grain size is measured, allowing α_d to be computed from Eq. (3.93b).

Summaries of abrasion coefficients from such tests are given in Shaw and Kellerhals (1982), Kodama (1994a) and Rice (1999). Figure 3.41 provides a summary of experimentally-determined abrasion rates. It is seen that α_d has been found to vary from about 1×10^{-5} km^{-1} to above 1×10^{-1} km^{-1}. The abrasion coefficient is partly a function of lithology, with quartz generally having a relatively low abrasion rate, limestone with a middling rate and some mudstones with a very high rate. In addition, it can vary with grain size itself. Finally, Mikoš (1993, 1994, 1995) has documented a tendency for the abrasion rate to decrease with increasing distance of travel, and for it to increase with increasing speed of a tumbling mill for the same travel distance.

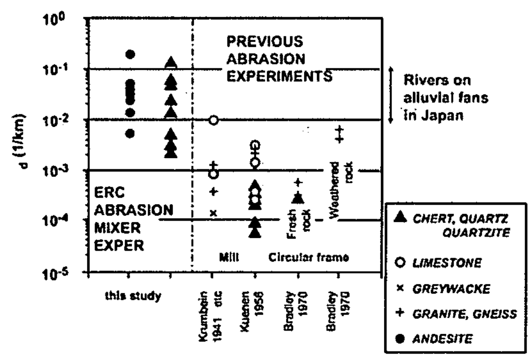


Figure 3.41 Abrasion coefficients α_d obtained from experiments by various researchers, as presented by Kodama (1994a).

In Figure 3.41 the abrasion rates reported by Kodama (1994a) are in the range $2 \times 10^{-3} \sim 2 \times 10^{-1}$ km^{-1}, and are generally substantially higher than those reported in earlier studies. Kodama is of the opinion that the earlier studies did not adequately replicate the violent grain-to-grain collisions during severe floods, and thus underestimated the abrasion rate. His experiments in a concrete mixer were designed to provide a better model of the process. The values reported by Mikoš (1995) are also higher than the earlier values, ranging from $3 \times 10^{-3} \sim 2 \times 10^{-2}$ km^{-1}.

3.9.2 Application to Rivers

Eq. (3.96a) can be used to define a "half-distance" $L_{1/2}$ for abrasion over which grain size is reduced by half;

$$L_{1/2} = \frac{0.693}{\alpha_d} \tag{3.97}$$

For a value of α_d of 1×10^{-5} km^{-1} $L_{1/2}$ takes the value 69,300 km, and abrasion is likely to play a negligible role in the downstream change in grain size in a river. For a value of α_d of 1×10^{-1} km^{-1} $L_{1/2}$ takes the value 6.93 km, and abrasion is likely to play a dominant role in downstream fining.

The application of abrasion coefficients to rivers is rather more complicated than simply plotting grain size as a function of distance using Eq. (3.96). There are two reasons for this. Eq. (3.96) does not account for grain size variation due to selective transport. In addition, when a moving grain strikes a non-moving grain on the bed, both can be expected to abrade, so that on the order of half of the abrasion is likely to be realized *in situ.*

To date there have not been many implementations of the abrasion term in the Exner equation of sediment continuity, Eq. (3.33). Parker (1991a,b) has, however, proposed a form. This form is most easily expressed in terms of the continuous probability densities $F(\psi)$, $f_I(\psi)$ and $f_b(\psi)$ for surface material, interfacial exchange material and bed-load material, respectively, rather than their discretized versions F_i, F_{Ii} and f_{bi}. Let $\alpha_d(\psi)$ define the abrasion coefficient, which is specifically allowed to be a function of grain size. Eq. (3.33) takes the continuous form

$$(1-\lambda_p)\left[f_I \frac{\partial \eta_b}{\partial t} + \frac{\partial}{\partial t}(L_a F)\right] = -\frac{\partial q}{\partial s} - A \tag{3.98a}$$

where $q(\psi)$ denotes the density of bed-load transport rate such that total gravel bed-load transport rate q_T is given as

$$q_T = \int_1^\infty q(\psi)d\psi \tag{3.98b}$$

and $A(\psi)$, given by the relation

$$\begin{aligned} A &= q_T\left[3\alpha_d f_b - \frac{1}{ln(2)}\frac{\partial}{\partial \psi}(\alpha_d f_b)\right] \\ &+ q_T\left[\int_1^\infty \alpha_d(\psi')f_b(\psi')d\psi'\right]\left[3F_{ae} - \frac{1}{ln(2)}\frac{\partial F_{ae}}{\partial \psi}\right] \end{aligned} \tag{3.98c}$$

denotes the density of the volume of material lost to abrasion per unit bed area per unit time, so that the total loss rate per unit area A_T is given as

$$A_T = \int_1^\infty A(\psi)d\psi \tag{3.98d}$$

In Eq. (3.98c) the parameter F_{ae} is defined as

$$F_{ae}(\psi) = \frac{F(\psi)2^{-0.5\psi}}{\int_1^{\infty} F(\psi)2^{-0.5\psi}} \tag{3.98e}$$

The lower limit of unity in the integral implies that only gravel is considered in the calculation; a value of ψ of 1 corresponds to a grain size D of 2 mm,

The first term on the right-hand side of Eq. (3.98c) denotes the abrasion density of bed-load particles, and the second term denotes the corresponding abrasion density of bed particles with which the bed-load particles collide. The derivative with respect to ψ in the same equation describes the flux of sediment through grain size space as grains are ground ever finer.

The discretized version of Eq. (3.98c) is

$$\begin{aligned} A_i = {} & q_T\left[3\alpha_{d,i}f_{b,i} - \frac{1}{ln(2)}\frac{\left(\alpha_{d,i+1}f_{b,i+1} - \alpha_{d,i}f_{b,i}\right)}{\Delta\psi_i}\right] \\ & + q_T\left[\sum_{j=1}^{n}\alpha_{d,j}f_{b,j}\right]\left[3F_{ae,i} - \frac{1}{ln(2)}\frac{\left(F_{ae,i+1} - F_{ae,i}\right)}{\Delta\psi_i}\right] \end{aligned} \tag{3.98f}$$

$$F_{ae,i} = \frac{F_i D_i^{-1/2}}{\sum_{i=1}^{n} F_i D_i^{-1/2}} \tag{3.98g}$$

where $\Delta\psi_i$ is given by Eq. (3.11c), $\alpha_{d,i}$ denotes the abrasion coefficient for the ith grain size range and $f_{b,i}$ is synonymous with f_{bi}. The total abrasion rate A_T is given as

$$\begin{aligned} & A_T = A_{silt} + A_{sand} \\ & A_{silt} = 6q_T\sum_{i=1}^{n}\left(\alpha_{d,i}f_{b,i}\right) \\ & A_{sand} = \frac{q_T}{\Delta\psi_1 ln(2)}\left[\alpha_{d,1}f_{b,1} + \left(\sum_{j=1}^{n}\alpha_{d,j}f_{b,j}\right)F_{ae,1}\right] \end{aligned} \tag{3.98h-j}$$

where A_{silt} and A_{sand} are the associated volume rates of production per unit time per unit bed area of silt and sand, respectively. In the case of crystalline rock it is common that very little sand is produced until the grain size reaches the range 5 ~ 10 mm. In many crystalline rocks the crystal size is on the order of mm in size, and so the weak planes between crystals allow for a sudden shattering to sand-sized grains. This effect has been invoked as one possible explanation of the sharp gravel-sand transition evident in Figure 3.10 (Yatsu, 1955).

The above formulation is implemented in Parker (1991b) and the program ACRONYM4 in Parker (1990b). Parker (1991a) also provides the generalization to multiple lithologies. Results from an application to the disposal of mine waste in the Ok Tedi-Fly River system, Papua New Guinea are reported in Cui and Parker (1999).

3.10 NUMERICAL MODELING OF BED LEVEL VARIATION WITH SORTING

3.10.1 Elements of a Numerical Model

The active layer formulation of the grain size-specific Exner equation of bed-load continuity combined with an appropriate grain size-specific predictor for bed-load transport form the basis for the numerical modeling of the variation of bed level and grain size distribution in bed-load-dominated rivers. To this must be added a) an appropriate formulation of the fluid mechanics, usually realized through the St. Venant shallow water equations, and b) an appropriate methodology for the computation of hydraulic resistance (including skin friction and form drag). The simple versions of the 1-D shallow water St. Venant given in Section 3.7.2 are here restated as

$$\begin{aligned} &\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial s}=-g\frac{\partial H}{\partial s}-g\frac{\partial \eta}{\partial s}-gS_f \\ &\frac{\partial H}{\partial t}+\frac{\partial UH}{\partial s}=0 \end{aligned} \qquad (3.99a,b)$$

where S_f denotes the friction slope, given by

$$S_f=\frac{C_f U^2}{gH}=\frac{n_m^2 U^2}{k_{nuisance} H^{4/3}} \qquad (3.99c)$$

In the above relations U denotes cross-sectionally averaged flow velocity, H denotes cross-sectionally averaged flow depth (or hydraulic radius), C_f is the dimensionless friction coefficient defined in Section 3.7.2, i.e.

$$C_f=\frac{\tau_b}{\rho U^2}=\frac{u_*^2}{U^2}=Cz^{-2} \qquad (3.99d)$$

where Cz is the dimensionless Chezy resistance coefficient, n_m is Manning's "n" and $k_{nuisance}$ takes a value of 1 using the MKS implementation of the SI system and 1.49 for an FPS implementation of "English" units.

It is possible to simplify the St. Venant equations depending upon the type of flow under consideration. When the channel is subject to a steady flow discharge, the classical quasi-steady approximation (de Vries, 1965) generally allows the neglect of the time terms in Eqs. (3.99a,b), while retaining them in the Exner equation of sediment continuity, i.e. Eq. (3.23) or Eq. (3.33). In field streams in general, and gravel-bed rivers in particular, however, the characteristic time of a hydrograph may be so short that it is necessary to retain the time terms. Any simplified model of flood wave propagation based on the St. Venant equations must be capable of resolving the time variation in boundary shear stress necessary for the computation of the time variation of sediment transport rate and size distribution.

In executing engineering applications to field rivers, both the Exner equation of sediment continuity and the St. Venant formulation must be modified. A minimal modification is outlined below.

3.10.2 Minimal Form for Field Application to Engineering Problems

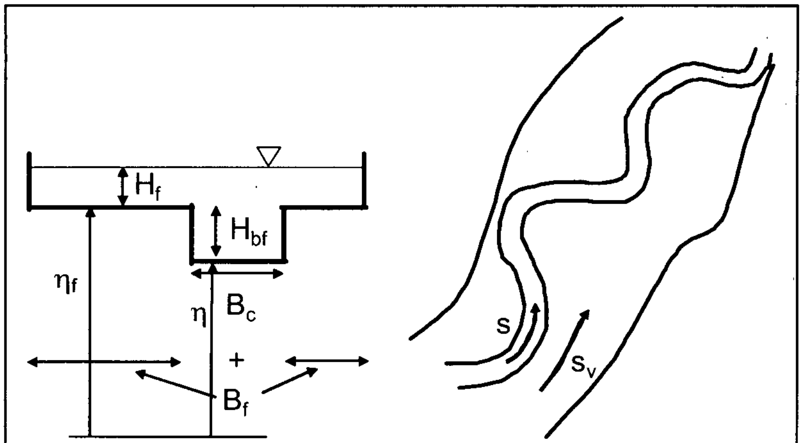


Figure 3.42 Definition diagram for in-channel and overbank flow in a river.

Modifications to the forms of Eq. (3.23) or (3.33) and Eqs. (3.99a,b) are required because a) rivers rarely have constant widths, b) they usually have floodplains, and c) they usually have some degree of sinuosity. Here the sinuosity Σ_{sin} is defined as the average along-channel distance s divided by the average along-valley distance s_v (Figure 3.42); it commonly has a value between 1.0 and 2.5. The importance of the floodplain is as follows. Rivers transport the bulk of their sediment load during floods. Once river stage exceeds the bank-full stage, however, the water spreads out on the floodplain; further increases in stage increase water surface level very little. In the case of a vegetated floodplain, floodplain sediment is usually not mobilized, and a further increase in discharge does not result in substantially increased sediment transport. In the case of sufficiently sinuous channels, the sediment transport rate at above-bank-full stage can actually decline somewhat with increasing stage because the thread of high velocity no longer precisely follows the channel which constitutes the source of bed material load (Leopold, 1994). The failure to include the damping effect of the floodplain in numerical modeling of variation in river bed elevation can result in the spurious prediction of river bed degradation during floods.

With this in mind, a down-valley coordinate s_v is defined in addition to the down-channel coordinate s. When averaged over several bends, the relation between these coordinates is

$$\frac{ds_v}{ds} = \frac{1}{\Sigma_{sin}} \tag{3.100}$$

This definition limits the spatial resolution of the model; cross-sections must be spaced by at least a bend or two. Channel width is denoted as B_c, which is here assumed to vary in the streamwise direction but not in time. The same holds true for floodplain width B_f, which here indicates the sum of the widths on both sides of the channel. In this simplest of implementations, the channel bed has elevation η, taken constant across the cross-section, and floodplain elevation η_f is similarly held constant across the floodplain (Figure 3.41). Channel bank-full depth is denoted as H_{bf}, where

$$H_{bf} = \eta_f - \eta \tag{3.101}$$

For below-bank-full flow the St. Venant equations take the form

$$\begin{gathered} \frac{\partial U_c}{\partial t} + U_c \frac{\partial U_c}{\partial s} = -g\frac{\partial H_c}{\partial s} - g\frac{\partial \eta}{\partial s} - gS_{fc} \\ B_c \frac{\partial H_c}{\partial t} + \frac{\partial B_c U_c H_c}{\partial s} = 0 \end{gathered} \tag{3.102a,b}$$

where the subscript "c" denotes channel. For overbank flow the formulation is modified to

$$\begin{gathered} \frac{\partial U_c}{\partial t} + U_c \frac{\partial U_c}{\partial s} = -g\frac{\partial (H_{bf} + H_f)}{\partial s} - g\frac{\partial \eta}{\partial s} - gS_{fc} \\ \frac{\partial U_f}{\partial t} + \Sigma_{sin} U_f \frac{\partial U_f}{\partial s} = -\Sigma_{sin} g \frac{\partial H_f}{\partial s} - \Sigma_{sin} g \frac{\partial \eta_f}{\partial s} - gS_{ff} \\ \frac{\partial}{\partial t}\left[B_c (H_{bf} + H_f) + \frac{B_f H_f}{\Sigma_{sin}}) \right] + \frac{\partial}{\partial s}\left[B_c (H_{bf} + H_f) U_c + B_f U_f H_f \right] = 0 \end{gathered} \tag{3.102c,d,e}$$

where the subscript f denotes floodplain, so that e.g. S_{ff} denotes the friction slope of the floodplain. The corresponding form for the Exner equation of sediment continuity applied to sediment within the channel is

$$(1-\lambda_p) B_{ca} \left[f_{Ii} \frac{\partial \eta_b}{\partial t} + \frac{\partial}{\partial t}(L_a F_i) \right] = -\frac{\partial B_{ca} q_i}{\partial s} - B_{ca} A_i \tag{3.103}$$

where the parameter η_b is defined in Figure 3.32 and B_{ca} denotes a channel width adjusted to describe sediment transport, as described below.

The above formulation must be augmented with relations for hydraulic resistance. In the case of the floodplain, it usually suffices to prescribe a floodplain value n_f of Manning's "n"based on the calibration of backwater curves. In the case of the channel, the resistance relation should include at the very least the effect of roughness due skin friction and bedforms. The resistance relations in Chapter 2 are formulated in terms of bed slope S for the case of normal flow. In the case of flow that varies in time and space, the energy slope S_e, which may be defined as

$$S_e = \frac{\tau_b}{\rho g H} = -\frac{\partial \eta}{\partial s} - \frac{\partial H_c}{\partial s} - \frac{1}{g}\left(\frac{\partial U_c}{\partial t} + U_c \frac{\partial U_c}{\partial s}\right) \tag{3.104}$$

must be used instead. In the above relation, τ_b refers to channel bed stress and H_c takes the value $H_b + H_f$ in the case of overbank flow. In addition, if the transport relation is based on skin friction τ_{bs} rather than total bed friction τ_b, the hydraulic resistance relation must allow for such a decomposition.

The adjusted width B_{ca} in the Exner equation (3.103) is in general a parameter that must be calibrated. It was seen in Section 3.7.16 that a complexity coefficient (or coefficients) must be introduced in order to account for the effects of channel complexity on sediment transport. One way to do this in a numerical model for a site-specific engineering application is to adjust the actual channel widths B_c at each cross-section.

This adjustment can be accomplished by the process of zeroing the model. Natural rivers typically (but not always) undergo change only at a morphologic time scale that is large compared to engineering time scales. When the actual channel widths B_c are input and the model run under natural conditions for which only minor morphologic change is expected, it usually turns out that spurious, unacceptable amounts of aggradation or degradation occur at specific nodes. Zeroing consists of modifying B_c to the value B_{ca} at each cross-section until such spurious bed level variation is reduced to an acceptable level. The model may be similarly zeroed by modest changes to the initial bed elevations. Without this process of zeroing the sediment transport and morphodynamic signals associated with engineering change such as flow diversion, dam removal or sediment dumping from a mine often cannot be seen through the spurious signals, much less accurately predicted.

In the case of a gravel-bed river, when the river aggrades to the point of filling its channel it can spread out on the floodplain. Any vegetation may be buried or ripped out, resulting in the formation of a braid plain over which the channel wanders. In such a case it is useful to compute the sediment transport within a channel of prescribed width and bank-full depth, but to spread the deposit out over the entire valley flat to as to simulate migration and avulsion. The form of the Exner equation for this case is

$$\begin{aligned} &(1-\lambda_p)B_v\left[f_{Ii}\frac{\partial \eta_b}{\partial t} + \frac{\partial}{\partial t}(L_a F_i)\right] = -\frac{\partial B_c q_i}{\partial s} - B_{ca}A_i \\ &B_v = B_c + B_f \end{aligned} \tag{3.105a,b}$$

where B_v denotes the width of the valley flat (including channel(s)).

It should be emphasized that the above treatment represents the simplest possible physically realistic engineering formulation for a field river. It nevertheless excludes myriad other important features of rivers and river flow, including transverse variation in floodplain elevation, dynamic channel-floodplain interaction and sorting due to 2-D and 3-D effects. One eventually reaches, however a point of vanishing returns; the repeated addition of poorly-constrained bells and whistles can degrade the predictive quality of a numerical model, in addition to making it difficult to use.

3.10.3 Examples of Numerical Models Using Grain Size Distributions

Several numerical models of bed level variation with sorting are described below. No attempt is made to be comprehensive. Rather, the goal is to provide the engineer with a brief summary of what kinds of models were available at the time of writing.

Belleudy and SOGREAH (2000) describe the latest developments of the model SEDICOUP. This model has been specifically designed to treat sediment mixtures. Earlier developments can be found in e.g. Holly and Rahuel (1990). SEDICOUP is a descendent of the model CARICHAR (Rahuel et al., 1989). Bezzola (1992) describes the application of the model MORMO to a flood in the Reuss River, Switzerland. Borah et al. (1982) present a numerical model designed for the study of the development of a static armor in rivers. The sediment transport equations used in the study are not grain size-specific; this feature is considered in terms of an adjustment for "residual transport capacity." Copeland and Thomas (1992) describe the dynamic sorting and armoring algorithm in the US Army Corps of Engineers TABS-1 model.

Cui et al. (1996) outline a model of grain sorting and aggradation verified against the experiments of Seal et al. (1997). This model is developed further in Cui and Parker (1997) for a shock-fitting of mobile gravel-sand transitions. Both models are descendants of ACRONYM 4 (Parker, 1990b). ACRONYM 4 was also adapted to study gravel transport, abrasion and change in bed elevation in the OKGRAV models applied to mine waste disposal in Papua New Guinea (Cui and Parker, 1999). Cui et al. (2003a, 2003b) develop the model further for the study of gravel pulses in rivers. See also Appendix A in this volume by Cui and Wilcox.

Hoey and Ferguson (1994) report on a model designed for and tested against downstream fining in the Allt Dubhaig, a river in Scotland, UK. Hoey and Ferguson (1997) use this model to study the controls on downstream fining. Ferguson et al. (2001) further develop this model and apply it to fluvial aggradation in the Vedder River, British Columbia, Canada. Van Niekerk et al. (1992) adapt the transport model of Bridge and Bennett (1992) to develop the numerical model MIDAS.. Vogel et al. (1992) apply this model to the downstream sorting of heavy sediments such as placers in rivers. Robinson and Slingerland (1998) have expanded this work to the study of downstream sorting of bimodal sediment mixtures.

Armanini (1991/1992) defines the basis for a numerical model of mixed grain sizes that describes the evolution of various moments of the grain size distribution, rather than that of the distribution itself.

3.11 STATIC AND MOBILE ARMORING: OBSERVATIONS, EXPERIMENTS AND MODELING

The intense program of dam building in the United States and other countries in the period 1920 – 1950 led to a strong interest in the problem of static armor formation downstream of dams. The question of engineering relevance pertains to the elevation to which the bed would degrade downstream of a dam before coarsening sufficiently to stabilize and prevent further erosion. If this were not accounted for in designing the dam itself and the apron downstream of the spillway, the structure itself could be undermined.

It is important to realize in this regard that sand-bed streams often have at least a trace of gravel, which can accumulate as the sand is carried downstream and eventually form a stable armor layer. The evolution of such an armor is illustrated for the bed downstream of Hoover Dam in Figure 3.15.

3.11.1 Static Armor

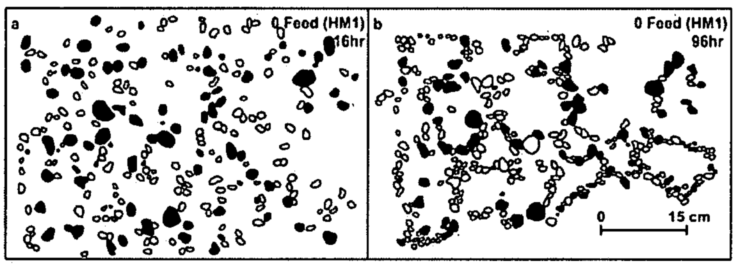


Figure 3.43 Evolution of stone cells on the bed surface of a laboratory flume as the bed evolves in response to the cutoff of sediment supply, as observed by Hassan and Church (2000). Hassan and Church also document the presence of these cells in the case of an equilibrium mobile-bed armor; the higher the sediment transport rate, the less developed are the cells.

The topic of static armoring remains of strong interest today. Ashida and Michiue (1971), Hirano (1971), Proffitt (1980), Gomez (1983), Egashira and Ashida (1990), Tsujimoto and Motohashi (1990), Tait et al. (1992), Marion et al. (1997), Willetts et al. (1998), Church et al. (1998) and Hassan and Church (2000) have studied the phenomenon. In all cases the bed surface is found to coarsen to a static armor as the sediment supply is cut off. Of recent interest is the tendency for the coarser grains to organize themselves into "clusters," "rings," and "stone cells" as the supply of gravel drops. Evidently armoring is not simply associated with the accumulation of coarser grains on the bed surface, but also with the organization of these grains into a pattern that increases the resistance to motion. An example of these structures is shown in Figure 3.43.

Full numerical models of the time evolution to static armor based on versions of the grain size-specific Exner equation of sediment continuity, Eq. (3.23) have been implemented by many researchers, including Park and Jain (1987), Vogel et al, (1992) and Tsujimoto and Motohashi (1990). An example of such a calculation and its comparison against data is shown in Figure 3.44.

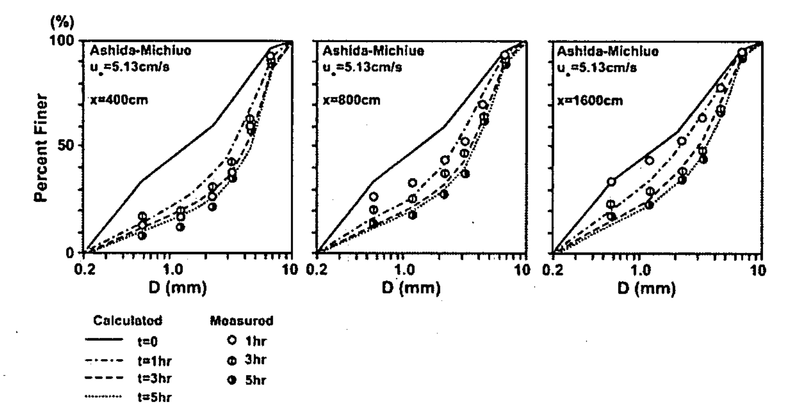


Figure 3.44 Examples of comparisons of a numerical model of evolution to static armor versus experimental data from a laboratory flume, in which x denotes distance downstream; from Tsujimoto (1999).

Ashida and Michiue (1971) devised a way to compute static armor in a much simpler way. This method was corrected by Proffitt (1980) and Sutherland (1987). The case of late-stage degradation is considered. By this time the active layer L_a is assumed to have achieved a near-constant thickness. Assuming that the bed is degrading to a substrate with a spatially constant grain size distribution with fractions $\bar{f}_i$, Eq. (3.23) may be rearranged with the aid of Eqs. (3.26) and (3.28) to yield.

$$\frac{\partial F_i}{\partial t} = \frac{1}{L_a}\left[(f_{bi} - \bar{f}_i)\frac{\partial \eta_b}{\partial t} - \frac{1}{1-\lambda_p} q_T \frac{\partial f_{bi}}{\partial s} \right] \tag{3.106}$$

As degradation progresses the term $\partial f_{bi} / \partial s$ can be expected to approach zero. Thus at late stage Eq. (3.106) simplifies with Eq. (3.24) to

$$\frac{dF_i}{d(\eta / L_a)} = f_{bi} - \bar{f}_i \tag{3.107}$$

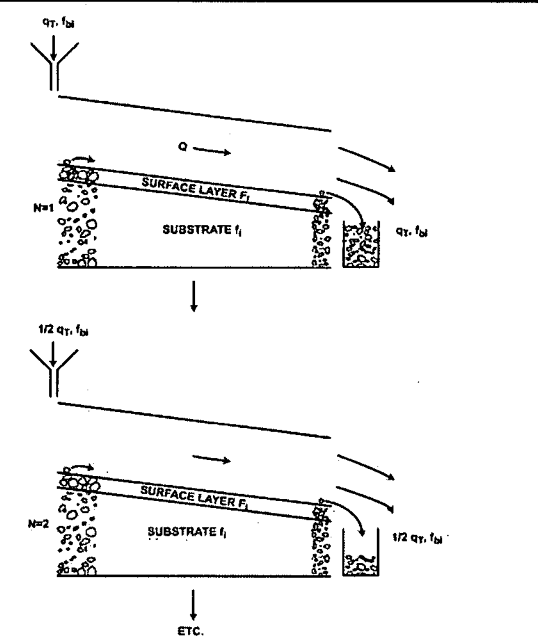


Figure 3.45 Conceptual diagram illustrating the evolution of a static armor from equilibrium mobile-bed conditions as the sediment feed rate is repeatedly halved.

In so far as the substrate fractions are given and the bed-load fractions can be computed from an appropriate sediment transport relation, the above equation can be solved iteratively until f_{bi} approaches $\bar{f}_i$, after which the bed will coarsen no more. Since the final state is the most important one to the engineer, Eq. (3.107) allows a considerable simplification over a full model.

Parker and Sutherland (1990) proposed an even simpler method. Consider Figure 3.45. The flume therein has a uniform substrate and is supplied with size fractions $\bar{f}_i$, constant water discharge and constant total sediment feed rate q_T with constant size fractions f_{bi}. The flume is allowed to develop to a mobile-bed equilibrium. The experiment is then repeated keeping the substrate and feed fractions constant but halving the total feed rate q_T. The water discharge is adjusted from experiment to experiment to insure that each reaches a mobile-bed equilibrium at the same bed slope S as the previous one. A static armor should be approached as q_T approaches zero.

The surface-based bed-load relation of Parker (1990a), i.e. Eqs. (3.79a-g) is used here as an example. Eqs. (3.26) and (3.28) can be used to reduce these to

$$W_i^* = \frac{Rgq_T f_{bi}}{F_i u_{*s}^3} = G\left[\omega\phi_{sgo}\left(\frac{D_i}{D_g}\right)^{-0.0951}\right] \tag{3.108a}$$

Solving for surface fractions F_i, it is found that

$$F_i = \frac{\dfrac{f_{bi}}{G\left[\omega\phi_{sgo}\left(\dfrac{D_i}{D_g}\right)^{-0.0951}\right]}}{\displaystyle\sum_{i=1}^{n}\dfrac{f_{bi}}{G\left[\omega\phi_{sgo}\left(\dfrac{D_i}{D_g}\right)^{-0.0951}\right]}} \tag{3.108b}$$

The static armor size distribution F_{ai} is then given as

$$F_{ai} = \lim_{q_T \to 0} F_i \tag{3.109}$$

This limit corresponds to extremely low transport rates, a range within which it is seen from Eq. (3.79f) that

$$G\left[\omega\phi_{sgo}\left(\frac{D_i}{D_g}\right)^{-0.0951}\right] \to \left[\omega\phi_{sgo}\left(\frac{D_i}{D_g}\right)^{-0.0951}\right]^{14.2} \tag{3.110}$$

Substituting Eqs. (3.108b) and (3.110) into Eq. (3.109), the following very simple relation for static armor is obtained;

$$F_{ai} = \frac{\bar{f}_i D_i^{1.35}}{\sum_{i=1}^{n} \bar{f}_i D_i^{1.35}} \tag{3.111}$$

This predictor requires nothing more complicated that a hand calculator or spreadsheet to implement. Parker and Sutherland (1990) found that the agreement with five sets of data from experiments on armoring and one set from Oak Creek could be optimized by lowering the exponent in Eq. (3.111) from 1.35 to 1.12. The agreement holds across the entire grain size distribution. Similar agreement was obtained with the Paintal (1971) bed-load transport model adapted for mixtures with the hiding function of Proffitt and Sutherland (1983). Any bed-load transport relation which satisfies a simple power law of the form of Eq. (3.51) at very low transport rates possesses such a simple limit for static armor.

3.11.2 Mobile Armor

The forms of Eqs. (3.108) and (3.109) raise another issue, however. In the thought experiment outlined above, the grain size distribution F_i of the surface layer cannot be expected to suddenly jump to the distribution for static armor F_{ai} as q_T is lowered; instead the change should be gradual. That is, at conditions of relatively low transport rate, even when the all sizes participate in the bed-load due to the constant grain size distribution of the sediment feed, the bed surface should be coarser than the bed-load. If the bed-load material is the same material as that placed in the flume to make the substrate, then the bed surface should be coarser than the substrate as well. This state of an armored bed under equilibrium transport of all sizes may be called a mobile armor.

Until the concept of mobile armor was introduced, it was often thought that the armor layer in gravel bed rivers present at low flow was suddenly broken up by an appropriate threshold discharge, leading to an unarmored state during active bed-load transport. The armor was thought to reform by downstream and vertical winnowing as the flow declined.

The existence of an equilibrium mobile-bed armor was first demonstrated in a sediment feed flume by Parker et al. (1982b). Parker and Klingeman (1982) offered a simple explanation for it as follows. Consider a flume containing just two grain sizes, one coarse and one fine. The coarse and fine halves of the load are fed in at the same rate until a mobile-bed equilibrium is reached. The coarser grains are intrinsically less mobile than the finer grains, even after accounting for hiding effects. But once equilibrium is reached both halves must be transported at exactly the same rate. The way the model river in the flume accomplishes this is by overrepresenting the coarse material on the bed surface, so that the availability of coarse grains is increased, and that of fine grains decreased, until their effective mobility is equalized.

Parker and Toro-Escobar (2002) have termed this the weak form of the "equal mobility" hypothesis. Simply put, it says that no matter what the grain size distribution of the sediment supply, in a stream that is locally in grade the bed surface must reorganize itself so that the coarse half of the feed moves through the system at the same rate as the fine half.

Mobile armor has been observed in laboratory sediment-feed flumes by Tsujimoto and Motohashi (1990), Egashira and Ashida (1990), Suzuki and Kato (1991), Suzuki and Hano (1992) and Hassan and Church (2000). Seal et al. (1997) documented the maintenance of a mobile armor under conditions of slow bed aggradation in a sediment feed flume. Parker et al. (2003) have documented the formation and maintenance of a mobile-bed armor under conditions of a repeated full hydrograph designed to model field gravel-bed rivers.

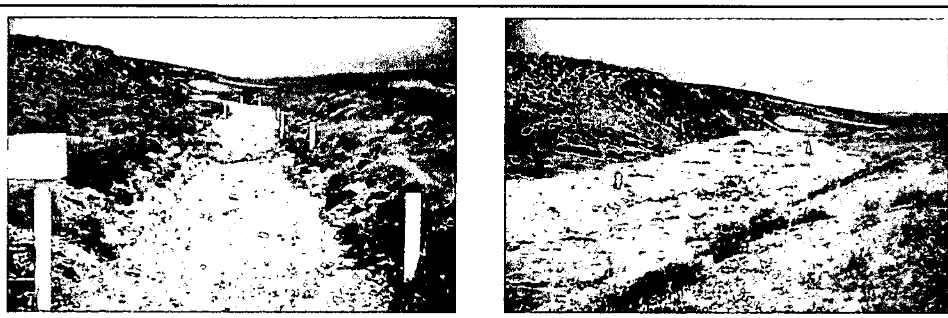
Mobile armor has also been observed in sediment recirculating flumes. The most comprehensive documentation in this configuration is outlined in Wilcock and Kenworthy (2002), but see also Marion and Fraccarollo (1997). The expression of mobile-bed armor in a recirculating flume is somewhat different from that in a sediment feed flume, in which all sizes in the feed are forced to move at mobile-bed equilibrium. As a result, partial transport with little transport of the coarsest grains, even when D_{u50} is mobilized, is common. The reader is referred to Wilcock (2001b) for a discussion of the differences between the configurations.

3.11.3 The Variation of Mobile Armor with Bed-load Transport Rate

Now it is of use to consider the the limit of high transport rate. In the case of the relation of Parker (1990a), as q_T (ϕ_{sgo}) becomes large, $G(\phi_{sgo})$ approaches the constant limit 5474 in Eq. (3.77f). As a result, Eq. (3.108b) devolves to the result

$$\underset{q_T \to \infty}{F_i} = f_{bi} \qquad (3.112)$$

That is, at high transport rates the grain size distribution of the surface layer must



a) b)

Figure 3.46 Flash flood in the ephemeral Nahal Eshtemoa, Israel:
a) arrival of the flood wave (looking upstream); and b) passage of the flood wave (looking downstream). Images courtesy J. Laronne.

approach that of the sediment supply. This same limit must be reached at high sediment transport rates for any sediment transport relation for which $q_i^* \rightarrow \left(\tau_i^*\right)^{3/2}$ or equivalently $W_i^* \rightarrow const$. Relations satisfying this condition include those of Ashida and Michiue (1972), Hunziker and Jaeggi (2002), Wilcock and Crowe (2003) and Powell et al. (2001).

One may inquire as to whether or not mobile armor is observed in the field. It is difficult to sample a mobile gravel bed during a flood. This notwithstanding, Andrews and Erman (1986) report such a measurement. Sagehen Creek is a perennial stream in the Sierra Nevada of California. At low flow it has a well-armored bed, with a value of (surface) D_{50} of 58 mm and a value of (substrate) D_{u50} of 30 mm. In addition, it has a wel-defined self-constructed floodplain. The value of bank-full Shields number τ_{bf50}^*, defined in Eq. (3.17e), is about 0.059, so that the stream fits in the center of the gravel-bed rivers of Figure 3.29, as is shown therein. The creek typically floods during snowmelt season. In 1983 the river went overbank during a snowmelt flood. Andrews and Erman sampled the surface layer both at low flow and near the flood peak, when particles as large as 86 mm were found to move. A mobile armor was found to be present during the flood, and the size distribution differed little from the static armor at low flow. The grain size distribution of the surface was sampled both at low flow and twice during the flood event. The surface grain size distribution at the peak of the flood had a median size of 46 mm. This value is somewhat finer than the low flow value of 58 mm, and considerably coarser than the substrate value of 30 mm. Evidently a mobile armor was present during an event that a) was above bank-full stage and b) mobilized grains larger than D_{50}. That is, the measured mobile armor had a median size that was coarser than that of the low-flow substrate but finer that that of the low-flow surface material.

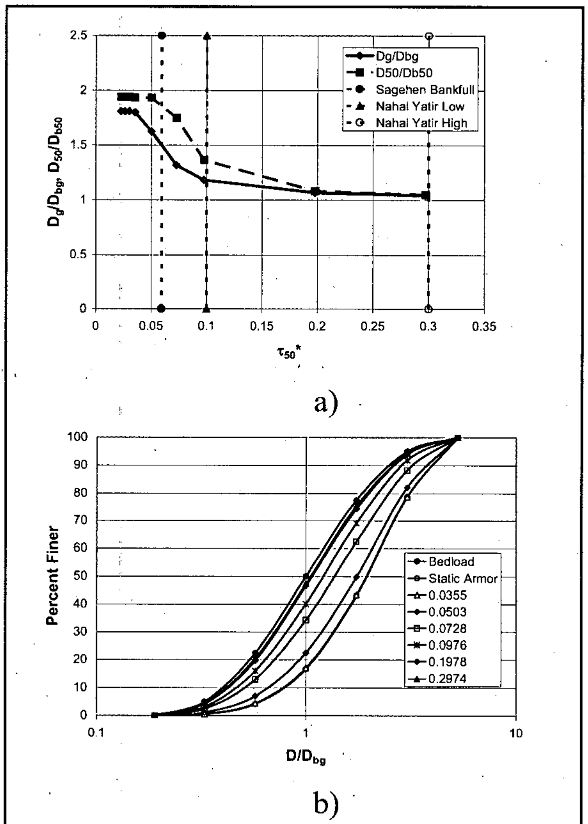


Figure 3.47 a) Predicted variation of the ratios D_g/D_{bg} and D_{50}/D_{b50} in τ_{50}^*, along with a bank-full value of τ_{50}^* for Sagehen Creek and two values of τ_{50}^* for the Nahal Yatir that bracket most of the bedload data.
b) Assumed normalized grain size distribution for bedload, along with predicted grain size distributions for static armor and mobile armor at the values of τ_{50}^* shown in the legend.

The Nahal Yatir is a desert wadi in Israel (Reid et al., 1995). It is subject to rare, intense flash floods. The arrival of a flash flood in a similar adjacent stream, the Nahal Eshtemoa, is documented in Figure 3.46. The floods subside so quickly that the bed has little time to reorganize itself. As a result, observations of the bed and substrate right after a flood more or less reflect the conditions at the flood peak. As can be seen in Figure 3.1, the Nahal Yatir is essentially unarmored (Laronne et al., 1994). A substantial amount of the data in Reid et al. (1995) on bed-load transport in the Nahal Yatir pertains to values of τ_{50}^* (Shields number based on surface D_{50}) in the range 0.1 – 0.3, where in analogy to Eq. (3.18c)

$$\tau_{50}^* = \frac{HS}{RD_{50}} \tag{3.113}$$

These values are well above those reported for gravel-bed rivers in Figure 3.29. This is because the Nahal Yatir is incised into tough loess and older alluvium that resists erosion.

A juxtaposition of the field measurements for Sagehen Creek and the Nahal Yatir suggests that the surface grain size distribution changes systematically during floods. As τ_{50}^* increases above a threshold for significant gravel motion of about 0.03, the ratio D_{50}/D_{u50} (surface median size to substrate median size), or alternatively the ratio D_g/D_{ug} (surface geometric mean size to substrate geometric mean size) should gradually decrease toward unity, at which point no discernible armor is present.

A simple calculation using ACRONYM2 (Parker, 1990b) was implemented in an attempt to model this behavior. ACRONYM2 performs the calculation of Eq. (3.108b) using the Parker (1990a) relation. A reasonable approximation of the substrate size distribution of Sagehen Creek was constructed for this exercise. In the normalized form of $\bar{f}_i$ versus D_i/D_{ug}, it also serves as a crude approximation of the substrate size distribution in the Nahal Yatir. This normalized size distribution was used to approximate the size fractions f_{bi} of the bed-load during transport events in both streams. A range of values of total bed-load transport rate q_T were input into the program to simulate bed evolution as a function of transport rate. The results of the analysis are shown in Figure 3.47.

Figure 3.47a shows the ratios D_{50}/D_{b50} and D_g/D_{bg} versus τ_{50}^*. ACRONYM2 predicts that in the case of bank-full flow in Sagehen Creek (τ_{50}^* = 0.059), these ratios should decline only modestly from values at the low flow. In the case of the Nahal Yatir, these ratios have dropped dramatically at a value of τ_{50}^* of 0.1, and by the value 0.3 they are very close to unity. Figure 3.47b shows the size distribution of the bed-load, that of the static armor and that of the mobile armor at various values of τ_{50}^*. The progressive approach of the surface grain size distribution to that of the bed-load as τ_{50}^* increases is evident.

In the above formulation, it has been assumed that the size distribution of the bed-load is always invariant and equal to that of the substrate, so that D_{b50} is equal to D_{u50} and D_{bg} is always equal D_{ug}. If this were true, Figs. 3.47a,b would imply that the mobile armor would become progressively finer as τ_{50}^* increases, eventually approaching the grain size distribution of the substrate in the limit of large τ_{50}^*. That is, the armor would vanish for sufficiently high values of τ_{50}^*. This is in fact what is observed in the Nahal Yatir.

The above results needs to be qualified with the observation that the grain size distribution of the bed-load is typically not invariant with stage, but varies systematically such that D_{b50} and D_{bg} typically become coarser with increasing stage. This effect may tend to mute the approach of the surface grain size distribution toward that of the substrate as stage becomes progressively higher. This notwithstanding, it seems reasonable to infer that a) mobile armor is well-developed in gravel-bed streams of the type shown in Figure 3.29 even at bank-full conditions, but b) mobile armor is either poorly developed or absent in gravel-bed streams that can sustain substantially larger Shields numbers and transport orders of magnitude more gravel, such as the Nahal Yatir.

A second look at Figure 3.1 is instructive. Along with the unarmored Nahal Yatir, the well-armored River Wharfe is shown therein. It can be inferred from the photographs with some degree of reliability that the gravel supply to the River Wharfe is much lower than that to the Nahal Yatir. Dietrich et al. (1989) have quantified this concept in terms of a way to estimate the relative difference in gravel load between two streams based on the degree of armoring observed at low flow. The formulation may be used as a rough but accessible indicator of the gravel supply to the river.

3.11.4 The Hypothesis of Equal Mobility

A short discussion of the concept of "equal mobility" is in order. In addition to the weak form of Parker and Klingeman (1982), Parker et al. (1982a) advocated a "strong form" (Parker and Toro-Escobar, 2002), according to which the size distribution of the gravel bed-load averaged over many floods should be close to that of the gravel portion of the substrate layer immediately below the surface layer. That is, as an approximation

$$< f_{bi} > = \bar{f}_i \tag{3.114}$$

where the brackets denote values based on the size distribution of the mean annual gravel load. Lisle (1995) has performed a comprehensive test of this hypothesis. These results are shown in Figure 3.48 in terms of $<f_{bi}>$ versus $\bar{f}_i$. All grain size distributions have been truncated so as to remove material finer than 1 mm. Of the 14 stream reaches shown in the diagram, the strong form of equal mobility is rigorously or approximately satisfied in 8 cases, such that

$$1 < \frac{D_{u50}}{D_{b50}} < 1.5 \tag{3.115}$$

whereas in 6 cases it is not. The strongest discrepancy is in the East Fork River, which is not far upstream of a gravel-sand transition. In the other cases, Lisle associates the deviation from the strong form of equal mobility with low-order tributaries high up in a drainage basin. In addition, he also suggests that the prominent formation of patches of fine gravel may contribute to the preferential transport of these sizes in such streams.

Church et al. (1991) provide a test of the hypothesis of equal mobility in fluvial sediment transport, with a focus on the sand fraction of the load.

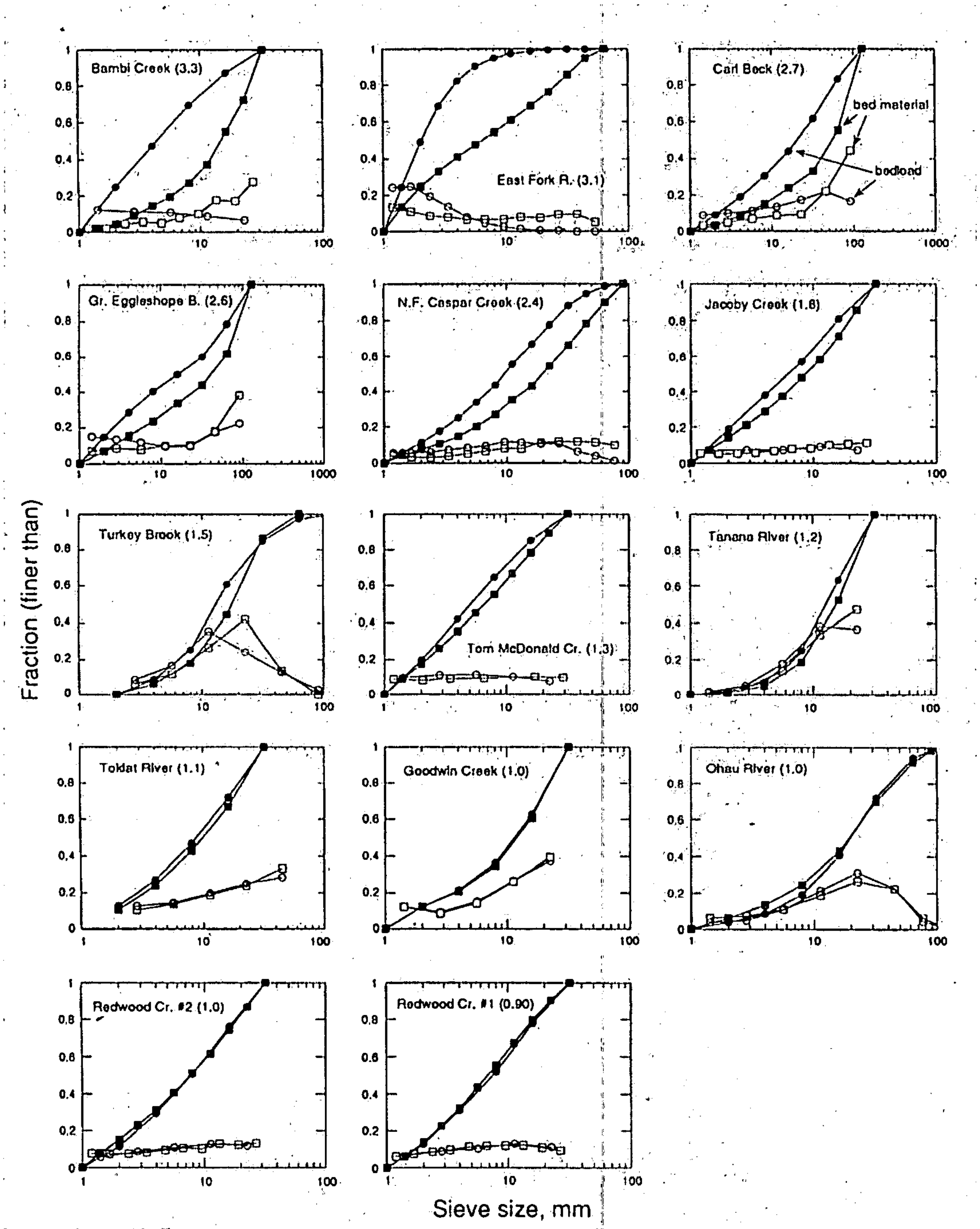
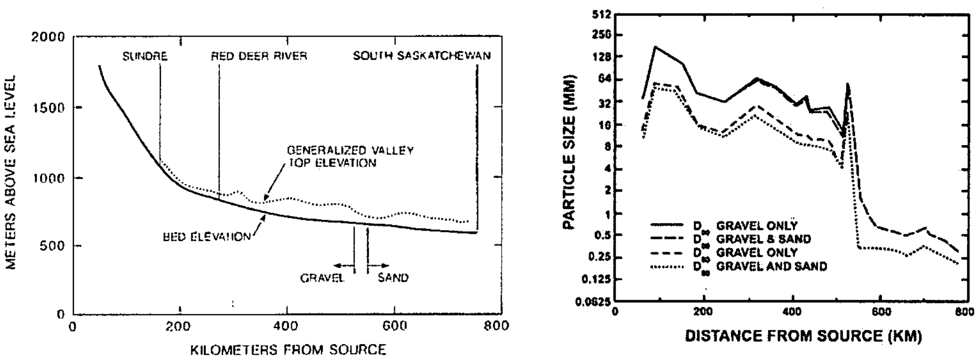


Figure 3.48 Normalized mean annual bedload (solid circles) and substrate (solid squares) grain size distributions for 14 gravel-bed rivers studied by Lisle (1995). The grain size distributions have been truncated at 1 mm. The hollow circles and squares pertain to fractions in each range.

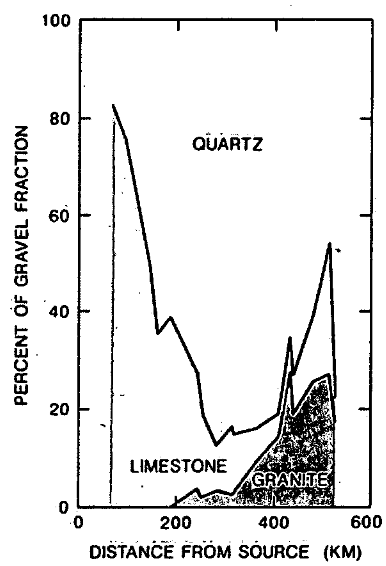
3.12 DOWNSTREAM FINING: OBSERVATIONS, EXPERIMENTS AND MODELING

3.12.1 Abrasion or Selective Sorting?



a) b)

Most but not all rivers are characterized by a concave-upward long profile, so that slope declines downstream. Many gravel-bed rivers with such a concave-upward profile also show a systematic tendency for the grain size of the bed material to become finer in the downstream direction. An example already discussed is the Kinu River, Japan, shown in Figure 3.10. A second example, shown in Figure 3.49, is the Red Deer River, Alberta, Canada (Shaw and Kellerhals, 1982). The long profile is seen to be concave-upward in Figure 3.49a. The surface sizes D_{50} and D_{90} is seen in Figure 3.49b to decline in the downstream direction over most of the 500 km of the gravel-bed reach, and then drop quickly to sand at a gravel-sand transition.



c)

Figure 3.49 Illustration of various aspects of downstream fining in the Red Deer River, Alberta, Canada. a) Long profile of the Red Deer River. b) Downstream variation in D_{50} and D_{90} in the Red Deer River. c) Downstream variation in three lithologies in the Red Deer River. From Shaw and Kellerhals (1982).

As noted above, a downstream decrease in gravel size may be due to selective transport of the finer gravel, abrasion or some combination of the two. In the case of the Red Deer River, lithology provides a hint, as shown in Figure 3.49c. The relative composition of various rock types in the river gravels is seen to change systematically. In particular, the fraction of the bed that is limestone declines relative to quartz and granite, to the point of near-vanishing content some 450 km downstream of the stream source. Shaw and Kellerhals (1982) present evidence to the effect that the limestone clasts in the river are more easily abraded than the granite clasts, and much more so than the quartz clasts. The implication is that the limestone is being ground out by abrasion, which thus may play an important or dominant role in the pattern of downstream fining.

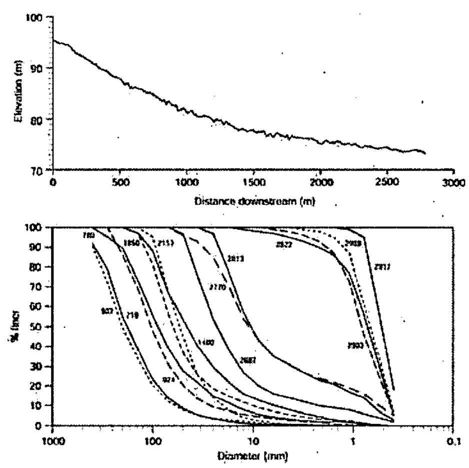


Figure 3.50 Illustration of downstream fining in the Allt Dubhaig, Scotland, UK, showing the long profile of the river (top) and grain size distributions of bulk surface samples taken at various points down the stream (bottom). From Ferguson et al. (1996).

Ferguson and Ashworth (1991) and Ferguson et al. (1996) provide another example of downstream fining that is very similar to the Red Deer River, yet very different from it. The Allt Dubhaig, Scotland, UK shows the same upward concave long profile and the same gravel-sand transition as the Red Deer (Figure 3.50). Yet in this case the amount of fining observed in the Red Deer River over hundreds of km is realized in the Allt Dubhaig over less than 4 km. In addition to the short distance, the durable nature of the rock types present in the river precludes an important role for abrasion. In this case, then, selective transport of the finer grains is the likely cause of the grain size variation.

Kodama (1994a,b) argues that the downstream fining observed in the Watarase River , Japan is primarily caused by abrasion. He argues that abrasion rates determined in mills and flumes severely underestimate the violent collisions associated with floods in the Watarase River, which are associated with typhoons. He used a concrete mixer to better approximate conditions in the Watarase River.

One might infer from the above that in a country such as Britain, which is geologically old, heavily glaciated and subject to a mild climatic regime, downstream fining might be wholly due to selective sorting, whereas a in geologically young, tectonically active country subject to violent storms such as Japan abrasion may tend to dominate. The picture is, however, not so simple. Seal and Paola (1995) observed rapid downstream fining over a 10 km reach upstream of a sediment retention dam on the North Fork Toutle River, Washington, USA (Figure 3.6). The sediment is largely derived from the Mount St. Helens eruption in 1980, and might be expected to abrade easily. Over the short distance of the deposit behind the dam, however, abrasion played a negligible role.

Gomez et al. (2001) have documented downstream fining over 90 km in the Waipaoa River, New Zealand. This example is of special interest because the median size of the substrate in the gravel-bed reach is in the pea gravel range. Rice (1998, 1999) has documented a pattern of "punctuated" downstream fining in British Columbia, Canada, in which abrasion appears to play little role. That is, a pattern of downstream fining is set up by selective transport between major sediment sources, some of which can refresh the supply of coarse grains and interrupt the pattern of progressive downsream fining. These sources can include tributaries, glacial moraines and bedrock cliff exposures.

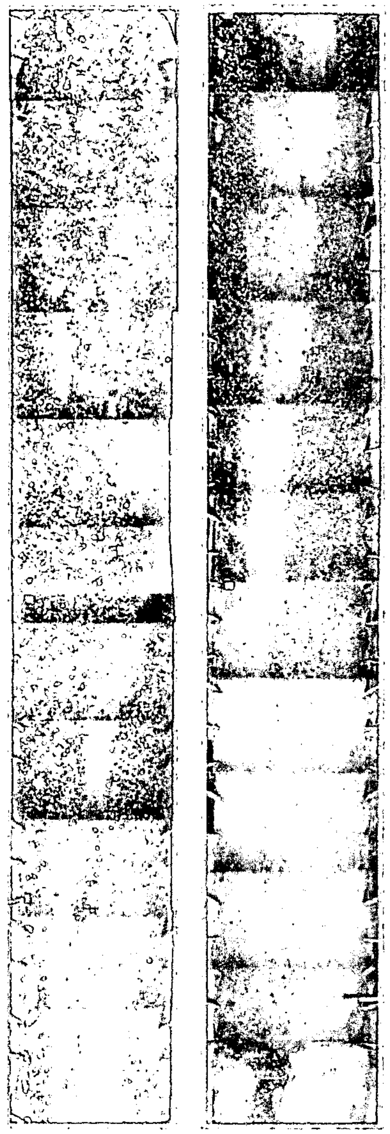
Gravel-bed rivers undergoing downstream fining often but not always end in a rather abrupt transition to a sand-bed reach over a few km. Yatsu (1955) documented these transitions on many Japanese streams. Recently Sambrook Smith and Ferguson (1995) have documented such transitions on 18 streams in Canada, England, Japan, Papua New Guinea, Romania and Scotland. The Waipaoa River discussed above also exhibits a gravel-sand transition. In most but not all cases the transition from gravel to sand is accompanied by a substantial drop in river bed slope. The reason for the transition is still a matter of debate, but it can often be ascribed to a bimodal grain size distribution with a gap or paucity somewhere near the interface between sand and gravel sizes. Fujita et al. (1998) document both downstream fining and gravel-sand transitions on a variety of Japanese streams, and present a conceptual model for the effect of engineering works on the location of the transition point.

Pizzuto (1995) has argued that downstream fining need be a consequence of neither abrasion nor downstream fining. Instead, it could be driven simply by a tendency for more distal tributaries to deliver finer sediment to the main stem of a river. His model underlines the importance of sediment provenance in considering the problem of downstream fining.

3.12.2 Laboratory Studies of Downstream Selective Sorting

Laboratory flumes are too short to allow modeling of downstream fining set up by abrasion, but they provide a useful venue for testing the process of selective sorting. An upward concave bed profile can usually be set up in a flume by forcing the bed to aggrade. The resulting downstream decrease in slope then ought to drive selective deposition of the coarser grains and transport of the finer grains. Curiously, however, one of the earliest documented studies of downstream sorting of heterogeneous sediments under aggradational conditions in the laboratory yielded the opposite result. Straub (1935) instead found a pattern of downstream coarsening caused by selective transport of the coarser grains. Kodama et al. (1992) specifically attempted to reproduce downstream fining in an aggrading channel and again obtained downstream coarsening. They describe this result as "quite contrary to common sense."

Paola et al. (1992b) and Seal et al. (1997) finally succeeded in reproducing downstream fining in the laboratory. Their channel was 0.3 m wide and over 50 m long; the sediment used in the study was a weakly bimodal mix of sand and gravel ranging from 0.125 mm to 90 mm. The sediment was fed in over an inerodible bed and allowed to prograde into standing water. The upward-concave profile of gravel ended in a distinct gravel front, downstream of which only sand prevailed. The height of this front was controlled by the base level of the standing water. Toro-Escobar et al. (2000) repeated the experiments in a much wider channel, again obtaining unambiguous downstream fining driven by selective transport. The channel bed at the end of one of the experiments in Figure 3.51 serves to illustrate the pattern of downstream fining. This set of experiments revealed that an increased content of sand in the sediment feed caused more rapid downstream fining of the gravels, a result that might be explainable in terms of the new model of gravel-sand transport of Wilcock and Crowe (2003; see also Wilcock, 1998a and Wilcock et al., 2001).



a) b)

Figure 3.51 Illustration of downstream fining produced in a laboratory channel; in Run 5 of Toro-Escobar et al. (2000). The channel width is 2.7 m. a) The upstream 20 m of the deposit. b) The downstream 20 m of the deposit. Flow was from top to bottom.

The reason why downstream coarsening was obtained in some studies of aggrading deposits and downstream fining in others was identified by Solari and Parker (2000). They delineated a mobility reversal for bed slopes exceeding about two percent. At higher slopes the direct effect of gravity acting to pivot out the larger exposed grains is enough to disturb the delicate balance between grain weight and grain protrusion that renders finer grains somewhat more mobile in a mixture at lower slopes. The experiments of Straub (1935) and Kodama et al. (1992) were above the threshold, whereas the experiments of Seal et al. (1997) and Toro-Escobar et al. (2000) were below the threshold.

Brummer and Montgomery (2003) have documented a similar tendency for downstream coarsening in field channels near their headwaters. More specifically, downstream coarsening was observed for drainage areas less that 10 km^3, or slopes exceeding about eight percent.

Such a mobility reversal has been observed in other contexts. Everts (1973) reported on the phenomenon of overpassing, by which rare coarse grains can skim over a bed of much finer grains at relatively high speed. As opposed to slope-driven mobility reversal, overpassing appears to require a significant difference in size between the overriding coarse grains and the fine grains below.

Transitions similar to gravel-sand transitions have been modeled in the laboratory using density difference as a surrogate for size difference. In the experiments of Fujita et al. (1998) and Paola et al. (2001) the transition was produced in an aggrading model river containing (heavy) sand and (light) crushed coal.

3.12.3 The Role of Tectonics and Base Level Variation

There are two ways to approach the phenomenon of downstream fining. Either one can take the initial long profile of the river as given and calculate downsteam change in grain size over it, or one may attempt to explain the shape of the long profile as well as the pattern of sorting.

The role of tectonics becomes important in the second case. The upward concave profile of a river is often set up as it flows from a zone of uplifting terrain to a zone of subsiding terrain. Indeed, rivers are attracted to zones of tectonic subsidence, as evidenced by the position of such major rivers as the Po and the Ganges. As a river migrates and avulses over the surface of such a zone, the accommodation space created by subsidence is gradually filled with sediment. While the process occurs over geomorphic rather than engineering time, engineering activities such as the disposal of mine waste in rivers can interrupt this slow, quasi-equilibrium process, and create major sedimentation problems. An inability to understand how a river establishes its long profile leads to an inability to predict the response of a river to such activities.

Not all rivers flow through depositional basins. Many of the streams on the west side of the northern Coast Range of California, such as the Mad River shown in Figure 3.14, are locked into place along synclines in an otherwise rapidly uplifting terrain. As a result, these streams show much less upward concavity in their profiles than rivers that flow into subsiding zones before reaching the sea. Before the advent of gravel mining, many of these rivers delivered gravel directly to the sea, with no gravel-sand transition. This balance, however, has been greatly altered by gravel mining.

Base level change can have a role analogous to tectonics. In particular, the 120 m rise in eustatic sea level since the end of the last glaciation has created accommodation space for the storage of sediment within the coastal plain and estuaries. Fujita et al. (1998) associate sea level rise with an upstream migration of gravel-sand transitions in Japan. Paola (2000) provides a comprehensive summary of numerical models of basin stratigraphy which include the effects of tectonics and base level variation.

3.12.4 Numerical Models of Downstream Fining

Abrasion, subsidence and delta progradation can all play a role in setting up the interaction between the long profile of the river and the heterogeneous bed sediment to produce downstream fining. In a numerical model, delta progradation can be handled with a migrating downstream boundary condition (e.g. Swenson et al., 2000; Kostic and Parker, 2003). Abrasion and subsidence (or uplift), however, must be incorporated directly into the Exner equation of sediment continuity.

The subsidence rate σ_{sub} may be as high as a few mm per year depending upon setting. Negative subsidence corresponds to uplift. For the purpose of most engineering models σ_{sub} can be taken as constant in time, but may vary in space. In order to account for subsidence, the Exner equation of sediment continuity, Eq. (3.33) must be modified to the form

$$(1-\lambda_p)\left[f_{Ii}\left(\frac{\partial \eta_b}{\partial t}+\sigma_{sub}\right)+\frac{\partial}{\partial t}(L_a F_i)\right]=-\frac{\partial q_i}{\partial s}-A_i \tag{3.116}$$

It is easily shown that a constant speed of subsidence drives an upward-concave long profile in the same way as an aggradational profile driven by a downstream dam the height of which is raised at a constant speed. That is, subsidence can set up conditions for downstream fining.

Rana et al. (1973) provide the first hint of a mechanistic formulation of downstream fining. The first full numerical model of downstream fining in a river was developed by Deigaard (1980) in the context of an engineering project on the sand-bed Niger River, Africa. This pioneering work was nevertheless rather primitive in nature, in that no hiding effects were included in the sediment transport relation. Paola et al. (1992a) developed a simple two-grain model of downstream fining as rivers fill subsiding depositional basins. One grain size is in the gravel range and the other is in the sand range. They used the Meyer-Peter and Müller (1948) transport equation and a constraint on bank-full Shields number in rivers to reduce the Exner equation to diffusional form with the subsidence term acting as a sink. Both gravel and sand deposit out to balance subsidence, but the gravel does so at a higher rate. The gravel-sand transition occurs when the river runs out of gravel to carry. Paola and Seal (1995) developed a model capable of handling a full grain size distribution and applied it to the deposit on the North Fork Toutle River, Washington, USA shown in Figure 3.6. They showed that the morphologic complexity associated with local patches of sorted sediment acts to increase the rate of downstream fining, as described in Section 3.7.16.

Parker (1991a,b) developed a numerical model, ACRONYM3, for the study of the effects of both aggradation and abrasion on downstream fining. Profile concavity was driven by the assumption of a wave-like progradational profile of constant form. The model was further developed along with ACRONYM4 for the purpose of predicting the response of the gravel-bed Ok Tedi, Papua New Guinea, to sediment supplied from a mine (Cui and Parker, 1999). Cui et al. (1996) and Cui and Parker (1997) tested the model against the downstream fining experiments of Seal et al. (1997). Parker and Cui (1998) and Cui and Parker (1998) went on to develop a numerical model of downstream fining in rivers with gravel-sand transitions the locations of which are stabilized by subsidence. In the case of bimodal sediments with a gap in the pea gravel range, they identified three ways to drive a transition: a) the gravel runs out due to deposition upstream; b) the gravel is ground out by abrasion; and c) sand moving as throughput load eventually deposits on the bed as slope drops off and overwhelms the gravel. The model of Cui and Parker (1998) treats the throughput load of sand by filling the pores of the gravel to a prescribed porosity as it aggrades, and passing the rest of the sand down to the gravel-sand transition.

Hoey and Ferguson (1994, 1997) developed a numerical model of downstream fining in the Allt Dubhaig, a stream in which neither abrasion nor subsidence appear to be playing a role. Rather, the fining is set up by the progradation of the river into a lake. In such cases the gravel-sand transition cannot stabilize; as long as there is gravel and sand supplied to the river the transition must migrate downstream. The sediment supply is low in the case of the Allt Dubhaig, so that the transition migrates only slowly.

Robinson and Slingerland (1998) developed a numerical model for downstream fining in the case of bimodal sand-gravel mixtures. They applied it to the prediction of grain-size trends in a depositional foreland basin. The model is a descendant of MIDAS (van Niekerk et al., 1992).

3.13 MORPHODYNAMICS OF LOCAL PLANFORM SORTING

3.13.1 2D Bed-load Transport of Sediment Mixtures

Local sorting of bed-load sediment is often dominated by 2D effects, and thus must be described in terms of 2D formulations of bed-load transport of sediment mixtures. Such 2D relations have been presented for the case of uniform sediment with size D in Chapter 2. Generalizations to mixtures are presented below.

Let

$$\vec{q}_i = (q_{i,s}, q_{i,n}), \quad \vec{\tau}_{bs} = (\tau_{bs,s}, \tau_{bs,n}) \tag{3.117a,b}$$

denote the 2D vectors of volume bed-load transport per unit width in the ith grain size range and boundary shear stress due to skin friction, respectively. Parker and Andrews (1985) have generalized the linearized Ikeda-Parker formulation (Parker, 1984) of Chapter 2 to the form

$$\vec{q}_i = |\vec{q}_i| \left[\frac{\vec{\tau}_b}{|\vec{\tau}_b|} - \beta \left(\frac{\tau^*_{s,mag,i}}{\tau^*_{sci}} \right)^{-n_t} \vec{\nabla}\eta \right] \tag{3.118}$$

where $\vec{\nabla}\eta$ denotes the 2D vectorial gradient of bed elevation in the (s, n) directions,

$$\tau^*_{s,mag,i} = \frac{|\vec{\tau}_{bs}|}{\rho R g D_i}, \quad \beta = \frac{1 + r\mu_d}{\mu_d}, \quad n_t = \frac{1}{2} \tag{3.119a,b,c}$$

and values for μ_d and r are given as Eqs. (2.112c,d) in Chapter 2. In addition, the parameters τ^*_{sci} are computed from the modified Egiazaroff hiding relation in the form of Eq. (3.73a). Under the condition $q_{i,n}/q_{i,s} << 1$ Eq. (3.118) further linearizes to the form

$$|\vec{q}_i| = q_{i,s}$$

$$q_{i,n} = q_{i,s}\left[\frac{\tau_{bs,n}}{\tau_{bs,s}} - \beta\left(\frac{\tau_{si}^*}{\tau_{sci}^*}\right)^{-n_t}\right]\frac{\partial\eta}{\partial n} \qquad (3.120a,b,c)$$

$$\tau_{si}^* = \frac{\tau_{bs}}{\rho RgD_i}$$

Parker and Andrews (1985) evaluated the streamwise bed-load transport rates q_{si} in Eq. (3.120) using a generalization to mixtures of the Parker (1979) bed-load transport relation, also using the modified Egiazaroff hiding relation of Eq. (3.73a).

Recently Hasegawa et al. (2000) have similarly modified the 2D nonlinear bed-load transport relation of Kovacs and Parker (1994) to a 2D form for sediment mixtures. The linearized form of the relation is identical to Eq. (3.120) but

$$\beta = \sqrt{2} \qquad (3.121)$$

and $q_{i,s}$ is evaluated using the formulation of Ashida and Michiue (1972). Other relations for the 2D transport of bed-load mixtures can be found in Yamasaka et al. (1987) and Olesen (1987).

3.13.2 Manifestations of Local Planform Sorting

As noted in Section 3.1, rivers may also sort sediment from bend to bend and from dune to dune. These local sorting processes are only discussed briefly here; the interested reader may refer to the references quoted.

The flow in river bends drives a characteristic pattern of sorting, with coarser material at the outside of the bend, and on the upstream side of the point bar on the inside of the bend. This pattern can be seen in Figure 3.4. Bridge and Jarvis (1976) document bend sorting in the River South Esk, Scotland. Dietrich and Smith (1984) and Dietrich and Whiting (1989) document patterns of flow, topography, sediment transport and sediment sorting in a reach of the meandering Muddy Creek, Wyoming, USA. The latter study provides a complete set of data for testing numerical models.

The flow in river bends sets up a topography with strong transverse slopes. As bed-load is transported downstream across such slopes, the coarser grains tend to preferentially move down the transverse slope. This process is one of several that play a fundamental role in driving sorting in bends.

In order to treat sediment transport and sorting in bends it is necessary to generalize Eq. (3.23) to the 2D form

$$(1-\lambda_p)\left[f_{Ii}\frac{\partial\eta_b}{\partial t}+\frac{\partial}{\partial t}(L_a F_i)\right]=-\frac{\partial q_{i,s}}{\partial s}-\frac{\partial q_{i,n}}{\partial n} \tag{3.122}$$

The form of Eq. (3.122) in conjunction with a 2D bed-load transport formulation of the form of Eq. (3.120b) allow for an intricate interplay between the depth-averaged flow in the s and n directions, the secondary flow set up by the bend and sorting of bed-load grains through the bend. Analytical and numerical models of bend sorting using the above formulation have been presented by Ikeda et al. (1987), Ikeda (1989), and Seminara et al. (1997) for the case of a bend of constant curvature; Parker and Andrews (1985) and Ashida et al. (1991) studied sorting in a meandering channel.

Rivers that are constrained from meandering or braiding by artificial, inerodible banks often develop a pattern of alternate bars instead. Lisle et al. (1997) have performed an experimental study of alternate bars in a steep channel containing heterogeneous sediment. Lanzoni and Tubino (1999) have developed a stability model of alternate bars in rivers that not only predicts realistic sorting pattern, with coarser grains accumulating toward the bar crests, but also demonstrates that the grain size distribution damps the growth of bar amplitude and reduces bar wavelength as well. A sorting model of the type of Eqs. (3.120b) and (3.122) is used to perform the analysis. Ashworth et al. (1991) describe sorting processes in braided streams. Predictive models for this case seem to be lacking.

Bed-load sheets are low sorting bedforms, the characteristics of which are shown in Figure 3.3. They have been observed in the laboratory by Iseya and Ikeda (1987) and Kuhnle and Southard (1988) and in the field by Whiting et al. (1988). It has been argued that bed-load sheets are simply immature dunes. This may be true of some bed-load sheets, but Seminara et al. (1996) have used stability analysis to delineate a nearly pure sorting wave that can propagate without evolving into a dune. The basis for the analysis is the Exner equation of sediment continuity, Eq. (3.23), the Parker (1990a) surface-based bed-load transport relation and a simplified k-ε turbulence closure for the flow field. The handling of the exchange fractions f_{Ii}, however, proves difficult in a stability analysis due to the discontinuity in treatment between aggradation and degradation inherent in Eqs. (3.31) and (3.32). This points out the need for an improved Exner relation for sediment conservation that does not have this feature. Progress toward such a model is discussed in Section 3.15. Tsujimoto (1991, 1999) has approached the same problem from the point of view of bed-load entrainment rather than bed-load transport.

Figure 3.52 Side view of step-pool topography formed in the laboratory. Image courtesy K. Hasegawa.

Seminara (1998) provides an excellent summary of the application of stability analysis to river morphodynamics, including sediment mixtures in general and bed-load sheets in particular.

Tsujimoto (1991, 1999) and Colombini and Parker (1995) have developed stability theories to explain the longitudinal gravel-sand streaks of Figure 3.8. Colombini and Parker (1995) found that at least some variation in grain size is necessary to trigger the instability. The basis for their analysis is a) the Exner equation of sediment continuity (3.23), b) the Parker (1990a) formulation for bed-load transport and c) the Speziale (1987) turbulence closure for the flow. Tsujimoto posed the problem of longitudinal streaks in terms of bed-load entrainment rather than transport.

Whittaker and Jaeggi (1982) and Ashida et al. (1984) have explained the step-pool topography in steep streams shown in Figure 3.5 in terms of antidunes. The boulders tend to collect at the crest of antidunes during rare floods, and then stabilize into resistant steps as they are reworked by declining flows. Grant et al. (1990) suggest that these floods may have a recurrence interval on the order of 50 years. Removal of the boulders can lead to wholesale destabilization of the channel (Ikeda, 2001). Tatsuzawa et al. (1999a, 1999b) have performed parallel laboratory and field studies to illustrate the grain sorting processes that give rise to and maintain step-pool bedforms. An example of one of their laboratory step-pool morphologies is given in Figure 3.52.

Lisle et al. (1997) describe the fate of sudden sediment pulses in streams such as the landslide shown in Figure 3.12. Sutherland et al. (2002), Cui et al. (2003a, 2003b) and Cui and Parker (in press) describe a numerical model of the disposition of pulses in rivers that includes both selective transport and abrasion. The basis of the model is Eq. (3.33) for sediment conservation (but modified for multiple lithologies), the St. Venant equations and the Parker (1990a) formulation of bed-load transport. The model was tested in the laboratory and applied successfully to the landslide of Figure 3.12 (Lisle et al, 1997; Lisle et al., 2001; Cui and Parker, in press).

3.14 THE CASE OF SUSPENSION-DOMINATED SAND-BED RIVERS

3.14.1 Sorting in Suspension-Dominated Streams

As was shown in Section 3.4, sand-bed streams tend to a) be suspension-dominated and b) contain sediment that is much more uniform than gravel-bed streams. This rule is not universal. Muddy Creek (Dietrich and Whiting, 1989), for example, is an example of a small, relatively steep sand-bed stream in which bed-load and suspended load are both important. This observation notwithstanding, the larger the bank-full discharge and the lower the slope, the more likely a sand-bed stream is to be suspension-dominated.

Even though the bulk of the bed material load might be carried in suspension, one must not dismiss out of hand the possibility that the bed-load might do most of the sorting in such streams. To this end, consider as an example the bed-load equation of Ashida and Michiue (1972), Eq. (3.77a). As the Shields number becomes large compared to the critical Shields number, the relation reduces to

$$\frac{q_i}{F_i\sqrt{RgD_i}D_i} = 17\left(\frac{\tau_{bs}}{\rho RgD_i}\right)^{3/2} \tag{3.123a}$$

or reducing with Eq. (3.47),

$$\frac{q_i}{F_i} = \frac{17}{Rg}u_{*s}^3 \tag{3.123b}$$

That is, q_i/F_i becomes independent of grain size. This result and Eq. (3.28) allow the conclusion that at Shields numbers sufficiently high to allow the neglect of the critical Shields numbers τ_{sci}^* in Eq. (3.77a) the bed-load size distribution becomes identical with that of the active layer, implying surface-based equal mobility and the absence of sorting.

The same result holds for the relations of Parker (1990a), Hunziker and Jaeggi (2002), Wilcock and Kenworthy (2002) and Powell et al. (2001) presented in Section 3.7. This is because in all these relations, for large values τ_i^* a) q_i^* varies with $(\tau_i^*)^{3/2}$ and b) the critical or reference Shields number containing the hiding function drops out. The near-absence of armoring in the Nahal Yatir at Shields numbers based on surface D_{50} between 0.1 and 0.3, as illustrated in Section 3.10.3, argues for the validity of this conclusion. In sand-bed streams of the type shown in Figure 3.29 the bank-full Shields number is on the order of 50 times the critical or reference value, with an average of 1.86. Even the assumption that as much as half of this is form drag does not change the conclusion that sorting due to bed-load should be rather minor in suspension-dominated sandbed streams. Some bed-load sorting may be caused topographically in accordance with Eq. (3.20b), however.

Before continuing with the issue of sediment sorting in suspension-dominated sand-bed streams, however, it is important to note that there is a class of streams which are bed-load-dominated but have beds with significant quantities of both sand and gravel and have median grain sizes falling in the ranges of coarse sand to fine gravel. These streams are seen in Figure 3.30 as the Japanese streams which fall in between the sand-bed and gravel-bed clusters of Figure 3.29. Kleinhans (2002) has described reaches of the Rhine, Allier and Meuse Rivers of Europe which fall into this range (see Figure 2.1 therein, which has the same format as Figures 3.30 and 3.31 here). Blom and Kleinhans (1999) and Kleinhans (2002) have modeled them experimentally, as have Wilcock et al. (2001). It is evident from Figure 3.2 that bedforms such as dunes play a major role in vertical sorting in such streams. The relations proposed by Wilcock and Kenworthy (2002) described in Section 3.7.9, Wilcock and Crowe (2003) described in Section 3.7.10 and Kleinhans and van Rijn (2002) mentioned in Section 3.7.14 may be used to predict grain size-specific bed-load transport in this type of river.

Sorting of suspended sediment arises from a rather different mechanism than that applying to bed-load. In turbulent suspensions of sediment, the finer particles tend to ride higher in the water column. This biases them toward a zone of higher velocity, and amplifies their downstream transport rate at the expense of the coarser grains. For the same reason finer particles are more likely to be carried overbank and deposited on the floodplain.

3.14.2 Modified Rouse-Vanoni Approach for Grain Size-Specific Suspended Load

The analysis of Chapter 2 is here modified for multiple grain sizes. The overbars below denote averages over turbulence. Let $\overline{c}_i(s, z, t)$ denote the volume concentration of suspended sediment of the *ith* grain size class at streamwise position s, normal distance above the bed z and time t. The grain size ranges are chosen so as to exclude wash load, which is conventionally (but not necessarily accurately) equated with the sediment in transport in the silt and clay sizes (< 0.0625 mm). The total concentration of bed material load in suspension is thus given as

$$\overline{c}_T = \sum_{i=1}^{n} \overline{c}_i \tag{3.124}$$

Eq. (3.23) is generalized to

$$(1-\lambda_p)\left[f_{Ii}\frac{\partial\eta_b}{\partial t} + \frac{\partial}{\partial t}(L_a F_i)\right] = -\frac{\partial q_i}{\partial s} + v_{si}\left(\overline{c}_{bi} - E_{si}^*\right) \tag{3.125}$$

where

$$\overline{c}_{bi} = \overline{c}_i\big|_{z=z_b} \tag{3.126}$$

denotes a near-bed reference concentration at elevation $z = z_b$ and v_{si} denotes the fall velocity of the *ith* grain size. In addition, E_{si}^* denotes a dimensionless rate of entrainment of sediment from the bed such that $E_{si} = v_{si}E_{si}^*$ is the volume rate of entrainment of sediment from the *ith* grain size range per unit time per unit bed area, and $v_{si}\bar{c}_{bi}$ denotes the deposition rate of the *ith* class per unit time per unit bed area.

In the case of an equilibrium suspension, entrainment into suspension balances deposition from it, so that

$$E_{si}^* = \bar{c}_{bi} \tag{3.127}$$

In general, however, $\bar{c}_i$ must satisfy the advection-diffusion equation of conservation of suspended sediment. This is presented below in 2-D form in the *s-z* plane with *z* denoting the upward normal direction and the parameter D_d denoting the kinematic eddy diffusivity of suspended sediment, here approximated by the corresponding value for momentum;

$$\frac{\partial \bar{c}_i}{\partial t} + \bar{u}\frac{\partial \bar{c}_i}{\partial s} + (\bar{w} - v_{si})\frac{\partial \bar{c}_i}{\partial z} = \frac{\partial}{\partial z}D_d\frac{\partial \bar{c}_i}{\partial z} \tag{3.128}$$

This equation is in turn coupled to the equations of streamwise momentum balance and continuity of the flow;

$$\frac{\partial \bar{u}}{\partial t} + \bar{u}\frac{\partial \bar{u}}{\partial s} + \bar{w}\frac{\partial \bar{u}}{\partial z} = -g\frac{\partial H}{\partial s} - g\frac{\partial \eta}{\partial s} + \frac{\partial}{\partial z}D_d\frac{\partial \bar{u}}{\partial z} \tag{3.129}$$

$$\frac{\partial \bar{u}}{\partial s} + \frac{\partial \bar{w}}{\partial z} = 0 \tag{3.130}$$

In Eqs. (3.128) and (3.129) the slender flow approximation has been used to a) drop the streamwise turbulent diffusion terms, b) drop the upward normal equation of momentum balance and c) approximate the pressure distribution as hydrostatic. The above three relations easily generalize to 3-D flow.

The boundary conditions on Eq. (3.128) are

$$-D_d\left.\frac{\partial \bar{c}_i}{\partial z}\right|_{z_b} = v_{si}E_{si}^*\,, \quad \left.\left(v_{si}\bar{c}_i + D_d\frac{\partial \bar{c}_i}{\partial z}\right)\right|_{z=H} = 0 \tag{3.131a,b}$$

where E_{si}^* is a specified function of the flow. The first of these specifies the near-bed rate of entrainment of sediment into suspension, and the second of these specifies the condition of vanishing upward normal sediment flux at the water surface. Eq. (3.131a) is sometimes replaced with a concentration boundary condition, according to which

$$\bar{c}_{bi} = \bar{c}_i\big|_{z=z_b} = \bar{c}_{bed,i} \tag{3.131c}$$

where $\bar{c}_{bed,i}$ is a specified function of the flow. In the case of equilibrium suspensions Eqs. (3.131a) and (3.131c) yield identical results in light of Eq. (3.127). In the case of disequilibrium suspensions Eq. (3.131a) is the preferred form, as outlined in e.g. Parker (1978a). The boundary conditions on the flow are

$$\frac{\bar{u}\big|_{z_b}}{u_*} = \frac{1}{\kappa} ln\left(30\frac{z_b}{k_s}\right), \quad D_d\frac{\partial\bar{u}}{\partial z}\bigg|_H = 0, \quad \bar{w}\big|_{z_b} = 0, \quad \left(\frac{\partial\bar{u}}{\partial t} + \bar{u}\frac{\partial\bar{u}}{\partial s} - \bar{w}\right)\bigg|_H = 0$$
(3.132a-d)

i.e. that the streamwise flow velocity matches the logarithmic law near the bed, the water surface is free of shear stress, the normal velocity vanishes at the bed and the kinematic boundary condition is satisfied at the water surface. In Eq. (3.132a) κ denotes the von Karman constant and k_s is the roughness height of the bed.

As described in Chapter 2, density stratification effects induced by suspended sediment can interact with the flow. The net effect is to increase the flow velocity and reduce the concentrations of suspended sediment. Wright and Parker (2004a,b) have shown that this effect is particularly important in large, low-slope sand-bed rivers.

Extending the model of Smith and McLean (1977) outlined in Chapter 2 to sediment mixtures, the turbulent eddy viscosity D_d is damped by a stratification effect mediated by the gradient Richardson number RI_g;

$$D_d = D_{do}F_{strat}\left(RI_g\right), \quad RI_g = \frac{-Rg\dfrac{\partial\bar{c}_T}{\partial z}}{\left(\dfrac{\partial\bar{u}}{\partial z}\right)^2} \tag{3.133a,b}$$

In the above relation $F_{strat}(RI_g)$ is a specified function of the gradient Richardson number that Smith and McLean (1977) equate to

$$F_{strat}\left(RI_g\right) = 1 - 4.7RI_g \tag{3.133c}$$

Note that according to Eq. (3.133c) the turbulence should be completely damped out for a gradient Richardson number of 0.21, a value that is fully in accord with the more advanced turbulence closure scheme of Mellor and Yamada (1974).

The above Eqs. (3.128) –(3.130) can be solved subject to Eq. (3.131a) or Eq. (3.131c), Eq. (3.131b), Eqs. (3.132), the above simple turbulence closure model and appropriate initial conditions to yield solutions for $\bar{c}_i(s,z,t)$ and $\bar{u}(s,z,t)$. The depth-averaged flow velocity U and concentrations C_i and the bed material part of the volume suspended load per unit width per unit time q_{si} are then computed as

$$UH = \int_{z_b}^{H} \bar{u}dz\,, \quad q_{si} = UC_iH = \int_{z_b}^{H} \overline{uc_i}dz \qquad (3.134a,b)$$

Eq. (3.128) can be depth-integrated subject to Eqs. (3.131a,b), yielding the relation

$$\frac{\partial C_i H}{\partial t} + \frac{\partial q_{si}}{\partial s} = v_{si}\left(\bar{c}_{bi} - E_{si}^*\right) \qquad (3.135)$$

As long as the time rate of change of the volume of suspended sediment stored in the water column per unit bed area is small (as can be expected for nearly all fluvial suspensions), the first term on the left-hand side of Eq. (3.135) can be dropped, so that Eq. (3.125) reduces to

$$(1-\lambda_p)\left[f_{Ii}\frac{\partial \eta_b}{\partial t} + \frac{\partial}{\partial t}(L_aF_i)\right] = -\frac{\partial q_i}{\partial s} - \frac{\partial q_{si}}{\partial s} = -\frac{\partial q_{bmi}}{\partial s} \qquad (3.136)$$

where q_{bmi} denotes the volume bed material load (bed-load + bed material suspended load) transport rate per unit time per unit width.

Let U_{ch}, H_{ch} and v_{sch} denote characteristic values for flow velocity, flow depth and sediment fall velocity. The parameter $(U_{ch}/v_{sch})H_{ch}$ defines an appropriate relaxation length for streamwise adjustment of the suspended sediment profile. When the length scale of interest for sorting due to suspension is smaller than this relaxation length the full 2D (or 3D) problem for the flow and suspended sediment profiles must be solved in order to determine the evolution of the bed elevation and sorting in accordance with Eq. (3.125). An example of this is the sorting of sediment over one bend or meander length of a suspension-dominated stream, in which case Eq. (3.125) must be amended to the 2D form

$$(1-\lambda_p)\left[f_{Ii}\frac{\partial \eta_b}{\partial t} + \frac{\partial}{\partial t}(L_aF_i)\right] = -\frac{\partial q_{s,i}}{\partial s} - \frac{\partial q_{n,i}}{\partial n} + v_{si}\left(\bar{c}_{bi} - E_{si}^*\right) \qquad (3.137)$$

in order to include transverse effects. In the above relation $(q_{s,i}, q_{n,i})$ denotes the volume bed-load transport rate per unit width in the (s, n) directions.

When the length scale of interest is, on the other hand, sufficiently long compared to the relaxation length it suffices to obtain q_{si} from a quasi-equilibrium solution for suspension and flow and allow the bed to evolve and sort according to, e.g. in the case of a 1D formulation, Eq. (3.136). An example of such a problem is downstream fining in suspension-dominated sand-bed streams.

The case of an equilibrium or quasi-equilibrium suspension is considered below. As in Chapter 2, for simplicity the turbulent eddy diffusivity in the absence of stratification D_{do} is chosen to be the one that yields the logarithmic profile;

$$D_{do} = \kappa u_* z\left(1-\frac{z}{H}\right) \tag{3.138}$$

For this case Eqs. (3.128) – (3.132) can be solved to yield

$$\bar{c}_i = E_{si}^* \exp\int_{z_b}^{z}\left[-\frac{v_{si}}{\kappa u_* z\left(1-\frac{z}{H}\right)F_{strat}\left(RI_g\right)}dz\right] \tag{3.139a}$$

and

$$\bar{u} = \frac{u_*}{k}\left[ln\left(30\frac{z_b}{k_s}\right)+\int_{z_b}^{z}\frac{1}{zF_{strat}\left(RI_g\right)}dz\right] \tag{3.139b}$$

The above two equations do not in and of themselves constitute a solution to the problem, because RI_g is a function of the concentration gradient $\partial\bar{c}_T/\partial z$ as specified by Eq. (3.133b). They can, however, be readily enough solved iteratively, starting with the Rouse-Vanoni concentration profile (Rouse, 1939) and logarithmic velocity profile that would prevail in the absence of stratification. These are obtained by setting F_{strat} equal to unity in Eqs. (3.139a,b), yielding the respective forms

$$\bar{c}_i = E_{si}^*\left[\frac{\left(1-\frac{z}{H}\right)}{\left(1-\frac{z_b}{H}\right)}\right]^{\frac{v_{si}}{\kappa u_*}} \qquad \bar{u} = \frac{u_*}{\kappa}ln\left(30\frac{z}{k_s}\right) \tag{3.140a,b}$$

Once the solutions for $\bar{c}_i$ and $\bar{u}$ are obtained the grain size-specific transport rates q_{si} are evaluated as

$$q_{si} = \int_{z_b}^{H}\bar{u}\bar{c}_i dz \tag{3.141}$$

and bed evolution and sorting can be evaluated from Eq. (3.136).

3.14.3 Grain Size-Specific Relations for Sediment Entrainment or Near-bed Concentration

Few relations specifically designed for predicting the entrainment (bed concentration) of heterogeneous suspended sediment appear to be available. One of these is due to Garcia and Parker (1991). Along the lines of Section 3, the following general form is assumed;

$$\frac{E_{si}^*}{F_i} \equiv \hat{E}_{si} = T_{se}\left(\frac{u_{*s}}{v_{si}}, \frac{D_i}{D_{50}}, Re_{pi}, \sigma\right), \quad Re_{pi} = \frac{\sqrt{RgD_i}D_i}{\nu} \qquad (3.142a,b)$$

Garcia and Parker (1991) used a similarity collapse of laboratory data, as well as field data from two small sand-bed streams, to obtain the following entrainment relation;

$$\hat{E}_{si} = \frac{AZ_{ui}^5}{1+\frac{A}{0.3}Z_{ui}^5} \quad , \quad Z_{ui} = \lambda_m \frac{u_{*s}}{v_{si}} Re_{pi}^{0.6}\left(\frac{D_i}{D_{50}}\right)^{0.2} \qquad (3.143a\text{-}d)$$
$$\lambda_m = 1 - 0.298\sigma \quad , \quad A = 1.3x10^{-7}$$

Recently Wright and Parker (2004b) found that the above relationship, while reasonably accurate for small to medium sand-bed streams, overpredicts the entrainment rate for large sand-bed streams. They have modified the relation as follows; $\hat{E}_{si}$ is still given Eq. (3.143a), but Z_{ui} is now given by the relation

$$Z_{ui} = \lambda_m\left(\frac{u_{*s}}{v_{si}} Re_{pi}^{0.6}\right) S^{0.08}\left(\frac{D_i}{D_{50}}\right)^{0.02} \qquad (3.143e)$$

where

$$A = 7.8x10^{-7} \qquad (3.143f)$$

and S denotes bed slope. In Eq. (3.143e), λ_m is still given by Eq. (3.143c).

In either the original or amended Garcia-Parker relations the value z_b at which the entrainment rate is evaluated is specified as

$$z_b = 0.05H \qquad (3.143g)$$

This value was chosen because data were available at this elevation with which to develop the relation. Once the concentration profile is determined it can be extrapolated downward to find values closer to the bed.

McLean (1991, 1992) formulates the problem in terms of the concentration boundary condition of the form of Eq. (3.131c) rather than the entrainment boundary condition of Eq. (3.131a). McLean presents the following relation for near-bed concentration. Let $\overline{c}_{bT}$ denote the total near-bed concentration summed over all grain sizes. Recalling that f_{bi} denotes the fractions in the bed-load, the computation for the near-bed concentrations $\overline{c}_{bi}$ proceeds as follows:

$$\overline{c}_{bi} = f_{sbi}\overline{c}_{bT} \tag{3.144a}$$

where $\overline{c}_{bT}$ denotes the total near-bed concentration summed over all grain sizes, f_{sbi} denotes the fraction of the near-bed suspended sediment in the ith grain size range and

$$\overline{c}_{bT} = \frac{\gamma_o\left(\dfrac{\tau_{bs}}{\tau_{bsc}}-1\right)}{1+\gamma_o\left(\dfrac{\tau_{bs}}{\tau_{bsc}}-1\right)}(1-\lambda_p) \quad , \quad \gamma_o = 0.004$$

$$f_{sbi} = \frac{\varphi_i f_{bi}}{\sum_{i=1}^{n}\varphi_i f_{bi}} \quad , \quad \varphi_i = \begin{cases} 1 & for \quad u_{*s}/v_{si} > 1 \\ \dfrac{u_{*s}-u_{*sc}}{v_i - u_{*sc}} & for \quad u_{*s}/v_{si} < 1 \end{cases} \tag{3.144b-g}$$

$$u_{*s} = \sqrt{\frac{\tau_{bs}}{\rho}} \quad , \quad u_{*sc} = \sqrt{\frac{\tau_{bsc}}{\rho}}$$

The McLean relation uses a single critical shear stress τ_{bsc} evaluated using size D_{50}; this value is applied to all grain sizes. The relation for the point z_b at which the near-bed concentrations are evaluated is

$$z_b = max\begin{pmatrix} a_D D_{84} \\ a_o\delta_B(D_{84}) \end{pmatrix} \quad , \quad \delta_B(D) = D\frac{A_1\left(\dfrac{\tau_{bs}}{\tau_{bsc}}-1\right)}{1+A_2\left(\dfrac{\tau_{bs}}{\tau_{bsc}}-1\right)} \tag{3.144h-i}$$

$$a_D = 0.12 \quad , \quad a_0 = 0.056 \quad , \quad A_1 = 0.68$$
$$A_2 = 0.0204(ln\,D)^2 + 0.022(ln\,D) + 0.0709 \tag{3.144j-m}$$

In the relation for A_2 the grain size must be in mm. The McLean formulation can also be used to specify the entrainment boundary condition, of Eq. (3.131a), in which case the functional form for E_{si}^* is simply taken to be

$$E_{si}^* = f_{sbi}\overline{c}_{bT} \tag{3.144n}$$

3.14.4 Grain Size-Specific Bulk Predictors for Bed Material Load

The relation of Ackers and White (1980) as generalized for mixtures by Proffitt and Sutherland (1983) has been presented in Section 3.7.13. In this form it predicts the transport rate and grain size distribution of the bed material load, i.e. bed-load and bed material component of suspended load. As a predictor of total bed material load in its original form, which is not grain size-specific, the relation of Ackers and White has been shown to perform quite well for both laboratory and field streams (Brownlie, 1981; see also Chapter 2). The grain size-specific dependency was, however, introduced with the aid of a hiding function developed for coarse material. It remains to be seen how well the relation sorts sand.

The bed material load predictor of Yang (1973) has been presented in Chapter 2. That formulation uses only a single grain size. As discussed in Section 3.7.14, Yang and Wan (1991) have extended this formulation for sediment mixtures. The accuracy of the predictions of total bed material transport rate summed over all sizes has been tested against data with excellent agreement. The accuracy of the predicted grain size distributions of the bed-load has not similarly been subjected to a thorough test.

The bulk predictor for bed material transport rate of Karim and Kennedy (1981) was presented in Chapter 2. Karim (1998) has generalized the formulation for sediment mixtures. The generalization appears to apply specifically to sand-bed streams. Karim's relation takes the form

$$\frac{q_{bmi}}{F'_{ai}\sqrt{RgD_i}\,D_i} = 0.00139\left(\frac{U}{\sqrt{RgD_i}}\right)^{2.97}\left(\frac{u_*}{v_{si}}\right)^{1.47}\eta_i$$

$$\eta_i = C_1\left(\frac{D_i}{D_{50}}\right)^{C_2}, \quad C_1 = 1.15\left(\frac{v_{s50}}{u_*}\right), \quad C_2 = 0.60\left(\frac{v_{s50}}{u_*}\right) \qquad (3.145a\text{-}d)$$

In the above relations F'_{ai} is computed from F_i as

$$F'_{ai} = \frac{(F_i / D_i)}{\sum_{i=1}^{n}(F_i / D_i)} \qquad (3.145e)$$

Karim (1998) reports good agreement between the predicted load and grain size distribution and the observed values in three sand-bed streams; the Niobrara River, the Middle Loup River and Missouri River. The above formulation may be used in conjunction with the resistance formulation of Karim and Kennedy (1981), which was developed in tandem with the original bulk predictor of total bed material load of that document.

In addition to the grain size-specific bulk predictor for bed-load transport presented in Section 3.7.10, Wu et al. (2000) also present the following grain size-specific bulk predictor for the bed material part of the suspended load;

$$W_{sui}^{*} = \frac{Rgq_{si}}{\bar{f}_i u_{*s}^{3}} = 0.0000262 \frac{1}{\left(\tau_{si}^{*}\right)^{3/2}} \left[\left(\frac{\tau_{si}^{*}}{\tau_{suri}^{*}} - 1 \right) \frac{U}{v_{si}} \right]^{1.74} \qquad (3.146)$$

The relation has the advantage of simplicity. Wu et al. report excellent agreement with data when Eqs. (3.85) and (3.146) are used to predict grain size-specific bed material load, i.e. $q_{bmi} = q_i + q_{si}$.

Recently Wright and Parker (2004b) have used Eqs. (3.143a,e,f,g), Eqs. (2.177-2.181) of Chapter 2 and a consideration of flow stratification to develop a grain size-specific predictor of suspended load in sand-bed rivers. While the method is intended to be of general applicability, the formulation is specifically intended to capture flow stratification effects that can be significant in large, low-slope sand-bed streams.

3.14.5 Downstream Fining in Sand-bed Streams

Downstream fining of bed sediment in a long reach of a large, low-slope sand-bed river is illustrated in Figure 3.53 for the Mississippi River between Cairo, Illinois and the Head of Passes, Louisiana, a reach nearly 1800 km long (Waterways Experiment Station, 1935, as quoted by Simons, 1971). Fig. 3.53a shows the streamwise variation of the complete grain size distribution and Fig. 3.53b shows the streamwise variation of the mean grain size of sand only. The former figure documents the pinch-out of the gravel, the coarse sand and then the medium sand as the bed fines. The latter figure documents a reduction in mean sand grain size from about 0.65 mm to under 0.20 mm over the reach.

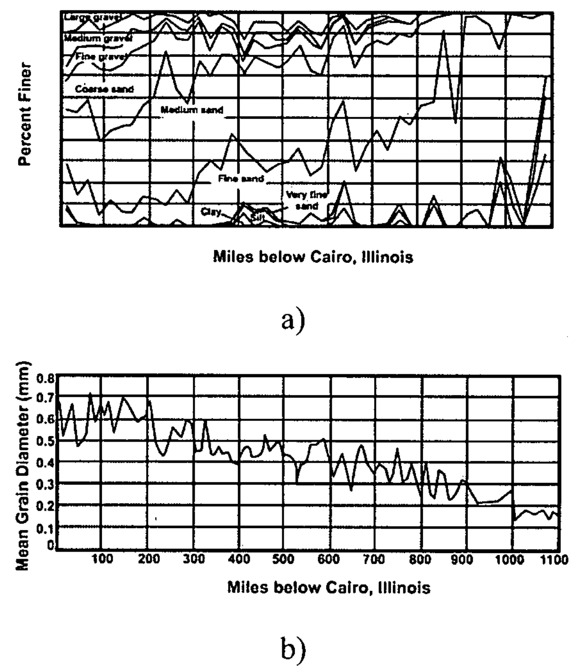


Figure 3.53 Downstream fining in the bed material of the Mississippi River, USA. a) Downstream variation in grain size distribution. b) Downstream variation in mean grain size.

Hydraulic sorting is only one cause of downstream fining. In the case of the Mississippi River, downstream fining may also be influcnece by the the delivery of successively finer sediment from tributaries farther downstream. In the case of the pattern of downstream fining in the middle Fly River, Papua New Guinea illustrated in Figure 3.54 (Pickup et al., 1979; Dietrich et al., 1999), however, the cause is unambiguously hydraulic sorting. This is because no important tributaries enter the Fly over the reach extending from 50 km to 450 km in Figure 3.54, so that the input of both water and sediment from tributaries is small. Hydraulic sorting also appears to be the dominant mechanism of downstream fining on the reach of the Beni River, Bolivia studied by Aalto (2002).

The pattern of downstream fining given in Figure 3.54 characterizes conditions before the advent of sediment disposal from the Ok Tedi copper mine in 1985. Since then both the sediment balance of the river and the pattern of downstream fining in the middle Fly River has been greatly modified, with median size reduced by about half and the intensity of downstream fining suppressed (Dietrich et al., 1999; Cui and Parker, 1999).

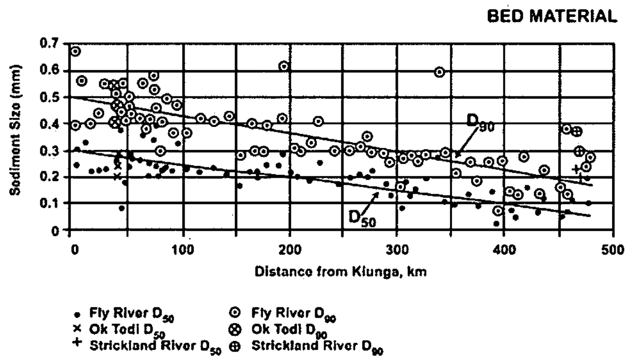


Figure 3.54 Downstream variation in D_{50} and D_{90} in the middle Fly River, Papua New Guinea in 1979, before the opening of the Ok Tedi copper mine in 1985.

The first attempt to numerically model downstream fining in any stream was the simple treatment of Deigaard (1980) applied to the sand-bed Niger River. Since that time the case of sand-bed streams has been neglected. Cui and Parker (1999), however, report on a model of downstream fining in the middle Fly River. The model uses water and sediment inputs specified on a daily basis, calculations of the flow based on a gradually-varied implementation of the St. Venant shallow water equation and a Rousean formulation neglecting stratification effects for q_{si}. Bed evolution is computed from an implementation of Eq. (3.136), with L_a scaling with dune height and with the addition of the subsidence term in Eq. (3.116). The model also includes a simple formulation for overbank deposition, as outlined in the next section.

Wright and Parker (2004a,b) have demonstrated that stratification effects are usually negligible in sand-bed streams with medium to steep slopes. In large, low-slope sand bed streams, however, stratification can be sufficient to a) substantially suppress the bed material suspended load, and b) substantially reorganize the size distribution of this load toward the finer. Stratification may thus play an important role in the pattern of downstream fining in such streams.

3.14.6 Grain Size-specific Formulations for Floodplain Deposition of Suspended Sediment

The ability of a river to access its floodplain during floods is illustrated in Figure 3.55. The study of overbank deposition of sediment due to floods has been until recently the province of geographers and geologists rather than engineers. A summary of recent literature on floodplain processes can be found in Anderson et al. (1996).

In recent years engineers have been drawn into the field of floodplain sedimentation in order to a) design river restoration projects, b) predict the deposition of anthropogenic sediment on floodplains and c) track the accumulation of toxic metals adsorbed onto the finest sediment grains as they deposit on the floodplain. Figure 3.56 illustrates a floodplain that has been heavily damaged by a flood which carried toxic sediments overbank in 1910.

Figure 3.55 View of the floodplain of the Minnesota River, Minnesota, USA during the flood of record in 1965.

The Exner equation of sediment continuity, Eq. (3.103) is here modified to the form

$$(1-\lambda_p)B_c\left(f_{Ii}\frac{\partial \eta_b}{\partial t}+L_a\frac{\partial F_i}{\partial t}\right)=-\frac{\partial B_c q_i}{\partial s}-\frac{\partial B_c q_{si}}{\partial s}-q_{obi} \qquad (3.147)$$

in order to include overbank deposition of sediment during floods. Here q_{obi} denotes the volume rate of overbank deposition of sediment in the *ith* grain size range per unit time per unit channel length, including both banks. (B_c in the above equation is modified to B_{ca} only after zeroing of the model, as described in Section 3.10.2).

a) b)

Figure 3.56 a) View of a reach of Silver Bow Creek, Montana, USA in which the floodplain is so rich in toxic sediments that vegetation cannot take hold. The toxic sediment is derived from the Anaconda copper mine near Butte, Montana; the flood that deposited the sediment occurred in 1910. b) View of an uncontaminated, healthy tributary of Silver Bow Creek.

Narinesingh (1995), Narinesingh et al. (1999) and Parker et al. (1996) have independently devised very similar models for the computation of the parameter q_{obi}, one in the context of river restoration in the Netherlands, and the other in the context of floodplain deposition of mine-derived sediment. The basis of both models is convective rather than diffusive. Consider the meandering river of Figure 3.57. The total floodplain or meander belt width over which floodplain deposition takes place is denoted as B_f; the value includes both sides of the river. Overbank flow is followed along a characteristic floodplain streamtube of length L_f from channel to channel. In the case of a vegetated floodplain, any sediment that deposits is unlikely to be resuspended. Let C_{fi} denote the depth-averaged volume concentration of sediment in the *ith* grain size range in the water column over the floodplain, and let H_f denote floodplain depth and U_f denote depth-averaged floodplain velocity. Where s_f denotes distance along the streamtube, then,

$$\frac{D}{Dt}\left(C_{fi}H_f\right)=U_f H_f\frac{dC_{fi}}{ds_f}=-v_{si}C_{fi} \qquad (3.148)$$

Integrating along the streamtube from channel to channel, the volume deposition rate of the of material in the *ith* grain size range per unit time per unit distance normal to the coordinate s_f is given as

$$v_{si}\int_0^{L_f} C_{fi}ds_f = v_{si}C_{ucfi}\frac{U_f H_f}{v_{si}}\left[1-exp\left(-\frac{v_{si}L_f}{U_f H_f}\right)\right]= \\ U_f H_f C_{ucfi}\left[1-exp\left(-\frac{v_{si}L_f}{U_f H_f}\right)\right] \qquad (3.149)$$

where C_{ucfi} denotes the concentration of sediment in the *ith* grain size range in the channel, averaged over that part of the channel flow that is above bank-full, i.e. over a layer with thickness H_f.

Now every such stream tube is of a different length, but one may reliably assume that L_f scales with B_f for most meandering streams. Assuming that the area of floodplain A_b delineated by a single bend scales as

$$A_{pb}\approx B_f L_f \approx B_f^2 \qquad (3.150)$$

and recalling that floodplain discharge Q_f is given by

$$Q_f = U_f B_f H_f \qquad (3.151)$$

the volume deposition rate per unit floodplain area per unit time D_{fpi} scales as

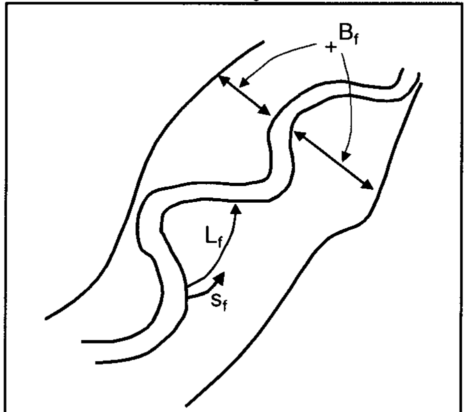


Figure 3.57 Diagram illustrating floodplain deposition.

$$D_{fpi} \approx \frac{C_{ucfi}Q_f}{B_f L_f}\left[1 - exp\left(-\frac{v_{si}L_f}{U_f H_f}\right)\right] \approx$$
$$\frac{C_{ucfi}Q_f}{B_f^2}\left[1 - exp\left(-\alpha_f \frac{v_{si}B_f^2}{Q_f}\right)\right] \equiv$$
$$Fl\frac{C_{ucfi}Q_f}{B_f^2}\left[1 - exp\left(-\alpha_f \frac{v_{si}B_f^2}{Q_f}\right)\right] \qquad (3.152)$$

where Fl is a dimensionless "floodplain number" and α_f is a dimensionless "attenuation coefficient," both of which might be expected to be of order unity. The parameter q_{obi} in Eq. (3.147) is thus given as

$$q_{obi} = D_{fpi}B_f = FlC_{ucfi}\frac{Q_f}{B_f}\left[1 - exp\left(-\alpha_f \frac{v_{si}B_f^2}{Q_f}\right)\right] \qquad (3.153)$$

The parameter C_{ucfi} can be computed from Eq. (3.132) as

$$C_{ucfi} = \frac{1}{H_f}\int_{H_{bf}}^{H_{bf}+H_f} \bar{c}_i dz = \frac{E_{si}}{H_f}\int_{H_{bf}}^{H_{bf}+H_f} exp\int_{z_b}^{z}\left[-\frac{v_{si}}{\kappa u_* z\left(1 - \frac{z'}{H}\right)F_{strat}\left(RI_g\right)}dz'\right]dz \qquad (3.154)$$

where H_b denotes bank-full depth. Eq. (3.146) can be coupled to a model of channel-floodplain flow such as that described in Section 3.10.2 in order to perform the calculation of floodplain deposition for each time step for which the channel is overbank. The parameters Fl and α_f must at this point be calibrated for every application. Cui and Parker (1999), however, were able to obtain reasonable results with the values 0.2 < Fl < 0.72 and $exp\left[-\alpha_f\left(v_{si}B_f^2\right)/Q_f\right] << 1$.

The above formulation of overbank deposition is both preliminary and incomplete. For example, it does not encompass splay deposits which provide a mechanism for bringing relatively coarse bed sediment onto the floodplain (e.g. Aalto, 2002).

3.14.7 Deposition of Fine Sediments in and Flushing from Gravels

As noted above, sand and silt often move through a gravel-bed river as throughput load during floods, with little interplay with the beds beyond partial filling of the interstices of newly-deposited gravels. When the concentrations of these "fines" are too high, or when the flow velocities are too low to prevent excess accumulation of within the gravel framework, the gravels can become polluted with fines. This fines pollution degrades the gravel bed as both spawning grounds and habitat for anadromous fish. The discharge of relatively sediment-free flushing flows, often from an upstream reservoir, can at least partially remove the fines and renew the gravel.

Reiser (1998) provides a summary of the ecological and biological requirements of gravel-bed rivers, with emphasis on the quality of the bed sediments. Diplas and Parker (1992) have described experimentally the process of pollution of gravel beds by fines; Huang and Garcia (2000) provide a predictive model of fines pollution. Milhous (1998) describes a numerical model for designing flushing flows in gravel-bed streams. Wilcock et al. (1996) describe how flushing can be implemented on the Trinity River, California, and Wilcock (1998b) provides general criteria for the design of flushing flows.

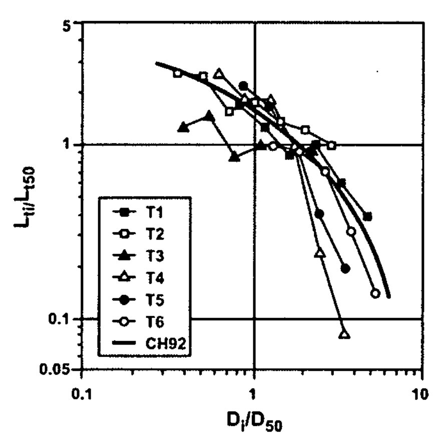


Figure 3.58 Relative travel distance of tracers in each size class as a function of relative grain size. From Ferguson and Wathen (1998).

3.15 TRACERS AND VERTICAL SORTING

3.15.1 Tracers

The use of tracer particles has a venerable history in the study of bed-load transport of mixed sizes in gravel-bed rivers (e.g. Leopold et al, 1966). In the early days of their use tracer particles were painted and placed on the bed of a stream during a dry period or at low flow. Recovery rates after a flood tended to be poor. More recently magnetically tagged particles have been used, much improving the recovery rates.

One way to characterize the relative mobility of grains of different sizes is to quantify the average distance L_{ti} moved by tracers in each size class during a single flood as a function of grain size. Hassan et al. (1992), for example, found that the L_{ti} tends to decrease only weakly with increasing grain size D_i for the finer sizes in a mix, but declines notably with increasing grain size for sufficiently coarse grains. This result has been confirmed by Wilcock (1997b) and Ferguson and Wathen (1998). Field data for L_{ti}/L_{t50} versus D_i/D_{50}, where L_{t50} denotes the average distance moved by tracers with the surface median size D_{50} are plotted in Figure 3.58. The data points are for the Allt Dubhaig (Ferguson and Wathen, 1998), and the solid line defines a relation determined by Church and Hassan (1992).

Tracers also provide an approximate method for characterizing the bed-load transport rate. The relation of Haschenburger and Church (1998) can be generalized to estimate the volume bed-load transport rate per unit width q_i for the *ith* grain size range as

$$q_i = (1-\lambda_p)v_{bi}L_aF_i \qquad (3.155)$$

where v_{bi} denotes the mean virtual velocity of the *ith* grain size and L_a denotes the thickness of the active layer over which the grains are mixed during a transport event. The mean virtual velocity v_{bi} is computed as the mean distance moved by tracers in the *ith* grain size range divided by the duration of the flood event during which they moved. It must be kept in mind that the value of q_i determined from Eq. (3.148) represents an average over one flood, as the tracers cannot usually be recovered until the flood has subsided.

An implemention of Eq. (3.155) requires a knowledge of the thickness of the active layer L_a. This thickness has been inferred from the probability distribution of depth of burial of tracers as well as direct measurements of bed level variation in terms of scour and fill over one flood (e.g. Schick et al., 1987; Hassan, 1990, Hassan and Church, 1994; Wilcock, 1997b; Haschenburger, 1999). Figure 3.59 illustrates the use of "Leopold chains" to monitor scour and fill during a flood. Hassan and Church (1994), for example, have found that for single-peak floods the probability distribution associated with the depth of burial tends to follow an exponential curve, the exponent of which varies somewhat with grain size. The study indicates that a single flood is often sufficient to bury at least some tracers to a depth of 5 D_{50} or more below the surface.

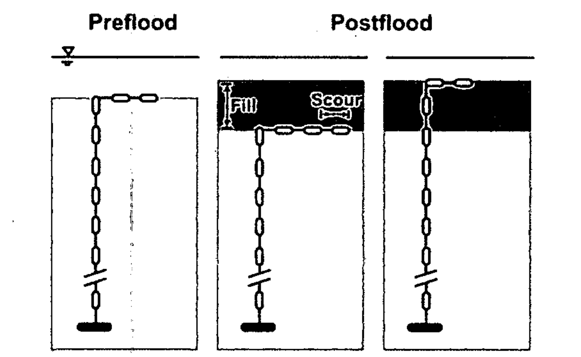


Figure 3.59 Diagram illustrating the use of "Leopold" scour chains to measure scour and fill associated with a flood. From Haschenburger (1999).

3.15.2 Extension of the Active Layer Model to Describe Vertical Sorting

The exponential curves for probability of depth of burial over a single flood are reminiscent of the curve for the probability of entrainment of a grain per unit time as a function of depth below the mean bed surface hypothesized in Figure 3.31c. That is, the exchange or active layer approximation of Figure 3.31d provides only the simplest possible description of the vertical exchange of particles of differing sizes associated with scour and fill. Schick et al. (1987), Hassan and Church (1994) and Haschenburger (1999) have devised

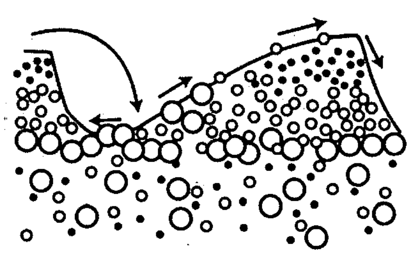


Figure 3.60 Schematization of the pattern of vertical sorting generated by the successive passage of dunes over a bed of heterogeneous sediment.

probabilistic models for vertical exchange of particles that use a probabilistic description with continuous variation in the vertical, rather than the simplification of a single, well-mixed layer underlain by a substrate that is never accessed in the absence of mean bed degradation.

The vertical exchange outlined in the papers above was likely accomplished in most cases by random scour and fill in the absence of well-developed dunes. Ribberink (1987) has investigated the case of vertical sorting of different sizes of sediment in a dune field, and has found a vertical structure of sorting that is too complex to explain in terms of the simple active layer model. This vertical sorting can be at least partially seen in Figure 3.2; a clearer schematization is given in Figure 3.60 (Blom et al., 2001). Blom and Ribberink (1999) and Blom and Kleinhans (1999) have found that as opposed to the typical case in gravel-bed streams, in the presence of dunes the coarser material tends to accumulate at the base of the dunes, creating a partial barrier between the somewhat finer substrate below and the considerably finer material in the migrating dunes above. Niño and Aracena (1999) have found a similar result for the case of ripples. Hooke (1968) describes an extreme case in which pebbles fed onto a sand bed covered with dunes migrated downward to form a one-grain thick immobile layer over which the dunes migrated.

In confirmation of the prediction of Suzuki and Michiue (1979), Blom and Ribberink (1999) and Blom and Kleinhans (1999) found that a wide grain size distribution tends to suppress dune amplitude. In addition, increasing stage of flow tends to mitigate the vertical sorting pattern.

The above observations have spurred the search for a formulation of the Exner equation for sediment continuity of size mixtures that is of more general validity than the active layer model of Section 3.5. Ribberink (1987), Ashida et al. (1989), Egashira and Ashida (1990) and Di Silvio (1991) introduced formulations with multiple layers in the vertical, each able to exchange with adjacent layers. Armanini (1995) went one step farther and developed a diffusion model for vertical mixing that is intrinsically continuous in nature.

Recently Parker et al. (2000) succeeded in developing a vertically continuous version of the Exner equation of sediment continuity for multiple grain sizes. The relation is based on a) the probability distribution associated with bed elevation fluctuations and b) structure functions for variation in the entrainment and deposition rates of sediment of various sizes with depth below the mean bed layer. The treatment draws heavily on the entrainment model of Tsujimoto (1991) for bed-load transport, as outlined in Section 3.5.5. The formulation can be briefly outlined as follows.

Let η denote the local mean bed elevation averaged over fluctuations (see Fig. 3.31a) and let $y = z - \eta$ denote elevation relative to the mean bed elevation. The probability density function of elevation fluctuation is denoted as $p_e(y)$, and the parameter P_s denoting the probability that the instantaneous bed is higher than elevation y is defined as

$$P_s(y) = 1 - \int_{-\infty}^{y} p_e(y)dy \tag{3.156}$$

The bed-load entrainment and deposition rates E_{bi} and D_{bi} are those specified in Section 3.5.5. The local volume concentration of sediment in the bed $c_{bed}(y)$ is related to porosity as

$$c_{bed} = 1 - \lambda_p \tag{3.157}$$

and the mean value of c_{bed} is given as

$$\bar{c}_{bed} = \int_{-\infty}^{\infty} c_{bed}(y) p_e(y) dy \tag{3.158}$$

Let $f_i(y)$ denote the grain size fractions of the bed at any relative elevation y and f_{bi} denote, as before, the grain size fractions in the bed-load. The conditions for grain size-specific sediment continuity then reduce to

$$\bar{c}_{bed} \frac{\partial \eta}{\partial t} = \sum_{i=1}^{n} (D_{bi} - E_{bi})$$

$$c_{bed} P_s \frac{\partial f_i}{\partial t} = p_e \left[D_{bi} \left(\beta_{iD} f_{bi} - \frac{c_{bed}}{\bar{c}_{bed}} f_i \right) - E_{bi} (\beta_{iE} - \frac{c_{bed}}{\bar{c}_{bed}}) f_i \right] \tag{3.159a,b}$$

where $\beta_{iD}(y)$ and $\beta_{iE}(y)$ are bias functions determining the grain size-specific variation of deposition and entrainment rate with relative elevation y. Defining

$$\beta_D = \sum_{i=1}^{n} \beta_{Di} f_{bi} \,, \quad \beta_E = \sum_{i=1}^{n} \beta_{Ei} f_i \,, \tag{3.160}$$

it can be demonstrated that

$$\beta_D = \beta_E = \frac{c_{bed}}{\bar{c}_{bed}} \tag{3.161}$$

An appropriate integral in y of Eqs. (3.159a,b) under simplifying assumptions recovers the active layer formulation of Eq. (3.40).

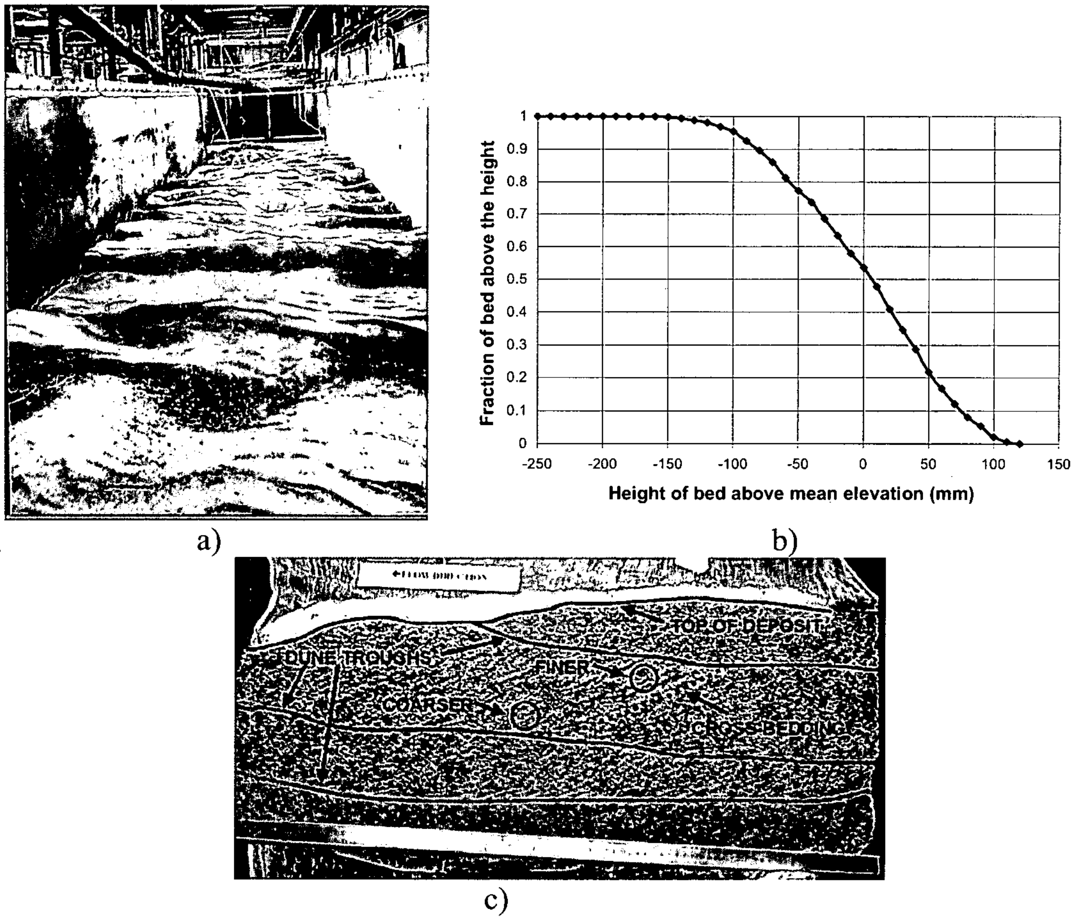


Figure 3.61 a) Experimental dunes. b) $P_s(y)$ as a function of y for the bed of part a). c) Pattern of stratification and sorting created by the passage of dunes in the flume illustrated in part a). From Parker et al. (2000).

Parker et al. (2000) did not specify general forms for the bias functions necessary to implement the model with confidence. Blom et al. (2001) have, however, implemented it in the case of the vertical dispersion of tracers in uniform material. In addition Blom (2003) has adapted the formulation for mixtures and specified bias functions for rivers which transport significant amounts of both gravel and sand as bed-load. Further development of such vertically continuous descriptions of grain size-specific sediment continuity holds the key to at least statistically describing the vertical structure of grain sorting in rivers. A case in point is the stratigraphy created by passing dunes illustrated in Figure 3.61.

REFERENCES

Aalto, R., 2002, "Geomorphic form and process of sediment flux within an active orogen: denudation of the Bolivian Andes and sediment conveyance across the Beni Foreland," Doctoral thesis, University of Washington, Seattle, 365 p.

Ackers, P. and W. R. White, 1973, "Sediment transport: a new approach and analysis," *Journal of Hydraulic Engineering*, 99(11), 2041-2060.

Ackers, P. and W. R. White, 1980, "Bed material transport: a theory for total load and its verification," *Proceedings*, International Symposium on River Sedimentation, International Research and Training Center on Erosion and Sedimentation, Beijing, China.

Almedeij, J. H. and P. Diplas, 2003, "Bedload transport in gravel-bed streams with unimodal sediment," *Journal of Hydraulic Engineering*, 129(11), 896-904.

Anderson, M. G., D. E. Walling and P. D. Bates, eds., 1996, "Floodplain Processes," John Wiley & Sons.

Andrews, E. D., 1983, "Entrainment of gravel from naturally sorted riverbed materials," *Geological Society of America Bulletin*, 94: 1225-1231.

Andrews, E. D. and Erman, D. C., 1986, "Persistence in the size distribution of surficial bed material during an extreme snowmelt flood," *Water Resources Research*, 22: 191-197.

Armanini, A., 1991/1992, "A new formulation for modeling the transport of non uniform sediment mixtures," *Excerpta*, 6: 115-132.

Armanini, A, 1995, "Non-uniform sediment transport: dynamics of the active layer." *Journal of Hydraulic Research*, 33(5): 611-622.

Ashida, K. and M. Michiue, 1971, "An investigation of river bed degradation downstream of a dam," *Proceedings*, 14th Congress, International Association of Hydraulic Research, Société Hydrotechnique de France, Paris, France 3: 247-256.

Ashida, K. and M. Michiue, 1972, "Study on hydraulic resistance and bedload transport rate in alluvial streams, *Transactions*, Japan Society of Civil Engineering, 206: 59-69 (in Japanese).

Ashida, K., S. Egashira and N. Andou, 1984, "Origin and geometry of step-pool bed form," *Proceedings*, 28th Annual Hydraulics Conference, Japan Society of Civil Engineering, Tokyo, Japan, 743-749.

Ashida, K., S. Egashira, and Y. Takamura, 1989, "Mechanism for grain sorting in movable beds," *Annuals*, Disaster Prevention Research Institute, Kyoto University, Japan, 32(B-2), 517-526.

Ashida, K., S. Egashira and B. Liu, 1991, "Numerical method on sediment sorting and bed variation in meander channels," *Proceedings*, Annual Conference on Hydraulic Engineering, Japan Society for Civil Engineering, Tokyo, Japan, 35: 383-390.

Ashworth, P. J. and R. I. Ferguson, 1989, "Size-selective entrainment of bed-load in gravel bed streams," *Water Resources Research*, 25, 627-634.

Ashworth, P. J., R. I. Ferguson and M. D. Powell, 1991, "Bedload transport and sorting in braided channels," *Dynamics of Gravel-bed Rivers*, Billi, P., R. D. Hey, C. R. Thorne, and P. Tacconi, eds., John Wiley & Sons, 495-515.

Ashworth, P. J., R. I. Ferguson, P. E. Ashmore, C. Paola, D. M. Powell, and K. L. Prestegaard, 1992, "Measurements in a braided river chute and lobe, 2, sorting of bedload during entrainment, transport and deposition," *Water Resources Research*, 28: 1887-1896.

Bakke, P. D., P. O. Baskedas, D. R. Dawdy and P. C. Klingeman, 1999, "Calibrated Parker-Klingeman model for gravel transport," *Journal of Hydraulic Engineering*, 125(6), 657-660.

Belleudy, Ph., and SOGREAH, 2000, "Numerical simulation of sediment mixture deposition part 1: analysis of a flume experiment," *Journal of Hydraulic Research*, 38(6), 417-425.

Bezzola, G, R, 1992, "The effect of sediment transport during the 1987-flood in the Reuss River," *Proceedings*, International Seminar on Grain Sorting, Ascona, Switzerland," Mitteilungen 117 der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH Zurich, 331-344.

Blom, A. and J. S. Ribberink, 1999, "Non-uniform sediment in rivers: vertical sediment exchange between bed layers," *Proceedings*, IAHR Symposium on River, Coastal and Estuarine Morphodynamics, G. Seminara, ed., Springer, New York, 45-54.

Blom, A. and Kleinhans, M., 1999, "Non-uniform Sediment in Morphological Equilibrium Situations – Data Report Sand Flume Experiments 97/98," *Research Report* CiT 99R-002/MICS-001, Civil Engineering and Management, Twente University, the Netherlands.

Blom, A., G. Parker and J. S. Ribberink, 2001, "Vertical exchange of tracers and non-uniform sediment in dune situations," *Proceedings*, 2nd IAHR Symposium on River, Coastal and Estuarine Morphodynamics, Obihiro, Japan S. Ikeda, ed.,. Hokkaido River Disaster Prevention Research Center, Sapporo, Japan.

Blom, A., 2003, "A continuum vertical sorting model for rivers with non-uniform sediment and dunes," Doctoral thesis, University of Twente, the Netherlands.

Borah, D. K., C. V. Alonso, and S. N. Prasad, 1982, "Routing graded sediment in streams: formulations," *Journal of Hydraulic Research*, 108: 1486-1503.

Bradley, W. C., 1970, "Effect of weathering on abrasion of granitic gravel, Colorado River (Texas)," *Geological Society of America Bulletin*, 81: 61:80.

Bridge, J. S., and J. Jarvis, 1976, "Flow and sedimentary processes in the meandering river South Esk, Glen Cova, Scotland," *Earth Surface Processes*, 1, 303-336.

Bridge, J. S. and S. J. Bennett, 1992, "A model for the entrainment and transport of sediment grains of mixed sizes, shapes and densities," *Water Resources Research*, 28(2): 337-363.

Brownlie, W. R., 1981, "Prediction of flow depth and sediment discharge in open channels," *Report* No. KH-R-43A, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Pasadena, California, USA, 232 p.

Brummer, C. J. and D. R. Montgomery, 2003, "Downstream coarsening in headwater channels," *Water Resources Research*, 39(10), 1294, 14 p.

Buffington, J. M, and D. R. Montgomery, 1997, "A systematic analysis of eight decades of incipient motion studies, with specific reference to gravel-bedded rivers," *Water Resources Research*, 33(8), 1993-2029.

Bunte, K. and S. T. Abt, 2001, "Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics and streambed monitoring. *General Technical Report* RMRS-GTR-74, US Department of Agriculture, US Forest Service, Rocky Mountain Research Station, Fort Collins, CO, 428 p.

Bunte, K., Abt, S. R. and Potyondy, J. P., 2004, Measurement of coarse gravel and cobble transport using portable bedload traps," *Journal of Hydraulic Engineering,* 130(9), 879-893.

Burrows, R. L., W. W. Emmett, and B. Parks, 1981, "Sediment transport in the Tanana River near Fairbanks, Alaska, 1977-1979," *Water Resources Investigation Report* 81-20, U.S. Geological Survey, U.S. Government Printing Office, Washington, D.C., 56 p.

Burrows, R. L., and P. E. Harrold, 1983, "Sediment transport in the Tanana River near Fairbanks, Alaska, 1980-1981," *Water Resources Investigation Report* 83-4064, U.S. Geological Survey, U.S. Government Printing Office, Washington, D.C., 116 p.

Carling, P. A., 1989, "Bedload transport in two gravel-bedded streams," *Earth Surface Processes and Landforms*, 14: 27-39.

Carling, P. A. and N. A. Reader, 1982, "Structure, composition and bulk properties of upland stream gravels," *Earth Surface Processes and Landforms*, 7: 349-386.

Carson, M. A. and G. A. Griffiths, 1987, "Bedload transport in gravel channels," *Journal of Hydrology New Zealand*, 26(1), 1-151.

Church, M. and K. Rood, 1983, "Catalogue of alluvial river data," *Report*, Department of Geography, University of British Columbia, Vancouver, B. C., Canada.

Church, M. A., D. G. McLean and J. F. Wolcott, 1987, "River bed gravels: sampling and analysis," *Sediment Transport in Gravel-bed Rivers*, Thorne, C. R., J. C. Bathurst, and R. D. Hey, eds., John Wiley & Sons, 43-79.

Church, M., J. F. Wolcott, and W. K. Fletcher, 1991, "A test of equal mobility in fluvial sediment transport: behavior of the sand fraction," *Water Resources Research*, 27(11): 2941-2951

Church, M., and M. A. Hassan, 1992, "Size and distance of travel of unconstrained clasts on a streambed," *Water Resources Research*, 28: 299-303.

Church, M., M. A. Hassan, and J. F. Wolcott, 1998, "Stabilizing self-organized structures in gravel-bed stream channels: field and experimental observations," *Water Resources Research*, 34(11): 3169-3179.

Colombini, M. and G. Parker, 1995, "Longitudinal streaks," *Journal of Fluid Mechanics*, 304: 161-183.

Copeland, R. R. and W. A. Thomas, 1992, "Dynamic sorting and armoring algorithm in tabs-1 numerical sedimentation model," *Proceedings*, International Seminar on Grain Sorting, Ascona, Switzerland," Mitteilungen 117 der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH Zurich, 359-368.

Cui, Y., G. Parker, and C. Paola, 1996, "Numerical simulation of aggradation and downstream fining," *Journal of Hydraulic Research*, 34(2), 184-204.

Cui, Y., and G. Parker, 1997, "A quasi-normal simulation of aggradation and downstream fining with shock fitting," *International Journal of Sediment Research*, 12(2): 68-82.

Cui, Y., and G. Parker, 1998, "The arrested gravel front: stable gravel-sand transitions in rivers. Part 2: General numerical solution," *Journal of Hydraulic Research*, 36(2): 159-182.

Cui, Y., and G. Parker, 1999, "Sediment Transport and Deposition in the Ok Tedi-Fly River System, Papua New Guinea: Modeling of 1998-1999. *Report* No. 7, Environment Department, Ok Tedi Mining Ltd., downloadable at http://cee.uiuc.edu/people/parkerg/_private/Reports/ (August 13, 2005).

Cui, Y., and A. Wilcox, in press, "Development and application of numerical modeling of sediment transport associated with dam removal," *Sedimentation Engineering*, ASCE Manual No. 54, Appendix A.

Cui, Y., G. Parker, T. E. Lisle, J. Gott, M. E. Hansler, J. E. Pizzuto, N. E. Allmendinger, and J. M. Reid, 2003a, "Sediment pulses in mountain rivers. Part 1. Experiments," *Water Resources Research*, 39(9), 1239, doi:10.1029/2002WR001803.

Cui, Y., G. Parker, J. E. Pizzuto, and T. E. Lisle, 2003b , "Sediment Pulses in Mountain Rivers. Part 2. Comparison between Experiments and Numerical Predictions," *Water Resources Research*, 39(9), 1240, doi:10.1029/2002WR001805.

Cui, Y. and G. Parker, in press, "Numerical model of sediment pulses and sediment supply disturbances in mountain rivers," *Journal of Hydraulic Engineering*.

Day, T. J., 1980, A Study of the Transport of Graded Sediments, *Report* No. IT 190, HRS Wallingford, Wallingford, U.K.

Deigaard, R., 1980, "Longitudinal and transverse sorting of grain sizes in alluvial rivers," *Series Paper* 26, Institute of Hydrodynamics and Hydraulic Engineering, Technical University of Denmark, 108 p.

Di Silvio, G., 1991, "Sediment exchange between stream and bottom: a four layer model," *Proceedings*, *Proceedings*, International Seminar on Grain Sorting, Ascona, Switzerland, Mitteilungen Nr. 117 der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH Zurich, 163-192.

Dietrich, W. E. and J. D. Smith, 1984, "Bedload transport in a river meander," *Water Resources Research*, 20(10): 1355-1380.

Dietrich, W. E., and P. J. Whiting, 1989, "Boundary shear stress and sediment transport in river meanders of sand and gravel," *Water Resources Monograph* 12, River Meandering, American Geophysical Union, 1-50.

Dietrich, W. E., J. W. Kirchner, H. Ikeda and F. Iseya, 1989, "Sediment supply and the development of the coarse surface layer in gravel-bedded rivers," *Nature*, 340, 215-217.

Dietrich, W. E., G. Day, and G. Parker, 1999, "The Fly River, Papua New Guinea: inferences about river dynamics, floodplain sedimentation and fate of sediment," *Varieties of Fluvial Form*, Miller, A. J. and A. Gupta, eds., John Wiley & Sons, New York, 345-376.

Dinehart, R. L., 1992, "Evolution of coarse-gravel bedforms, field measurements at flood stage," *Water Resources Research*, 28(10): 2667-2689.

Diplas, P., 1987, "Bedload transport in gravel-bed streams," *Journal of Hydraulic Engineering*, 113: 277-292.

Diplas, P., and A. J. Sutherland, 1988, "Sampling techniques for gravel sized sediments," *Journal of Hydraulic Engineering*, 114(5): 484-501.

Diplas, P., and G. Parker, 1992, "Deposition and removal of fines in gravel-bed streams," *Dynamics of Gravel-bed Rivers*, Billi, P., R. D. Hey, C. R. Thorne, and P. Tacconi, eds, John Wiley & Sons, 314-326.

Duan, J.G. and L. Chen, 2003, "Sediment transport study in the Las Vegas Wash," *Technical Report*, Division of Hydrologic Sciences, Desert Research Institute, Las Vegas, Nevada USA.

Egashira, S. and Ashida, K., 1990, "Mechanism of armoring phenomena," *International Journal of Sediment Research*, 5(1), 49-55.

Egiazaroff, I. V., 1965, Calculation of non-uniform sediment concentrations, *Journal of Hydraulic Engineering*, 91(4), 225-248.

Einstein, H. A., 1950, "The Bed-load Function for Sediment Transportation in Open Channel Flows," *Technical Bulletin* 1026, U.S. Dept. of the Army, Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C.

Emmett, W. W., 1976, "Bedload transport in two large, gravel-bed rivers, Idaho and Washington," *Proceedings*, Third Federal Inter-Agency Sedimentation Conference, Denver, Colorado, March 22-26, U.S. Government Printing Office, Washington, D.C..

Emmett, W. W., R. H. Myrick, and R. H. Meade, 1980, "Field Data Describing the Movement and Storage of Sediment in the East Fork River, Wyoming, Part 1. River Hydraulics and Sediment Transport," *Open-File Report* 80-1189, U. S. Geological Survey, U.S. Government Printing Office, Washington, D.C.

Everts, C. H., 1973, "Particle overpassing on flat granular boundaries," *Journal of the Waterways and Harbors Division*, 99: 425-438.

Ferguson, R., and P. Ashworth, 1991, "Slope-induced changes in the channel character along a gravel-bed stream: the Allt Dubhaig, Scotland," *Earth Surface Processes and Landforms*, 16: 65-82.

Ferguson, R., T. Hoey, S. Wathen, and A. Werrity, 1996, "Field evidence for rapid downstream fining of river gravels through selective transport." *Geology*, 24(2): 179-182.

Ferguson, R. I. and S. J. Wathen, 1998, "Tracer-pebble movement along a concave river profile: virtual velocity in relation to grain size and shear stress," *Water Resources Research*, 34(8), 2031-2038.

Ferguson, R. I., M. Church and H. Weatherley, 2001, "Fluvial aggradation in the Vedder River: testing a one-dimensional sedimentation model," *Water Resources Research*, 37(12), 3331-3348.

Fernandez Luque, R. and R. van Beek, 1976, "Erosion and transport of bedload sediment," *Journal of Hydraulic Research*, 14(2): 127-144.

Fripp, J. B. and P. Diplas, 1993, "Surface sampling in gravel streams," *Journal of Hydraulic Engineering*, 119(4): 473-490.

Fujita, K., K. Yamamoto and Y. Akabori, 1998, "Evolution mechanisms of the longitudinal bed profiles of major alluvial rivers in Japan and their implications for profile change prediction," *Transactions*, Japan Society of Civil Engineering, 600(II-44): 37–50 (in Japanese).

Galay, V. J., 1983, "Causes of river bed degradation," *Water Resources Research*, 19:1057-1090.

García, M., and G. Parker, 1991, "Entrainment of bed sediment into suspension," *Journal of Hydraulic Engineering*, 117(4): 414-435.

Gomez, B., 1983, "Temporal variations in bedload transport rates: the effect of progressive bed armoring," *Earth Surface Processes and Landforms*, 8: 41-54.

Gomez, B. and M. Church, 1989, "An assessment of bed load sediment transport formulae for gravel bed rivers," *Water Resources Research*, 25(6): 1161-1186.

Gomez, B., R. L. Naff and D. W. Hubbell, 1989, "Temporal variations in bedload transport rates associated with the migration of bedforms," *Earth Surface Processes and Landforms*, 14: 135-156.

Gomez, B., B. J. Rosser, D. H. Peacock, D. M. Hicks and J. A. Palmer, 2001, "Downstream fining in a rapidly aggrading gravel bed river," *Water Resources Research*, 37(6), 1813-1824.

Grant, G. E., F. J. Swanson and M. G. Wolman, 1990, "Pattern and origin of stepped-bed morphology in high-gradient streams, Western Cascades, Oregon," *Geological Society of America Bulletin*, 102: 340-352.

Günter, A. 1971, "Die kritische mittlere Sohlenschubspannung bei Gescheibemischungen unter Berücksichtigung der Deckschichtbildung und der turbulenzbedingten

Sohlenschubspannungsschwankungen ," *Mitt.* 3, Versuchsanstalt für Wasserbau, ETH, Zurich, Switzerland.

Hamamori, A, 1962, "A Theoretical Investigation on the fluctuations of bedload transport," *Report* R4, Delft Hydraulics Laboratory.

Haschenburger, J. K. and M. Church, 1998, "Bed material transport estimated from the virtual velocity of sediment," *Earth Surface Processes and Landforms*, 23: 791-808.

Haschenburger, J. K., 1999, "A probability model of scour and fill depths in gravel-bed channels," *Water Resources Research*, 35(9): 2857-2869.

Hasegawa, K,. T. Fujita, H. Meguro and H. Tatuzawa, 2000, "Bed forms in steep channels with heterogeneous bed materials induced by bottom elevation instability and sorting instability," *Suikougaku Ronbunshuu*, 44, 659-664 (in Japanese).

Hassan, M. A., 1990, "Scour, fill and burial depth of coarse material in gravel bed streams," *Earth Surface Processes and Landforms*, 15: 341-356.

Hassan, M. A., M. Church and P. J. Ashworth, 1992, "Virtual rate and mean distance of travel of individual clasts in gravel-bed channels," *Earth Surface Processes and Landforms*, 17: 617-627.

Hassan, M. A. and Church, M., 1994, "Vertical mixing of coarse particles in gravel bed rivers: a kinematic model," *Water Resources Research*, 30: 1173-1185.

Hassan, M. A. and Church, M., 2000, "Experiments on surface structure and partial sediment transport on a gravel bed," *Water Resources Research*, 36(7): 1885-1985.

Hassan, M. A., and Church, M. 2001, "Sensitivity of bed load transport in Harris Creek: Seasonal and spatial variation over a cobble-gravel bar," *Water Resources Research*, 37, 813-825.

Hassan. M. A. and R. Egozi, 2001, "Impact of wastewater on the channel morphology of ephemeral streams," *Earth Surface Processes and Landforms*, 26(12) 1285-1302.

Hay, D. F., ed., 1998, "Wetlands Engineering River Restoration Conference 1998, Engineering Approachs to Ecosystem Restoration," CD containing proceedings available from American Society of Civil Engineers.

Hayward, J. A., 1980, "Hydrology and Stream Sediment From Torlesse Stream Catchment," *Special Publication* 17, Tussock Grasslands and Mountain Lands Institute, Lincoln College, Canterbury, New Zealand.

Hey, R. D., 1979, "Flow resistance in gravel-bed rivers," *Journal of Hydraulic Engineering*, 105(4), 365-380.

Hey, R., 1989, "Bar form resistance in gravel-bed rivers," *Journal of Hydraulic Engineering*, 114(12): 1498-1508.

Hirano, M., 1971, "On riverbed variation with armoring," *Proceedings,* Japan Society of Civil Engineering, 195: 55-65 (in Japanese).

Hoey, T. B., and R. I. Ferguson, 1994, "Numerical simulation of downstream fining by selective transport in gravel bed rivers: Model development and illustration," *Water Resources Research*, 30, 2251-2260.

Hoey, T. B. and R. Ferguson, 1997, "Controls of strength and rate of downstream fining about a river base level," *Water Resources Research*, 33(11): 2601-2608.

Hollingshead, A. B., 1971, "Sediment transport measurements in a gravel river," *Journal of Hydraulic Engineering*, 97(11): 1817-1834.

Holly, F. M., and J. L. Rahuel, 1990, "New numerical/physical framework for mobile-bed modeling," *Journal of Hydraulic Research*, 28(5), 545-564.

Hooke, R. LeB., 1968, "Laboratory study of the influence of granules on flow over a sand bed," *Geological Society of America Bulletin*, 79: 495-500.

Hotchkiss, R. H. and M. Glade, eds., 2000, "Symposium on River Restoration," *Proceedings*, 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management, CD available from American Society of Civil Engineers

Huang, X. and M. H. García, 2000, "Pollution of gravel spawning grounds by deposition of suspeneded sediment," *Journal of Environmental Engineering*, 126(10), 963-965.

Hubbell. D. W., 1987, "Bedload sampling and analysis," *Sediment Transport in Gravel-bed Rivers,* Thorne, C. R., J. C. Bathurst, and R. D. Hey, eds., John Wiley & Sons, 89-106.

Hunziker, R., and M. N. R. Jaeggi, 2002, "Grain sorting processes," *Journal of Hydraulic Engineering*, 128(12), 1060-1068.

Ikeda, H., 2001, "An Eye for Seeing Landforms," Kokon Shoin, Tokyo, Japan, 152 p. (in Japanese).

Ikeda, S., 1982, "Incipient motion of sand particles on side slopes," *Journal of Hydraulic Engineering*, 108: 95-114.

Ikeda, S., M. Yamasaka and M. Chiyoda, 1987, "Bed topography and sorting in bends," *Journal of Hydraulic Engineering*, 113(2): 190-205.

Ikeda, S., 1989, "Sediment transport and sorting at bends," *Water Resources Monograph* 12, River Meandering, American Geophysical Union, 103-126.

Iseya, F. and H. Ikeda, 1987, "Pulsations in bedload transport induced by a longitudinal sediment sorting; a flume study using sand gravel mixtures," *Geografiska Annaler*, 69: 15-27.

Kamphuis, J.W., 1974, "Determination of Sand Roughness for Fixed Beds," *Journal of Hydraulic Research*, 12(2), 193-202.

Keulegan, G. H., 1938, "Laws of turbulent flow in open channels," *National Bureau of Standards* Research Paper RP 1151, Washington, D.C..

Karim, F., 1998, "Bed material discharge prediction for nonuniform bed sediments," *Journal of Hydraulic Engineering*., 124(6): 597-604.

Karim, F., and J. F. Kennedy, 1981, "Computer-based predictors for sediment discharge and friction factor of alluvial streams," *Report* No. 242, Iowa Institute of Hydraulic Research, University of Iowa, Iowa City, Iowa.

Kellerhals, R. and D. I. Bray, 1971, "Sampling procedures for coarse fluvial sediments," *Journal of Hydraulic Engineering*, 98(8): 1165-1180.

Kellerhals, R., C. R. Neill, and D. I. Bray, 1972, "Hydraulic and geomorphic characteristics of rivers in Alberta," River Engineering and Surface Hydrology Report No. 72-1, Research Council of Alberta, Edmonton, Alberta, Canada.

Kellerhals, T. and D. Gill, 1973, "Observed and potential downstream effects of large storage projects in northern Canada," *Proceedings*, 12th Congress, International Commission on Large Dams, Madrid, 731-754.

Kelsey, A. R., 1996, "Modelling the sediment transport process," *Advances in Fluvial Dynamics and Stratigraphy*, Carling, P. A., and M. R. Dawson, eds., John Wiley and Sons, 229:262.

Kleinhans, M. G., 2002, "Sorting out sand and gravel: sediment transport and deposition in sand-gravel bed rivers", Doctoral thesis, Netherlands Geographical Studies 293, Faculty of Geographical Sciences, Utrecht, University, the Netherlands, 317 p.

Kleinhans, M. G. and van Rijn, L. C., 2002, "Stochastic prediction of sediment transport in sand-gravel bed rivers," *Journal of Hydraulic Engineering*, Special Issue on Stochastic Sediment Transport and Hydraulics, 128(4), 412-425.

Klingeman, P. C., C. J. Chaquette, and S. B. Hammond, 1979, "Bed Material Characteristics near Oak Creek Sediment Transport Research Facilities, 1978-1979," *Oak*

Creek Sediment Transport Report No. BM3, Water Resources Research Institute, Oregon State University, Corvallis, Oregon, June.

Kodama, Y., H. Ikeda, and H. Iijima, 1992, "Longitudinal sediment sorting along a concave upward stream profile in a large flume," *Report*, Hydraulic Experimental Center, Tsukuba University, 16: 119-123 (in Japanese).

Kodama, Y., 1994a, "Experimental study of abrasion and its role in producing downstream fining in gravel-bed rivers," *Journal of Sedimentary Research*, A64(1), 76-85.

Kodama, Y., 1994b, "Downstream changes in the lithology and grain size of fluvial gravels, the Watarase River, Japan: Evidence of the role of abrasion in downstream fining," *Journal of Sedimentary Research*, A64(1): 68-75.

Komar, P. D., 1987, "Selective gravel entrainment and the empirical evaluation of flow competence," *Sedimentology*, 34: 1165-1176

Komar, P. D., 1987, "Selective grain entrainment by a current from a bed of mixed sizes: a reanalysis," *Journal of Sedimentary Research*, 57: 203-211.

Komar, P. D. and P. A. Carling, 1991, "Grain sorting in gravel-bed streams and the choice of particle sizes for flow competence evaluations," *Sedimentology*, 38: 489-502.

Kondolf, G. M. and P. R. Wilcock, 1996, "The flushing flow problem: defining and evaluating objectives," *Water Resources Research*, 32(8): 2589-2599.

Kostic, S. and G Parker, 2003, "Progradational sand-mud deltas in lakes and reservoirs. Part 1: Theory and numerical model," *Journal of Hydraulic Research*, 41(2), 127-140.

Kovacs, A. and G. Parker, 1994, "A new vectorial bedload formulation and its application to the time evolution of straight river channels," *J. Fluid Mech.*, 267, 153-183.

Kuhnle, R. A. and J. B. Southard, 1988, "Bedload transport fluctuations in a gravel bed laboratory channel," *Water Resources Research*, 24: 247-260.

Kuhnle, R. A., J. C. Willis, and A. J. Bowie, 1989, "Variations in the transport of bed load sediment in a gravel-bed stream, Goodwin Creek, Mississippi, USA," *Proceedings*, 4th International Symposium on River Sedimentation, International Research and Training Center on Erosion and Sedimentation, Beijing, China, 539-546.

Kuhnle, R. A., 1992, "Fractional transport rates of bedload on Goodwin Creek," *Dynamics of Gravel-bed Rivers*, Billi, P., R. D. Hey, C. R. Thorne and P. Tacconi, eds., John Wiley & Sons, 141-155.

Kuhnle, R. A., 1993, "Fluvial transport of sand and gravel mixtures with bimodal size distributions," *Journal of Sedimentary Geology*, 85:17-24.

Kuhnle, R. A., 1996, "Unsteady transport of sand and gravel mixtures," *Advances in Fluvial Dynamics and Stratigraphy*, Carling, P. A. and M. R. Dawson, eds., John Wiley and Sons, 184-201.

Lanzoni, S. and M. Tubino, 1999, "Grain sorting and bar instability," *Journal of Fluid Mechanics*, 393: 149-174.

Laronne, J., I. Reid, Y. Yitshak, and L. E. Frostick, 1994, "The non-layering of gravel streambeds under ephemeral flood regimes," *Journal of Hydrology*, 159: 353-363.

Lenzi, M. A., V. D'Agostino, F. Comiti, G. R. Scussel, U. De Col., and G. Asti, 2000, "Bedload transport data from Rio Cordon torrent: comparison with sediment transport equations and field data from other Alpine streams," *In* Special Issue, Dynamics of Water and Sediments in Mountain Basins, Quaderni di Idronomia Montana, Editoriale Bios, Italy.

Leopold, L. B., 1994, "A View of the River," Harvard University Press, Cambridge, Massachusetts USA, 298 p.

Leopold, L. B., M. G. Wolman and J. P. Miller, 1964, "Fluvial Processes in Geomorphology," W. H. Freeman and Company, San Francisco, 522 p.

Leopold, L. B., W. W. Emmett and R. H. Myrick, 1966, "Channel and hillslope processes in a semiarid area, New Mexico," *Professional Paper* 352G, U.S. Geological Survey, U.S. Government Printing Office, Washington, D.C., .

Liu, X. L., 1986, "Nonuniform Bed Load Transport Rate and Coarsening Stabilization," M.S. Thesis, Chengdu University, China (in Chinese).

Lisle, T. E., 1989, "Sediment transport and resulting deposition in spawning gravels, north coastal California," *Water Resources Research*, 25(6): 1303-1319.

Lisle, T. E. and M. A. Madej, 1992, "Spatial variation in armoring in a channel with high sediment supply," *Dynamics of Gravel-bed Rivers*, Billi, P., R. D. Hey, C. R. Thorne, and P. Tacconi, eds., John Wiley & Sons, 277-296.

Lisle, T. E., 1995, "Particle size variations between bed load and bed material in natural gravel bed channels," *Water Resources Research*, 31(4), 1107-1118.

Lisle, T. E., J. E. Pizzuto, H. Ikeda, F. Iseya and Y. Kodama, 1997, "Evolution of a sediment wave in an experimental channel," *Water Resources Research*, 33(8): 1971-1981.

Lisle, T.E., Y. Cui, G. Parker, J. E. Pizzuto and A. M. Dodd, 2001, "The dominance of dispersion in the evolution of bed material waves in gravel-bed rivers," *Earth Surface Processes and Landforms*, 26, 1409-1420.

Marion, A., and L. Fraccarollo, 1997, "Experimental investigation of mobile armoring development," *Water Resources Research*, 33(6), 1447-1453.

Marion, A., I. McEwan and S. Tait, "On the competitive effects of particle re-arrangement and vertical sorting," *Proceedings*, 27th Congress of the International Association for Hydraulic Research, Volume 2, International Association of Hydraulic Engineering and Research, Madrid, Spain, 1493-1498.

Maunsell and Partners, 1982, "Waste rock and sedimentation methodology," *Ok Tedi Environmental Study*, Ok Tedi Mining Ltd., Tabubil, Papua New Guinea.

McLean, S. R., 1991, "Depth-integrated suspended-load calculations," *Journal of Hydraulic Engineering,* 117(11): 1440-1458.

McLean, S. R., 1992, "On the calculation of suspended load for non-cohesive sediments," 1992, *Journal of Geophysical Research*, 97(C4), 1-14.

Mellor, G.L., and T. Yamada, 1974. "A hierarchy of turbulence closure models for planetary boundary layers," *Journal of Atmospheric Science*: 31, 1791-1806.

Meyer-Peter, E., and R. Müller, 1948, "Formulas for bed-load transport," *Proceedings*, 2nd Congress International Association for Hydraulic Research, Stockholm, Sweden, 39-64.

Mikoš, M., 1993, "Fluvial Abrasion of Gravel Sediments," Mitteilungen 123 der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH Zurich, 322 p.

Mikoš, M., 1994, "The downstream fining of gravel-bed sediments in the alpine Rhine River," *Dynamics and Geomorphology of Mountain Rivers*, Ergenzinger, P. and K-H Schmidt, eds, Springer, 93-108.

Mikoš, M., 1995, "Fluvial abrasion: converting size reduction coefficients to weight reduction coefficients," *Journal of Sedimentary Research*, A65(3), 472-476.

Milhous, R. T., 1973, "Sediment Transport in a Gravel-bottomed Stream," *Ph.D. thesis*, Oregon State University, Corvallis, Oregon.

Milhous, R. T., 1998, "Numerical modeling of flushing flows in gravel-bed rivers," *Gravel-Bed Rivers in the Environment*, Klingeman, P. C., R. L. Beschta, P. D. Komar, and J. B. Bradley, eds., Water Resources Publications, Highlands Ranch, Colorado, USA, 579-602.

Millar, R. G., 1999, "Grain and form resistance in gravel-bed rivers," *Journal of Hydraulic Research*, 37(3): 303-312.

Misri, R. L, Garde, R. J., and Ranga Raju, K. G., 1984, "Bed load transport of nonuniform sediments," *Journal of Hydraulic Engineering*, 110(3): 312-328.

Nakagawa, H., T. Tsujimoto, and S. Nakano, 1982, "Characteristics of sediment motion for respective grain sizes of sand mixtures," *Bulletin*, Disaster Prevention Research Institute, Kyoto University, 32:1-32.

Narinesingh, P., 1995, "Nature Restoration and Floodplain Sedimentation," M.S. thesis, No. HH 218, IHE Delft, the Netherlands.

Narinesingh, P., G. J. Klaasen, and D. Ludikhuize, 1999, "Floodplain sedimentation along extended river reaches," *Journal of Hydraulic Research,* 37(6), 827-846.

van Niekerk, A., K. R. Vogel, R. L. Slingerland and J. S. Bridge, 1992, "Routing of heterogeneous sediments over mobile bed: model development," *Journal of Hydraulic Engineering*, 118(2): 246-252.

Neill, C. R., 1968, "A reexamination of the beginning of movement for coarse granular bed materials," *Report* INT 68, Hydraulics Research Station, Wallingford, England.

Niño, T. and D. Aracena, 1999, Experimental observations of ripple growth in non-uniform sediment," *Proceedings*, IAHR Symposium on River, Coastal and Estuarine Morphodynamics, G. Seminara, ed., Università degli Studi di Genova, Italy, 241-150.

Olesen, K. W., 1987, "Bed topography in shallow river bends," *Ph.D thesis*, University of Delft, the Netherlands, 265 p.

Onishi, Y., S. C. Jain and J. F. Kennedy, 1972, "Effects of meandering on sediment discharges and friction factors of alluvial streams," *Report* No. 141, Iowa Institute of Hydraulic Research, University of Iowa, Iowa City, Iowa USA.

Paintal, A. S., 1971, "Concept of critical shear stress in loose boundary open channels," *Journal of Hydraulic Research*, 9: 91-113.

Paola, C., P. L. Heller and C. L. Angevine, 1992a, "The large-scale dynamics of grain-size variation in alluvial basins. I: Theory," *Basin Research*, 4, 73-90.

Paola, C., G. Parker, R. Seal, S. K. Sinha, J. B. Southard, and P. R. Wilcock, 1992b, "Downstream fining by selective deposition in a laboratory flume," *Science*, 258: 1757-1760.

Paola, C. and R. Seal, 1995, "Grain size patchiness as a cause of selective deposition and downstream fining," *Water Resources Research*, 31(5), 1395-1407.

Paola, C., 1996, "Incoherent structure: turbulence as a metaphor for stream braiding," Coherent Flow Structures n Open Channels, Ashworth, P. J., S. J. Bennett, J. L. Best and S. J. McLelland, eds, John Wiley & Sons, 705-724.

Paola, C., G. Parker, D. C. Mohrig, and K. X. Whipple, 1999, "The influence of transport fluctuations on spatially averaged topography on a sandy, braided fluvial plain," *Numerical Experiments in Stratigraphy*, SEPM Special Publication 62, 211-218.

Paola, C., 2000, "Quantitative models of sedimentary basin filling," *Sedimentology*, 47(Supplement 1): 121-178.

Paola, C., J. Mullin, C. Ellis, D. C. Mohrig, J. Swenson, G. Parker, T. Hickson, P. L. Heller, L. Pratson, J. Syvitski, B. Sheets, and N. Strong, 2001, "Experimental stratigraphy," *GSA Today*, 11(7): 2-9.

Park, I. and S. C. Jain, 1987, "Numerical simulation of degradation of alluvial channel beds," *Journal of Hydraulic Engineering*, 113(7): 845-859.

Parker, G., 1978, Self-formed rivers with stable banks and mobile bed: Part I, the sand-silt river, *Journal of Fluid Mechanics*, 89(1), 109-126.

Parker, G, and A. G. Anderson, 1977, "Basic principles of river hydraulics," *Journal of Hydraulic Engineering*, 103(9): 1077-1087.

Parker, G., 1978, "Self-formed rivers with stable banks and mobile bed: Part I, the sand-silt river," *Journal of Fluid Mechanics*, 89(1), pp. 109-126.

Parker, G., 1978, "Self-formed rivers with equilibrium banks and mobile bed: Part II, the gravel river, "*Journal of Fluid Mechanics*, 89(1), 127-148.

Parker, G., 1979, "Hydraulic geometry of active gravel rivers," *Journal of Hydraulic Engineering*, 105(9), 1185-1201.

Parker, G. and A. W. Peterson, 1980, "Bar resistance of gravel-bed streams," *Journal of Hydraulic Engineering*, 106(10) 1559-1575.

Parker, G. and P. C. Klingeman, 1982, "On why gravel bed streams are paved," *Water Resources Research*, 18(5): 1409-1423.

Parker, G., P. C. Klingeman and D. G. McLean, 1982a, "Bedload and size distribution in paved gravel-bed streams," *Journal of Hydraulic Engineering*, 108(4): 544-571.

Parker, G., S. Dhamotharan, and S. Stefan, 1982b, "Model experiments on mobile, paved gravel bed streams," *Water Resources Research*, 18(5), 1395-1408.

Parker, G., 1984, "Discussion of 'Lateral bed load transport on side slopes'," *Journal of Hydraulic Research*, 110(2), 197-199.

Parker, G., and E. D. Andrews, 1985, "Sorting of bed load sediment by flow in meander bends," *Water Resources Research*, 21(9): 1361-1373.

Parker, G., 1990a, "Surface-based bedload transport relation for gravel rivers," *Journal of Hydraulic Research*, 28(4): 417-436.

Parker, G., 1990b, The ACRONYM Series of PASCAL Programs for Computing Bedload Transport in Gravel Rivers, *External Memorandum* M-200, St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, Minnesota USA.

Parker, G. and A. J. Sutherland, 1990, "Fluvial armor," *Journal of Hydraulic Research*, 28(5), 529-544.

Parker, G., 1991a, "Selective sorting and abrasion of river gravel. I: Theory," *Journal of Hydraulic Engineering*, 117(2): 131-149.

Parker, G., 1991b, "Selective sorting and abrasion of river gravel. II: Application," *Journal of Hydraulic Engineering*, 117(2): 150-171.

Parker, G., 1992, "Some random notes on grain sorting," *Proceedings*, International Seminar on Grain Sorting, Ascona, Switzerland," Mitteilungen 117 der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH Zurich, 19-76.

Parker, G., Y. Cui, Imran, J. and W. Dietrich, 1996 "Flooding in the lower Ok Tedi, Papua New Guinea due to the disposal of mine tailings and its amelioration," *Proceedings* International Seminar on Recent Trends of Floods and their Preventive Measures, Hokkaido River Disaster Prevention Research Center, Sapporo, Japan, 21-48.

Parker. G., and Y. Cui, 1998, "The arrested gravel front: stable gravel-sand transitions in rivers. Part 1: Simplified analytical solution," *Journal of Hydraulic Research*, 36(1): 75-100.

Parker, G., C. Paola, and Leclair, S., 2000, "Probabilistic form of Exner equation of sediment continuity for mixtures with no active layer," *Journal of Hydraulic Engineering*, 126(11): 818-826.

Parker, G., and C. M. Toro-Escobar, 2002, "Equal mobility of gravel in streams: the remains of the day," *Water Resources Research*, 38(11), 1264, doi:10.1029/2001WR000669.

Parker, G., C. M. Toro-Escobar, M. Ramey and S. Beck, 2003, "The effect of floodwater extraction on the morphology of mountain streams," *Journal of Hydraulic Engineering*, 129(11), 885-895.

Pickup, G., R. J. Higgins, and R. F. Warner, 1979, "Impact of Waste Rock Disposal from the Proposed Ok Tedi Mine on Sedimentation Processes in the Fly River and its Tributaries, Papua New Guinea," *Report*, Dept. of Minerals and Energy and Office of Environment and Conservation, 138 pp.

Pizzuto, J. E., 1995, "Downstream fining in a network of gravel-bedded rivers," *Water Resources Research*, 31: 753-759.

Powell, D. M., 1998, Patterns and processes of sediment sorting in gravel-bed rivers," *Progress in Physical Geography*, 22(1): 1-32.

Powell, D. M., I. Reid and J. B. Laronne, 2001, "Evolution of bedload grain-size distribution with increasing flow strength and the effect of flow duration on the caliber of bedload sediment yield in ephemeral gravel-bed rivers," *Water Resources Research*, 37(5), 1463-1474.

Powell, D. M., Laronne, J. B. and Reid, I., 2003, "The dynamics of bedload sediment transport in low-order, upland, ephemeral gravel-bed rivers," *Advances in Environmental Monitoring and Modelling*, 1(2), http://www.kcl/ac/uk/advances/ .

Profitt, G. T., 1980, "Selective transport and armoring of non-uniform alluvial sediments," *Research Report* 80/22, Department of Civil Engineering, University of Canterbury, New Zealand, 203 p.

Proffitt, G. T. and A. J. Sutherland, 1983, "Transport of non-uniform sediments," *Journal of Hydraulic Research*, 21(1), 33-43.

Rahuel, J. L., F. M. Holly, J. P. Chollet, P. J. Belleudy, and G. Yang, 1989, "Modeling of riverbed evolution for bedload sediment mixtures," *Journal of Hydraulic Engineering*, 115(11): 1521-1542.

Rana, S. A., D. B. Simons, and K. Mahmood, 1973, "Analysis of sediment sorting in alluvial channels," *Journal of Hydraulic Engineering*, 99(11): 1967-1980.

Reid, I., L. E. Frostick, and J. T. Layman, 1985, "The incidence and nature of bedload transport during flood flows in coarse-grained alluvial channels," *Earth Surface Processes and Landforms*, 10: 33-44.

Reid, I. and L. E. Frostick, 1986, "Dynamics of bed load transport in Turkey Brook, a coarse-grained alluvial channel," *Earth Surface Processes and Landforms*, 11: 143-155.

Reid, I., J. B. Laronne, and D. M. Powell, 1995, "The Nahal Yatir bedload database: sediment dynamics in a gravel-bed ephemeral stream," *Earth Surface Processes and Landforms*, 20: 845-857.

Reiser, D. W., 1998, "Sediment in gravel bed rivers: ecological and biological considerations," *Gravel-Bed Rivers in the Environment*, Klingeman, P. C., R. L. Beschta, P. D. Komar, and J. B. Bradley, eds., Water Resources Publications, Highlands Ranch, Colorado, USA, 199-225.

Ribberink. J. S., 1987, Mathematical Modeling of One-dimensional Morphological Changes in Rivers with Non-uniform Sediment, *Ph.D. thesis*, Delft University of Technology, 200 p.

Rice, S., 1998, "Which tributaries disrupt fining along gravel-bed rivers?." *Geomorphology*, 22: 39-56.

Rice, S., 1999, "The nature and controls on downstream fining within sedimentary links," *Journal of Sedimentary Research*, 69(1): 32-39.

van Rijn, L. C., 1984, "Sediment transport. I: Bedload transport," *Journal of Hydraulic Engineering*, 110(10), 1613-1641.

Robinson, R. A. J., and R. L. Slingerland, 1998. "Origin of fluvial grain-size trends in a foreland basin: the Pocono formation on the Central Appalachian Basin," *Journal of Sedimentary Research* 68(3), 473-486.

Rood, K. and M. Church, 1994, "Modified freeze-core technique for sampling the permanently wetted streambed," *North American Journal of Fisheries Management*, 14, 852-861.

Rouse, H., 1939, "Experiments on the mechanics of sediment suspension," *Proceedings* 5th International Congress on Applied Mechanics, Cambridge, Mass,, 550-554.

Samaga, B. R., K. E. Ranga Raju, and R. J. Garde, 1986, "Suspended load transport of sediment mixtures," *Journal of Hydraulic Engineering*, 112(11): 1019-1035.

Sambrook Smith, G. H. and R. Ferguson, 1995, "The gravel-sand transition along river channels," *Journal of Sedimentary Research*, A65(2): 423-430.

van der Scheer, P., A. Blom and J. S. Ribberink, 2001, "Transport Formulas for Graded Sediment. Behavior of Transport Formulas and Verification with Experimental Data," *Research Report* 2001-R-004/MICS-023, University of Twente, the Netherlands, 12 p.

Schick, A. P., J. Lekach and Hassan, M. A., 1987, "Vertical exchange of coarse bedload in desert streams," *Desert Sediments: Ancient and Modern*, Frostick, L. E. and I. Reid, eds., Geological Society of London Special Publication No. 25, Blackwell Scientific, 7-16.

Seal, R. and C. Paola, 1995, "Observations of downstream fining on the North Fork Toutle River near Mount St. Helens, Washington," *Water Resources Research*, 31(5): 1409-1419.

Seal, R., C. Paola, G. Parker, J. B. Southard, and P. R. Wilcock, 1997, "Experiments on downstream fining of gravel: I. Narrow-channel runs," *Journal of Hydraulic Engineering*, 123(10): 874-888.

Seminara, G., M. Colombini, and G. Parker, 1996, "Nearly pure sorting waves and formation of bedload sheets," *Journal of Fluid Mechanics*, 312: 253-278.

Seminara, G., L. Solari and M. Tubino, 1997, "Finite amplitude scour and grain sorting in wide channel bends," *Proceedings*, 27th Congress of the International Association for Hydraulic Research, Volume 2, 1445-1450.

Seminara, G,. 1998. Stability and morphodynamics. *Meccanica*, 33: 59-99.

Shaw, J. and R. Kellerhals, 1982, "The Composition of Recent Alluvial Gravels in Alberta River Beds," *Bulletin* 41, Alberta Research Council, Edmonton, Alberta, Canada.

Shields, I. A., 1936, "Anwendung der ahnlichkeitmechanik und der turbulenzforschung auf die gescheibebewegung," *Mitt. Preuss Ver.-Anst.*, 26, Berlin, Germany.

Shih, S.-H., and Komar, P. D., 1990, "Differential bedload transport rates in a gravel-bed stream: a grain-size distribution approach," *Earth Surface Processes and Landforms*, 15: 539-552.

Sidle, R. C., 1988, "Bed load transport regime of a small forest stream,"" *Water Resources Research*, 24(2): 207-218.

Simons, D., 1971, "River and canal morphology," *River Mechanics*, Shen, H. W., ed., publ., Water Resources Publications, LLC, Highlands Ranch, Colorado, Chapter 20: 20-1 – 20-60.

Smart, G. M. and M. N. R. Jaeggi, 1983, "Sediment transport on steep slopes," *Mitteilungen* 64 der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH Zurich, 19-76.

Smart, G. M., 1984, "Sediment transport formula for steep channels," *Journal of Hydraulic Engineering,* 110(3): 267-276.

Smith, J. D. and S. R. McLean, 1977, "Spatially averaged flow over a wavy surface," *Journal of Geophysical Research*, 82(12): 1735-1746.

Smith, R. D., 1990, "Streamflow and bedload transport in an obstruction-affected, gravel-bed stream," Ph.D. thesis, Oregon State University, Corvallis, Oregon, Colorado, 191 p.

Smith, R. D., R. C. Sidle and P. E. Porter, 1993, "Effects on bedload transport of experimental removal of woody debris from a forest gravel-bed stream," *Earth Surface Processes and Landforms*, 18: 455-468.

Solari, L., and G. Parker, 2000, "The curious case of mobility reversal in sediment mixtures," *Journal of Hydraulic Engineering*, 126(3): 198-208.

Speziale, C. G., 1987, "On nonlinear *k-l* and *k*-ε models of turbulence," *Journal of Fluid Mechanics*, 178: 459-475.

Straub, L. G., 1935, "Some observations of sorting of river sediments," *Transactions*, American Geophysical Union Annual Meeting, 16: 463-467.

Sutherland, A. J., 1987, "Static armor layers by selective erosion," *Sediment Transport in Gravel-bed Rivers*, Thorne, C. R. etc., eds., John Wiley & Sons, 343-267.

Sutherland, D. G., M. H. Ball, S. J. Hilton, and T. E. Lisle, 2002, "Evolution of a landslide-induced sediment wave in the Navarro River, California," *Bulletin Geological Society of America*,114(8), 1036-1048.

Suzuki, K, and M. Michiue, 1979, "On the dune height and the influence of sand mixture on its characteristics," *Proceedings*, 23rd Annual Conference on Hydraulic Engineering, Japan Society for Civil Engineering, Tokyo, Japan, 151-156.

Suzuki, K., and K. Kato, 1991, "Mobile bed armoring of bed surface in a steep slope river with gravel and sand mixture," *Proceedings*, International Workshop on Fluvial Hydraulics of Mountain Regions, Trento, Italy, Università degli Studi de Trento, Trento, Italy, 393-404.

Suzuki, K., and A. Hano, 1992, "Grain size change of bed surface layer and sediment discharge of an equilibrium river bed," *Proceedings*, International Seminar on Grain Sorting, Ascona, Switzerland," Mitteilungen 117 der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, ETH Zurich, 151-156.

Swenson, J. B., V. R. Voller, C. Paola, G. Parker, and J. Marr, 2000, "Fluvio-Deltaic Sedimentation: A Generalized Stefan Problem," *Euro. J. Applied Math.*, 11, 433–452.

Tacconi, P., and P. Billi, 1987, "Bed load transport measurements by vortex-tube trap on Virginio Creek, Italy," *Sediment Transport in Gravel-bed Rivers*, Thorne, C. R., J. C. Bathurst, and R. D. Hey, eds., John Wiley & Sons, 583-606.

Tait, S. J., B. B. Willetts, and J. K. Maizels, 1992, "Laboratory observations of bed armoring and changes in bedload composition," *Dynamics of Gravel Bed Rivers*, Billi, P., etc., eds., John Wiley & Sons, 205-225.

Tatsuzawa, H., H. Hayashi and K. Hasegawa, 1999a, "Role of heterogeneous property of bed materials in the formation of step-pool systems in mountain rivers," *Journal of Hydroscience and Hydraulic Engineering*, 17(1), 37-45.

Tatsuzawa, H., H. Hayashi and K. Hasegawa, 1999b, "A study on small-scale bed topography in mountain streams," *Proceedings*, Japan Society for Civil Engineering, 656(II-52), 83-101 (in Japanese).

Thompson, S. M., 1985, "Transport of gravel by flows up to 500 m^3/s, Ohau River, Otago, N. Z.," *New Zealand Journal of Hydraulic Research*, 23(3): 285-303.

Toro-Escobar, C. M., G. Parker and C. Paola, 1996, "Transfer function for the deposition of poorly sorted gravel in response to streambed aggradation," *Journal of Hydraulic Research*, 34(1): 35-53.

Toro-Escobar, C. M., C. Paola, G. Parker, P. R. Wilcock, and J. B. Southard, 2000, "Experiments on downstream fining of gravel. II: Wide and sandy runs," *Journal of Hydraulic Engineering*, 126(3): 198-208.

Tsujimoto, T. and K. Motohashi, 1990, "Static armoring and dynamic pavement," *Journal of Hydroscience and Hydraulic Engineering*, 8(1): 55-67.

Tsujimoto. T., 1991, "Mechanics of Sediment Transport of Graded Materials and Fluvial Sorting," *Report*, Project 01550401, Kanazawa University, Japan, 126 p.

Tsujimoto, T, 1999, "Sediment transport processes and channel incision: mixed size sediment transport, degradation and armoring," *Incised River Channels,* Darby, S. E. and A. Simon, eds., John Wiley & Sons.

Vogel, K. R., A. van Niekerk, R. Slingerland, and J. S. Bridge, 1992, "Routing of heterogeneous sediments over movable bed: model verification," *Journal of Hydraulic Engineering*, 118(2): 263-279.

de Vries, M., 1965, "Considerations about non-steady bed-load transport in open channels," *Proceedings*, 11th Congress, International Association for Hydraulic Research, Leningrad, International Association of Hydraulic Engineering and Research, Madrid, Spain, 381-388.

Waterways Experiment Station, 1935 "Analysis of Mississippi River bed materials," *Paper* 17, Waterways Experiment Station, U. S. Army Corps of Engineers, Vicksburg, MS.

Wathen, S. J., R. I. Ferguson, T. B. Hoey, and A. Werrity, 1995, "Unequal mobility of gravel and sand in weakly bimodal river sediments," *Water Resources Research*, 31(8): 2087-2096.

White, W. R., E. Paris and R. Bettess, 1980, "The frictional characteristics of alluvial streams: a new approach,", *Proceedings* Institution of Civil Engineers, Part 2, 69:737-750.

White, W. R. and T. J. Day, 1982, "Transport of graded gravel bed material," *Gravel-bed Rivers*, Hey, R. D, C. Thorne, and J. Bathurst, eds., John Wiley & Sons, 181-223.

Wiberg, P. L. and J. D. Smith, 1987, "Calculations of the critical shear stress for motion of uniform and heterogeneous sediments," *Water Resources Research*, 23(8): 1471-1480.

Whiting, P. J., W. E. Dietrich, L. B. Leopold, T. G. Drake, and R. L. Shreve, 1988, "Bedload sheets in heterogeneous sediment," *Geology*, 16(2): 105-108.

Whiting, P. J., 1996, "Sediment sorting over bed topography," *Advances in Fluvial Dynamics and Stratigraphy*, Carling, P. A., and M. R. Dawson, eds., John Wiley & Sons, 203-228.

Whittaker, J.G. and M. N. R. Jaeggi, 1982, Origin of step-pool systems in mountain streams, *Journal of Hydraulic Engineering*, 108(6): 758-773.

Wiberg, P. L., and J. D. Smith, 1987, "Calculations of critical shear stress for motion of uniform and heterogeneous sediments," *Water Resources Research*, 23(8): 1471-1480.

Wilcock, P. R., 1988, "Methods for estimating the critical shear stress of individual fractions in mixed-size sediment," *Water Resources Research*, 24(7): 1127-1135. ✓

Wilcock, P. R. and J. B. Southard, 1988, "Experimental study of incipient motion in mixed-size sediment," *Water Resources Research*, 24(7): 1137-1151.

Wilcock, P. R., and B. W. McArdell, 1993, "Surface based fractional rates: mobilization thresholds and partial transport of a sand-gravel sediment," *Water Resources Research*, 25(7), 1629-1641.

Wilcock, P. R., G. M. Kondolf, W. V. G. Mathews and A. F. Barta, 1996, "Specification of sediment maintenance flows for a large gravel-bed river," *Water Resources Research*, 32(9), 2911-2921.

Wilcock, P. R., 1997a, "The components of fractional transport rate," *Water Resources Research*, 33(1): 247-258.

Wilcock, P. R., 1997b, "Entrainment, displacement and transport of tracer gravels," *Earth Surface Processes and Landforms*, 22: 1125-1138.

Wilcock, P. R. and B. W. McArdell, 1997, "Partial transport of a sand/gravel sediment," *Water Resources Research*, 33(1): 235-245.

Wilcock, P. R., 1998a, "Two-fraction model of initial sediment motion in gravel-bed rivers," *Science*, 280: 410-412.

Wilcock, P. R., 1998b, "Sediment maintenance flows: feasibility and basis for prescription," *Gravel-Bed Rivers in the Environment*, Klingeman, P. C., R. L. Beschta, P. D. Komar, and J. B. Bradley, eds., Water Resources Publications, Highlands Ranch, Colorado, USA, 609-633.

Wilcock, P. R., 2000, "The flow, the bed, and the transport: Interaction in flume and field," *Proceedings*, Fifth Gravel-Bed River Workshop, M. P. Mosley, ed., Water Resources Publications, LLC, Highlands Ranch, Colorado, 183-219.

Wilcock, P. R., 2001, "Toward a practical method for estimating sediment-transport rates in gravel-bed rivers," *Earth Surface Processes and Landforms,* 26, 1395-1408.

Wilcock, P. R., Kondolf, G. M., Mathews, W. V. G. and A. F. Bartha, 1996, "Specification of sediment maintenance flows for a large gravel-bed river," *Water Resources Research*, 32(9), 2911-2921.

Wilcock, P. R., S. T. Kenworthy and J. C. Crowe, 2001, "Experimental study of the transport of mixed sand and gravel," *Water Resources Research*, 37(12), 3349-3358.

Wilcock, P. R. and S. T. Kenworthy, 2002, "A two fraction model for the transport of sand-gravel mixtures," *Water Resources Research,* 38(10), 1194-2003.

Wilcock, P. R., and J. C. Crowe, 2003, "Surface-based transport model for mixed-size sediment," *Journal of Hydraulic Engineering*, 129(2), 120-128.

Williams, G. P. and M. G. Wolman, 1984, "Downstream effects of dams on alluvial rivers," *Professional Paper* 1286, US Geological Survey, U.S. Government Printing Office, Washington, D.C., 83 p.

Williams, G. P. and D. L. Rosgen, 1989, "Measured total sediment load (suspended load and bed load) for 93 United States streams," *Open-File Report* 89-67, USGS.

Willetts, B. B., G. Pender, and I. K. McEwan, 1998, "Experiments on the transport of graded sediment," *Proceedings Institution of Civil Engineers Waterways, Maritime and Energy,* 130: 217-225.

Wolman, M. G., 1954, "A method of sampling coarse riverbed material," *Eos Transactions* American Geophysical Union, 35: 951-956.

Wright, S. and G. Parker, 2004a, "Density stratification effects in sand-bed rivers," *Journal of Hydraulic Engineering*, 130(8), 783-795.

Wright, S. and G. Parker, 2004b, "Flow resistance and suspended load in sand-bed rivers: simplified stratification model," *Journal of Hydraulic Engineering*, 130(8), 796-805.

Wu, W., S. S. Y. Wang, and Y. Jia, 2000, "Nonuniform sediment transport in alluvial rivers," *Journal of Hydraulic Research*, 38(6), 427-434.

Yamasaka, M., S. Ikeda and S. Kizaki, 1987, "Lateral sediment transport of heterogeneous bed materials," *Proceedings,* Japan Society of Civil Engineering, 387(II-8): 105-114 (in Japanese).

Yamamoto, K., 1994, *The Study of Alluvial Rivers*," Sankaidou, Tokyo, Japan (in Japanese).

Yang, C. T., 1973, "Incipient motion and sediment transport," *Journal of Hydraulic Engineering*, 99(10), 1679-1704.

Yang, C. T., 1984, Unit stream power equation for gravel," *Journal of Hydraulic Engineering,* 110(12), 1783-1797.

Yang, C. T. and S. Wan, 1991, "Comparisons of selected bed-material load formulas," *Journal of Hydraulic Engineering*, 117(8), 973-990.

Yang, C. T., 1996, *Sediment Transport Theory and Practice*, Mc-Graw Hill, 396 p.

Yatsu, E., 1955, "On the longitudinal profile of the graded river," *Transactions*, American Geophysical Union, 36: 655-663.

Notation for Chapter 3

A_i = volume rate per unit bed area per unit time at which material is lost from gravel in the ith grain size range due to abrasion [LT^{-1}];

A_T = $\sum_{i=1}^{n} A_i$ [LT^{-1}];

A_{sand} = volume rate per unit bed area per unit time at which sand is produced by abrasion of gravel in the ith grain size range [LT^{-1}];

A_{silt} = volume rate per unit bed area per unit time at which silt is produced by abrasion of gravel in the ith grain size range [LT^{-1}];

B_{bf} = bank-full channel width [L];

$\hat{B}$ = B_{bf}/D_{50} = dimensionless bank-full width;

B_c = channel width [L];

B_{ca} = adjusted channel width for sediment transport calculations [L];

B_f = floodplain width [L];

B_v = width of valley flat [L];

C_f = $\tau_b/(\rho U^2)$ = dimensionless bed friction coefficient;

C_{fbf} = dimensionless bed friction coefficient at bank-full flow;

Cz = $U/u_* = C_f^{-1/2}$ = dimensionless Chezy resistance coefficient;

Cz_{bf} = estimate of bank-full value of dimensionless Chezy resistance coefficient;

C_i = dimensionless depth-averaged volume concentration of sediment in the ith grain size range in the channel flow;

C_{fi} = dimensionless depth-averaged volume concentration of sediment in the ith grain size range in the floodplain flow;

C_{ucfi} = dimensionless depth-averaged volume concentration of sediment in the ith grain size range in the layer of channel flow above the level of the floodplain;

$\bar{c}_i$ = local dimensionless volume concentration of suspended sediment averaged over turbulence;

$\bar{c}_T$ = $\sum_{i=1}^{n} \bar{c}_i$ = local dimensionless total volume concentration of suspended sediment;

$\bar{c}_{bi}$ = local near-bed dimensionless volume concentration of suspended sediment averaged over turbulence;

c_{bed} = $= 1-\lambda_p$ = dimensionless volume concentration of sediment in the bed deposit;

$\bar{c}_{bed}$ = dimensionless layer-averaged value of c_{bed}

D = grain size in mm [L];

D_i = characteristic grain size of the ith size range in mm [L];

D_x = grain size such that x percent in a sample is finer [L];

D_{50} = surface median surface grain size [L];

D_{90} = grain size such that 90 percent in a surface sample is finer [L];

D_{84} = grain size such that 84 percent in a surface sample is finer [L];

D_{16} = grain size such that 16percent in a surface sample is finer [L];

D_{u50} = substrate median grain size [L];
D_g = surface geometric mean grain size [L];
D_{ug} = substrate geometric mean grain size [L];
D_m = surface arithmetic mean grain size [L];
D_{um} = substrate arithmetic mean grain size [L];
D_{bulk60} = size such that 60 percent of a bulk bed sample is finer [L];
D_σ = $D_g\sigma_g$ [L];
D_{bi} = volume rate per unit bed area at which sediment in the *i*th grain size range
= is deposited from bed-load transport [LT^{-1}];
D_{bi}^* = $D_{bi}/\sqrt{RgD_i}$ = dimensionless bed-load deposition rate;
D_d = turbulent kinematic eddy viscosity [L^2T^{-1}];
D_{do} = value of D_d for unstratified flow [L^2T^{-1}];
E_{bi} = volume rate per unit bed area at which sediment in the *i*th grain size range is entrained into bed-load transport [LT^{-1}];
E_{bi}^* = $E_{bi}/\sqrt{RgD_i}$ = dimensionless bed-load entrainment rate;
E_{si} = volume rate per unit bed area at which sediment in the *i*th grain size range is entrained into suspension [LT^{-1}];
E_{si}^* = E_{si}/v_{si} = dimensionless entrainment rate into suspension;
$\hat{E}_{si}$ = E_{si}^*/F_i = dimensionless entrainment rate into suspension normalized with content in the active layer of the bed;
F_i = mass fraction of surface material in the *i*th grain size range;
F_{ai} = mass fraction of material in the *i*th grain size range of a surface armor;
F_1 = mass fraction of surface material in the first grain size range;
F_g = mass fraction of the surface material that is gravel;
F_s = mass fraction of the surface material that is sand;
F_{aei} = $= \left(F_iD_i^{-1/2}\right)\Big/\left(\sum_{i=1}^{n}F_iD_i^{-1/2}\right)$ = mass fraction of surface material in the *i*th grain size range adjusted for exposure in computing abrasion;
F_{ai}' = $= \left(F_iD_i^{-1}\right)\Big/\left(\sum_{i=1}^{n}F_iD_i^{-1}\right)$ = adjusted mass fraction of surface material in the *i*th grain size range used in the formulation of Karim (1998);
f_i = local mass fraction of material in the *i*th grain size range of the substrate;
$\bar{f}_i$ = mass fraction of material in the *i*th grain size range averaged over a thick layer of substrate just below the surface layer;
f_{bi} = mass fraction of material in the *i*th grain size range of the bed-load;
$<f_{bi}>$ = mass fraction of material in the *i*th grain size range of the bed-load averaged over morphology;
f_{bG} = mass fraction of bed-load that consists of gravel (rather than sand);
f_{Ii} mass fraction of material in the *i*th grain size range that is interchanged across the surface-substrate interface as the bed aggrades or degrades;
Fr_{bf} = $U_{bf}/\sqrt{gH_{bf}}$ = dimensionless Froude number of bank-full flow;
Fl = dimensionless "floodplain" number in Eq. (3.153);

g	=	acceleration of gravity [LT^{-2}];
H	=	mean channel depth [L]
H_{bf}	=	channel bank-full depth [L];
$\hat{H}$	=	H_{bf}/D_{50} = dimensionless bank-full depth;
H_f	=	depth of flow over floodplain [L];
k_s	=	roughness height of bed [L];
L_a	=	thickness of active (surface) layer of the bed [L];
$L_{1/2}$	=	distance of travel for abrasion to halve grain size [L];
L_{ti}	=	mean distance of travel of a tracer particle in the *i*th size range [L];
L_{t50}	=	mean distance of travel of a tracer particle with size D_{50} [L];
n	=	one of two parameters: a) number of grain size ranges used to discretize the grain size distribution, and b) cross-channel transverse coordinate [L];
n_a	=	L_a / D_{90} = dimensionless factor for active layer thickness;
n_k	=	k_s / D_{90} = dimensionless factor for roughness height;
n_L	=	exponent in a generic bed-load transport relation;
$p(\psi)$	=	volume probability density of of size ψ in a sediment sample;
$p_f(\psi)$	=	cumulative probability that the fraction of sediment in a sample is less than size ψ;
$P_s(y)$	=	probability that the instantaneous bed is higher than relative elevation y;
$p_e(y)$	=	probability density of bed elevation fluctuations;
Q	=	water discharge [L^{3}T^{-1}];
Q_{bf}	=	bank-full water discharge [L^{3}T^{-1}]
$\hat{Q}_{bf}$	=	$Q_{bf} / \left(\sqrt{RgD_{50}}\, D_{50}^2\right)$ = dimensionless bank-full water discharge;
q	=	volume transport rate of bed-load per unit width [L^{2}T^{-1}];
q^*	=	$q / \left(\sqrt{RgD}\, D\right)$ = a dimensionless Einstein number;
q_i	=	volume transport rate of bed-load per unit width of *ith* size range [L^{2}T^{-1}];
q_i^*	=	$q_i / \left(F_i \sqrt{RgD}\, D\right)$ = a surface-based dimensionless Einstein number;
$q_{s,i}$		volume transport rate of bed-load per unit width in the s (streamwise) direction [L^{2}T^{-1}];
$q_{n,i}$		volume transport rate of bed-load per unit width in the n (transverse) direction [L^{2}T^{-1}];
q_{ui}^*	=	$q_i / \left(\bar{f}_i \sqrt{RgD}\, D\right)$ = a substrate-based dimensionless Einstein number;
q_{si}	=	volume transport rate of suspended sediment per unit width of *ith* size range [L^{2}T^{-1}];
$q_{s,i}$	=	volume transport rate of bed-load per unit width of *ith* size range in the s (streamwise) direction [L^{2}T^{-1}];
$q_{n,i}$	=	volume transport rate of bed-load per unit width of *ith* size range in the n (transverse) direction [L^{2}T^{-1}];
q_{bmi}	=	$q_i + q_{si}$ = volume transport rate per unit width of bed material load in the *i*th grain size range [L^{2}T^{-1}];
q_{bmi}^*	=	$q_{bmi} / \left(F'_{ai} \sqrt{RgD_i}\, D_i\right)$ = a dimensionless Einstein number for total bed material load;

q_T	=	$\sum_{i=1}^{n} q_i$ = total volume bed-load transport rate per unit width [L^2T^{-1}];
q_{obi}	=	volume rate per unit streamwise distance at which sediment in the *i*th size range is delivered from the channel to the floodplain [L^2T^{-1}];
R	=	$(\rho_s - \rho)/\rho$ = dimensionless submerged specific gravity of sediment;
Re_p,	=	$\left(\sqrt{RgD}\, D\right)/\nu$ = a dimensionless particle Reynolds number;
Re_{pg},	=	$\left(\sqrt{RgD_g}\, D_g\right)/\nu$ = a dimensionless particle Reynolds number;
Re_{pug}	=	$\left(\sqrt{RgD_{ug}}\, D_{ug}\right)/\nu$ = a dimensionless particle Reynolds number;
Re_{p50}	=	$\left(\sqrt{RgD_{50}}\, D_{50}\right)/\nu$ = a dimensionless particle Reynolds number;
Re_{pm}	=	$\left(\sqrt{RgD_m}\, D_m\right)/\nu$ = a dimensionless particle Reynolds number;
Re_{pi}	=	$\left(\sqrt{RgD_i}\, D_i\right)/\nu$ = a dimensionless particle Reynolds number;
RI_g	=	dimensionless gradient Richardson number defined by Eq. (3.133b);
S	=	dimensionless downchannel bed slope;
S_e	=	dimensionless downchannel energy slope;
S_f	=	dimensionless downchannel friction slope;
s	=	downchannel streamwise coordinate [L];
s_v	=	downvalley streamwise coordinate [L]
t	=	time [T];
U	=	depth-averaged or cross-sectionally averaged streamwise flow velocity [LT^{-1}];
U_{bf}	=	bank-full value of U [LT^{-1}];
$\overline{u}$	=	local streamwise flow velocity averaged over turbulence [LT^{-1}];
u_*	=	$\sqrt{\tau_b/\rho}$ = shear velocity [LT^{-1}];
u_{*bf}	=	$\sqrt{\tau_{bbf}/\rho}$ = estimate of shear velocity at bank-full flow [LT^{-1}];
u_{*s}	=	$\sqrt{\tau_{bs}/\rho}$ = shear velocity due to skin friction [LT^{-1}];
V_p	=	particle volume [L^3];
v_{bi}	=	mean virtual velocity of transport of the *i*th grain size [LT^{-1}];
v_{si}	=	fall velocity of size D_i [LT^{-1}];
W^*	=	$(Rgq)/u_{*s}^3$ = a dimensionless bed-load transport rate;
W_i^*	=	$(Rgq_i)/\left(F_i u_{*s}^3\right)$ = a dimensionless bed-load transport rate;
W_{ui}^*	=	$(Rgq_i)/\left(\bar{f}_i u_{*s}^3\right)$ = a dimensionless bed-load transport rate;
W_{sui}^*	=	$(Rgq_{si})/\left(\bar{f}_i u_{*s}^3\right)$ = a dimensionless suspended load transport rate;
W_r^*	=	dimensionless reference value of W^*;
$\overline{w}$	=	local upward normal flow velocity averaged over turbulence [LT^{-1}];
y	=	$z - \eta$ = local bed elevation relative to mean bed elevation [L];
z	=	upward normal coordinate from the bed in the water column; vertical coordinate within the bed deposit [L];
z_b	=	reference value of z above the bed for calculations of near-bed suspended sediment concentrations [L];

α_v	=	grain volume abrasion coefficient [L^{-1}];
α_d	=	grain size abrasion coefficient [L^{-1}];
α_{di}	=	grain size abrasion coefficient for *i*th grain size range [L^{-1}];
β	=	dimensionless coefficient in Eq. (3.118) for transverse bed-load rate
$\beta_{iD}(y)$	=	dimensionless grain size-specific bias function for bed-load deposition at level *y* relative to the mean position of the bed;
$\beta_{iE}(y)$	=	dimensionless grain size-specific bias function for bed-load entrainment at level *y* relative to the mean position of the bed;
γ	=	exponent in power hiding relations
ϕ	=	- ψ; grain size on base-2 logarithmic scale;
η	=	bed elevation [L];
η_b	=	elevation to base of the active layer of the bed [L];
η_f	=	elevation of top of floodplain [L];
κ	=	0.4; dimensionless von Karman constant;
λ_p	=	dimensionless porosity of bed deposit;
ν	=	kinematic viscosity of water [L^2/T]
ρ	=	density of water [ML^{-3}];
ρ_s	=	material density of sediment [ML^{-3}];
Σ_{sin}	=	dimensionless channel sinuosity;
σ	=	arithmetic standard deviation of surface grain size distribution on ψ scale;
σ_u	=	arithmetic standard deviation of substrate grain size distribution on ψ scale;
σ_g	=	geometric standard deviation of surface grain size distribution on ψ scale;
σ_{ug}	=	geometric standard deviation of substrate grain size distribution on ψ scale;
σ_{sub}	=	subsidence rate due to tectonism or other effects [LT^{-1}];
τ_b	=	boundary shear stress at bed [$ML^{-1}T^{-2}$];
τ_{bs}	=	boundary shear stress due to skin friction at bed [$ML^{-1}T^{-2}$];
$\vec{\tau}_{bs}$	=	$(\tau_{bs,s}, \tau_{bs,n})$ = vectorial boundary shear stress due to skin friction with components in the *s* (streamwise) and *n* (transverse) direction, respectively [$ML^{-1}T^{-2}$];
τ_s^*	=	$\tau_{bs}/(\rho RgD)$ = a dimensionless Shields number;
τ_{bbf}	=	estimate of boundary shear stress at bed at bank-full flow according to Eq. (3.14a);
τ_{bf50}^*		$\tau_{bbf}/(\rho RgD_{50})$ = a dimensionless Shields number;
τ_{50}^*	=	$\tau_b/(\rho RgD_{50})$ = a dimensionless Shields number;
τ_{si}^*	=	$\tau_{bs}/(\rho RgD_i)$ = a dimensionless Shields number;
τ_{sg}^*	=	$\tau_{bs}/(\rho RgD_g)$ = a dimensionless Shields number;
τ_{sm}^*	=	$\tau_{bs}/(\rho RgD_m)$ = a dimensionless Shields number;
τ_{s50}^*	=	$\tau_{bs}/(\rho RgD_{50})$ = a dimensionless Shields number;
τ_{bsci}	=	critical value of τ_{bs} for the onset of motion for the *i*th grain size [$ML^{-1}T^{-2}$];

τ^*_{sci}	=	$\tau_{bsci}/(\rho RgD_i)$ = a dimensionless critical Shields number;
τ_{bscg}	=	critical value of τ_{bs} for the onset of motion for the size D_g [$ML^{-1}T^{-2}$];
τ^*_{scg}	=	$\tau_{bscg}/(\rho RgD_g)$ = a dimensionless critical Shields number;
τ_{bscm}	=	critical value of τ_{bs} for the onset of motion for the size D_m [$ML^{-1}T^{-2}$];
τ^*_{scm}	=	$\tau_{bscm}/(\rho RgD_m)$ = a dimensionless critical Shields number;
τ_{bssri}	=	surface-based reference value of τ_{bs} for the size D_i [$ML^{-1}T^{-2}$];
τ^*_{ssri}	=	$\tau_{bssri}/(\rho RgD_i)$ = a dimensionless reference Shields number;
τ_{bssrg}	=	surface-based reference value of τ_{bs} for the size D_g [$ML^{-1}T^{-2}$];
τ^*_{ssrg}	=	$\tau_{bssrg}/(\rho RgD_g)$ = a dimensionless reference Shields number;
τ_{bssr50}	=	surface-based reference value of τ_{bs} for the size D_{50} [$ML^{-1}T^{-2}$];
τ^*_{ssr50}	=	$\tau_{bssr50}/(\rho RgD_{50})$ = a dimensionless reference Shields number;
τ_{bsuci}	=	substrate-based critical value of τ_{bs} for the size D_i [$ML^{-1}T^{-2}$];
τ^*_{suci}	=	$\tau_{bsuci}/(\rho RgD_i)$ = a dimensionless critical Shields number;
τ_{bsucg}	=	substrate-based critical value of τ_{bs} for the size D_{ug} [$ML^{-1}T^{-2}$];
τ^*_{sucg}	=	$(\tau_{bsucg}/\rho RgD_{ug})$ = a dimensionless critical Shields number;
τ_{bsuri}	=	substrate-based reference value of τ_{bs} for the size D_i [$ML^{-1}T^{-2}$];
τ^*_{suri}	=	$\tau_{bsuri}/(\rho RgD_i)$ = a dimensionless reference Shields number;
τ_{bsurg}	=	substrate-based reference value of τ_{bs} for the size D_{ug} [$ML^{-1}T^{-2}$];
τ^*_{surg}	=	$\tau_{bsurg}/(\rho RgD_{ug})$ = a dimensionless reference Shields number;
τ^*_{su50}	=	$\tau_{bs}/(\rho RgD_{u50})$ = a dimensionless Shields number;
τ_{bsur50}	=	substrate-based reference value of τ_{bs} for the size D_{u50} [$ML^{-1}T^{-2}$];
τ^*_{sur50}	=	$\tau_{bsur50}/(\rho RgD_{u50})$ = a dimensionless reference Shields number;
τ_{bsuc50}	=	substrate-based critical value of τ_{bs} for the size D_{u50} [$ML^{-1}T^{-2}$];
τ^*_{sc50}	=	$\tau_{bsuc50}/(\rho RgD_{u50})$ = a dimensionless critical Shields number;
ξ		water surface stage or elevation [L]
ψ	=	grain size on base-2 logarithmic psi scale defined by Eq. (3.1);
ψ_m	=	arithmetic mean size of surface material on psi scale;
ψ_i	=	ith bounding grain size on psi scale defining ranges in size distribution;
$\overline{\psi}_i$	=	$(\psi_i + \psi_{i+1})/2$ = characteristic size on phi scale of ith grain size range.

Figure Captions

Figure 3.1 Contrasts in surface armoring between a) the River Wharfe, UK, a perennial stream with a low sediment supply (left) and b) the Nahal Yatir, Israel, an ephemeral stream with a high rate of sediment supply (right). From Powell (1998).

Figure 3.2 Sediment sorting in the presence of a dune field. Flow was from top to bottom. Image courtesy A. Blom.

Figure 3.3 Pulsations associated with experimental bed-load sheets composed of a mixture of sand and gravel. a) Alternating arrangement of three bed states. b) Fluctuation in gravel transport rate. c) Fluctuation in sand transport rate. From Iseya and Ikeda (1987).

Figure 3.4 View of the Ooi River, Japan, showing sorting of gravel and sand on bars. From Ikeda (2001).

Figure 3.5 Step-pool topography in the Hiyamizu River, Japan. Image courtesy K. Hasegawa

Figure 3.6 View of sedimentation upstream of a sediment retention dam on the North Fork Toutle River, Washington, USA. Flow is from bottom to top. From Seal and Paola (1995).

Figure 3.7 Sorted sediment patches on the North Fork Toutle River, Washington, USA: a) coarse patch on fine sediment; b) fine patch on coarse sediment. From Paola and Seal (1995).

Figure 3.8 Streaks of sorted sediment in a) a laboratory flume (from Günter, 1971; courtesy A. Müller), and b) a river (image courtesy T. Tsujimoto).

Figure 3.9 Coarse static armor (dark grains) with a partial coverage of finer, mobile sediment (light grains) on the bed of the Trinity River, California, USA. The coarse grains are rendered immobile by the presence of the Lewiston Dam upstream. Image courtesy A. Bartha. a) View of the river. b) Closeup of the bed.

Figure 3.10 a) Long profile and b) downstream change in grain size of the Kinu River, Japan, illustrating downstream fining and a gravel-sand transition. Redrafted from an original in Yatsu (1955).

Figure 3.11 Grain size distribution of 174 samples of bed sediment from rivers in Alberta, Canada. From Shaw and Kellerhals (1982).

Figure 3.12 View of a landslide that blocked the Navarro River, California., USA in 1995. Image courtesy T. Lisle.

Figure 3.13 Four sediment samples from the Ok Tedi River system, Papua New Guinea. a) 1 km downstream of the Southern Dumps of the Ok Tedi Mine, and after having passed over a high waterfall, in the Harvey Creek debris flow fan as it enters the Ok Mani; b) 8 km downstream, at the fluvial fan of the Ok Mani where it enters the Ok Tedi; c) 27 km downstream on the Ok Tedi near the junction with the Ok Menga; and d) 90 km downstream on the Ok Tedi at Ningerum Flats. Note that the grains become progressively rounder as the distance from the source increases.

Figure 3.14 Evidence of channel degradation on the Mad River, California under the Highway 101 bridge.

Figure 3.15 Bed surface median grain size downstream of Hoover Dam on the Colorado River before and after closure. From Williams and Wolman (1984).

Figure 3.16 a) View of waste rock dump site at the Ok Tedi Mine, Papua New Guinea. b) View of the gravel-bed Ok Tedi downstream of the mine. The channel bed has aggraded and widened in response to disposal of mine sediment. c) View of the sand-bed Fly River downstream of its confluence with the Ok Tedi. Aggradation of bed sediment has exacerbated both flooding and the overbank deposition of fine sediment, resulting in the loss of riparian forest.

Figure 3.17 a) Diagram illustrating the probability density and distribution functions of a unimodal sediment sample. b) Diagram illustrating the probability density and distribution functions of a bimodal sediment sample. c) Plot of probability distribution function for a sand-gravel mix with constant content density as percent finer versus logarithmic grain size ψ. d) Plot of the same probability distribution function versus D in mm on a linear scale.

Figure 3.18 Plot of number of reaches for which characteristic grain size is within the specified grain size range for streams in Alberta, Canada and Japan.

Figure 3.19 Diagram illustrating the definition of bank-full discharge in terms of the stage-discharge (ξ - Q) relation.

Figure 3.20 Dimensionless bank-full depth $\hat{H}$ versus dimensionless bank-full discharge $\hat{Q}$.

Figure 3.21 Dimensionless bank-full width $\hat{B}$ versus dimensionless bank-full discharge $\hat{Q}$.

Figure 3.22 Channel bed slope S versus dimensionless bank-full discharge $\hat{Q}$.

Figure 3.23 Dimensionless Shields number $\tau_{bf50}{}^*$ based on bank-full flow and D_{50} versus dimensionless bank-full discharge $\hat{Q}$.

Figure 3.24 Dimensionless Shields number τ_{bf50}^* based on bank-full flow and D_{50} versus channel bed slope S.

Figure 3.25 Dimensionless Chezy friction coefficient Cz_{bf} versus channel bed slope S.

Figure 3.26 Dimensionless Chezy friction coefficient Cz_{bf} versus dimensionless depth $\hat{H}$.

Figure 3.27 Froude number at bank-full flow Fr_{bf} versus channel bed slope S.

Figure 3.28 Bank-full width-depth ratio B/H versus channel bed slope S.

Figure 3.29 Dimensionless Shields number based on bank-full flow τ_{bf50}^* versus particle Reynolds Re_{p50} number based on D_{50}. Also included is a point from Sagehen Creek, California, USA.

Figure 3.30 Extended version of Figure 3.29 including data from Japanese streams and the empirical regime relation of Yamamoto (1994).

Figure 3.31 Definition diagram showing a) the spatial variation of bed elevation at a given time or temporal variation of bed elevation at a given location; b) the probability density of bed elevation; c) the probability of entrainment per unit time of a grain as a function of elevation in the bed; and d) the approximation of c) embodied in the active layer approximation.

Figure 3.32 Definition diagram for the active layer concept.

Figure 3.33 Plots illustrating the use of similarity. a) Plot of W_i^* versus τ_{si}^* for a case for which similarity collapse is realized. b) Similarity plot of the data of the figure to the left which results in a perfect collapse. c) Plot of W_i^* versus τ_{si}^* for a case for which similarity collapse is not realized. d) Similarity plot of the data of the figure to the left does not results in a collapse.

Figure 3.34 Plot of critical Shields number versus particle Reynolds number showing a) the Brownlie (1981) fit to the original Shields (1936) curve, b) the modified Brownlie fit of Eq. (3.71), c) the data of Buffington and Montgomery (1997) pertaining to τ_{cv50m}^* and d) the gravel-bed rivers of Figure 3.29.

Figure 3.35 Plots of a) hiding function obtained from Egiazaroff relation, the modified Egiazaroff relation, the condition of size-independence, the condition of equal-threshold, and the power relations of Eqs. (3.74a,b) using $\gamma_{subref} = 0.81$, $\gamma_{surfref} = 0.90$ and $\gamma_{surflarg} = 0.72$; and b) reduced hiding functions corresponding to a) above.

Figure 3.36 Plots of the functions $\sigma_O(\phi_{sgo})$ and $\omega_O(\phi_{sgo})$ for the Parker (1990a) relation.

Figure 3.37 Plot of D_u/D_{50} as a function of τ_{50}^* for the hiding function of Proffitt and Sutherland (1983) as applied to the sediment transport relation of Ackers and White (1973).

Figure 3.38 Predictions of bed-load transport using the relations of Ashida and Michiue (1972) (A-M), Parker (1990a) (P(S)), Powell et al. (2001) (P-R-L), Hunziker and Jaeggi (2002) (H-J) and Wilcock and Crowe (2003) (W-C). a) Grain size distributions for bed-load calculations, b) total gravel bed-load transport rate, c) geometric mean size of gravel bed-load, d) gravel geometric standard deviation of gravel bed-load, and e) fraction of gravel in bed-load (the rest being sand).

Figure 3.39 Plots of q_i/F_i versus D_i for a) Oak Creek field data as presented by Wilcock (1997a); b) experiments of Wilcock and McArdell (1997); and c) Nahal Eshtemoa field data of Powell et al. (2001).

Figure 3.40 Dimensionless Einstein number based on total bed-load transport rate q_T^* versus Shields number τ_{50}^* for six streams: Goodwin Creek, Mississippi, USA, East Fork River, Wyoming, USA, Oak Creek, Oregon, USA, Nahal Yatir, Israel, Turkey Brook, England, UK and Torlesse Stream, New Zealand. From Reid et al., (1995).

Figure 3.41 Abrasion coefficients α_d obtained from experiments by various researchers, as presented by Kodama (1994a).

Figure 3.42 Definition diagram for in-channel and overbank flow in a river.

Figure 3.43 Evolution of stone cells on the bed surface of a laboratory flume as the bed evolves in response to the cutoff of sediment supply, as observed by Hassan and Church (2000). Hassan and Church also document the presence of these cells in the case of an equilibrium mobile-bed armor; the higher the sediment transport rate, the less developed are the cells.

Figure 3.44 Figure 3.44 Examples of comparisons of a numerical model of evolution to static armor versus experimental data from a laboratory flume, in which x denotes distance downstream; from Tsujimoto (1999).

Figure 3.45 Conceptual diagram illustrating the evolution of a static armor from equilibrium mobile-bed conditions as the sediment feed rate is repeatedly halved.

Figure 3.46 Flash flood in the ephemeral Nahal Eshtemoa, Israel: a) arrival of the flood wave (looking upstream); and b) passage of the flood wave (looking downstream). Images courtesy J. Laronne.

Figure 3.47 a) Predicted variation of the ratios D_g/D_{bg} and D_{50}/D_{b50} in τ_{50}^*, along with a bank-full value of τ_{50}^* for Sagehen Creek and two values of τ_{50}^* for the Nahal Yatir that bracket most of the bed-load data. b) Assumed normalized grain size distribution for bed-load, along with predicted grain size distributions for static armor and mobile armor at the values of τ_{50}^* shown in the legend.

Figure 3.48 Normalized mean annual bed-load (solid circles) and substrate (solid squares) grain size distributions for 14 gravel-bed rivers studied by Lisle (1995). The grain size distributions have been truncated at 1 mm. The hollow circles and squares pertain to fractions in each range.

Figure 3.49 Illustration of various aspects of downstream fining in the Red Deer River, Alberta, Canada. a) Long profile of the Red Deer River. b) Downstream variation in D_{50} and D_{90} in the Red Deer River. c) Downstream variation in three lithologies in the Red Deer River. From Shaw and Kellerhals (1982).

Figure 3.50 Illustration of downstream fining in the Allt Dubhaig, Scotland, UK, showing the long profile of the river (top) and grain size distributions of bulk surface samples taken at various points down the stream (bottom). From Ferguson et al (1996).

Figure 3.51 Illustration of downstream fining produced in a laboratory channel; in Run 5 of Toro-Escobar et al. (2000). The channel width is 2.7 m. a) The upstream 20 m of the deposit. b) The downstream 20 m of the deposit. Flow was from top to bottom.

Figure 3.52 Side view of step-pool topography formed in the laboratory. Image courtesy K. Hasegawa.

Figure 3.53 Downstream fining in the Mississippi River, USA. a) Downstream variation in grain size distribution. b) Downstream variation in mean grain size.

Figure 3.54 Downstream variation in D_{50} and D_{90} in the middle Fly River, Papua New Guinea in 1979, before the opening of the Ok Tedi copper mine in 1985.

Figure 3.55 View of the floodplain of the Minnesota River, Minnesota, USA during the flood of record in 1965.

Figure 3.56 a) View of a reach of Silver Bow Creek, Montana, USA in which the floodplain is so rich in toxic sediments that vegetation cannot take hold. The toxic sediment is derived from the Anaconda copper mine near Butte, Montana; the flood that deposited the sediment occurred in 1910. b) View of an uncontaminated, healthy tributary of Silver Bow Creek.

Figure 3.57 Diagram illustrating floodplain deposition.

Figure 3.58 Relative travel distance of tracers in each size class as a function of relative grain size. From Ferguson and Wathen (1998).

Figure 3.59 Diagram illustrating the use of "Leopold" scour chains to measure scour and fill associated with a flood. From Haschenburger (1999).

Figure 3.60 Schematization of the pattern of vertical sorting generated by the successive passage of dunes over a bed of heterogeneous sediment.

Figure 3.61 a) Experimental dunes. b) $P_s(y)$ as a function of y for the bed of part a). c) Pattern of stratification and sorting created by the passage of dunes in the flume illustrated in part a). From Parker et al. (2000).

Sec 2.3 Ref 23

Pan Evaporation Records for the South Carolina Area

Southeast Regional Climate Center Columbia, SC

by: John C. Purvis

(http://www.dnr.sc.gov/climate/sco/Publications/pan_evap_records.php)

Evaporation is an important, but often-overlooked, climate element. Evaporation affects both plant and animal life and is a major factor in man's comfort and well-being. In spite of its importance, evaporation is routinely measured at only a few meteorological stations in South Carolina.(1)

The usual way of measuring evaporation is through the use of a type of atmometer, an evaporation pan (2). The National Weather Service's Class-A Evaporation Pan is a cylindrical container fabricated of monel metal with a depth of ten inches and a diameter of forty-eight inches. The pan is leveled at a site that is usually well-sodded and free from obstructions. The pan is filled with water to a depth of about eight inches, and daily measurements are made of the water level. When the water level drops to seven inches, the pan is refilled. Daily measurements are corrected as necessary for rainfall, and in some cases water temperature. The resulting daily water loss is the pan evaporation for the period considered, usually 24 hours.

Pan evaporation is usually greater than the actual evaporation from nearby land surfaces. A widely accepted coefficient of pan evaporation to the actual evaporation is approximately 0.70(3). For example, if pan evaporation on a typical day were 0.20 inches and the coefficient of pan evaporation were 0.70, the true evaporation would be approximately 0.14 inches (0.20 x 0.7). One reason that the pan evaporation measurements average more than evaporation from nearby land surfaces is that the evaporation pan always presents a freely evaporating surface to the atmosphere. Another factor is that the sensible-heat transfer through evaporation pans can be appreciable and tends to increase the pan evaporation.

Prompted by the need for evaporation data, the Southeast Regional Climate **(SERCC), in cooperation with the National Climatic Data** (NCDC), initiated an evaporation study of pan evaporation data collected in the Southeast. The purpose of this study is to increase the reliability of this data and to enhance usage in meeting the evaporation needs of agriculture, industry, state water planning, and related research demands.

The first work is limited to pan evaporation data collected in South Carolina and nearby stations located in North Carolina and Georgia. Once operating quality control and estimation procedures have been finalized and techniques developed for meeting these objectives, the study will be expanded to include pan evaporation data available across the Southeast.

The first location selected for this study was Clemson University's Edisto Experiment Station. This evaporation station is located in southern South Carolina approximately three miles west of Blackville, South Carolina. Edisto Experimental Station is in a rural area and is representative of a large progressive agricultural area.

An examination of pan evaporation records from the Edisto Experiment Station revealed some missing data, mostly of a one to two day event occurrence. It was decided to use a method devised by Thornthwaite and Mather(4) using temperature to calculate unadjusted potential evapotranspiration. This is basically an empirical measurement of the evaporative power of the air. Other more accurate methods using solar radiation were investigated but not used due to the lack of solar radiation measurements. Thornthwaite's technique may not be the most accurate method, but it does surprisingly well in the Southeast(5). It operates on the assumption that mean temperature and day length represent the most important criteria which influence potential evaporation and that all other factors tend to average out in most cases over an extended period. Based on the above assumption (6), the mean temperature (Figure 1) and the day length in units of 12 hours (Figure 2) were calculated for each occurrence of missed pan evaporation data. Using this information the unadjusted potential evapotranspiration (PET) was computed for each date of missing data.

Since evaporation pans tend to increase the actual pan evaporation (7), it is necessary to inflate the unadjusted potential evaporation data computed by the Thornthwaite method, before substituting these data for the missing pan readings. Kohler, Nordenson, and Bader computed evaporation pan coefficients for the entire nation. Kohler's values were used to adjust the potential evapotranspiration to reflect pan evaporation (Figure #3). These adjusted values were then substituted for the missed entries.

1. ANALYSIS OF DATA:

After all short periods of missing data were computed, pan evaporation data for the various sites in or near South Carolina were grouped, as available, for each decade beginning with 1950. Since the period of study ended with the 1992 records, the decade beginning with 1990 only included 1990-1992 information. Comments concerning this grouping are as follows:

A. ATHENS COLLEGE OF AGRICULTURE, GEORGIA (See Table #1)
(1) Number: 09043202
(2) Lat., Long.: 33 55N 083 22W
(3) Elevation: 689ft MSL
(4) Time of Obsn: unknown
(5) Significant Moves: Moved to University of Georgia Plant Science Farm in 1971.

B. UNIVERSITY OF GEORGIA PLANT SCIENCE FARM (See Table #2)
(1) Number 09895002
(2) Lat., Long.: 33 52N 083 22W
(3) Elevation: 840ft MSL

(4) Time of Obsn: 08
(5) The University of Georgia Plant Science Farm is sevaral miles southwest of the Athens College of Agriculture observation site. The combined observation record from these two sites cover the period 1953-1992. It is difficult to isolate a definite trend although the measurements from the University of Georgia Science Farm after 1971 are slightly higher than those from the Athens College Station. It is interesting to note that these locations are a higher elevation than the Clark Hill site. This should contribute to a lower evaporation rate at these two stations than that of Clark Hill. In sharp contrast to this expectation, however, the reverse is true. The readings from the Georgia stations are not lower but considerably higher than Clark Hill's.

B. CATALOOCHEE, N.C. (See Table #3)
(1) Number 31156401
(2) Lat., Long.: 35 37N, 83 6W
(3) Elevation: 2620ft MSL
(4) Significant Moves: Before 1972 the evaporation pan was located at Lat. 35 38N, Long. 083 05W. Although located outside South Carolina pan evaporation measurements from this station give some indication of what might be expected in the higher elevations of the mountains of South Carolina. Readings during the colder period of the year, December-March are not available. No definite trends were noted in the Cataloochee records.

C. CHAPEL HILL, N.C. (See Table #4)
(1) Number 31167703
(2) Lat., Long.: 35 55N, 79 06W
(3) Elevation: 500ft MSL
(4) Time of Obsn.: 08
(5) Significant Moves: none
Due to the breaks in the Chapel Hill data, it is impossible to define any specific trend. If South Carolina isolines were extended into North Carolina, the average decadal pan evaporation values are approximately what would be expected.

D. CHARLESTON, S.C. (CHARLESTON AIRPORT, See Table #5)
(1) Number 38154407
(2) Lat., Long.: SC 32 54N, 80 02W
(3) Elevation: 40ft MSL
(4) Time of Obsn.: Mid
(5) Significant Moves: Evaporation pan was relocated on the other side of the Airport in 1982. Changes in elevation and exposure were minor.
(6) Remarks: Charleston's pan evaporation records were averaged for each decade beginning 1960. These decadal annual averages showed an upward trend with January 1970-79 having the lowest values.

E. CLARK HILL, S.C. (See Table #6)
(1) Number: 38172605
(2) Lat., Long., 33 40N, 82 11W

(3) Elevation 380ft MSL
(4) Time of Obsn.: 08
(5) Significant Moves: none
The pan evaporation records for Clark Hill differ considerable from those of surrounding stations. This anomaly merits further study. The Clark Hill pan evaporation site is downwind from Thurmond Lake, a large hydro-electric facility on the Savannah River. It appears that this site is not representative of a large portion of the Savannah Valley. Decadal annual pan evaporation averages for Clark Hill decreased through 1979 but increased significantly during the 1980-89 period. The period 1990-92, however, showed a decrease in all monthly averages except January and February which revealed an upward trend.

F. CLEMSON, S.C. (see Table#7)
(1) Number 38177002
(2) Lat., Long.: 34 41N 082 49W
(3) Elevation: 819ft MSL
(4) Time of Obsn.: 08*
Observation time was 1700 from beginning of observations until July 1963, and from October 1965 to April 1973.
(5) Significant moves: Before August 1973 the evaporation pan was located at Lat. 34 40N, Long. 082 50W.
Clemson's pan evaporation data were summarized in decadal form from 1950 to 1992. Annual averages increased through 1979 but have shown a downward trend beginning with the 1980-89 decade. The average monthly decadal values for January and February, however, do not reflect the same trend, and have fallen from 1950 through the decade ending in 1989, but increased during the 1990-92 period.

G. EDISTO EXPERIMENTAL STATION (Blackville 3W, See Table #8)
(1) Number: 38076407
(2) Lat., Long.: 33 22N, 81 19W
(3) Elevation 324ft MSL
(4) Time of Obsn.: 17
(5) Significant Moves: The Edisto Experiment Station located three miles west of Blackville began pan evaporation measurements in 1963. The average annual pan evaporation during the periods 1963-1969 and 1970-79 increased but showed a slight decrease during the 1980-89 decade. This decrease was more significant during the summers of the 1990-92 period.

H. FLORENCE 8NE (See Table #9)
(1) Number: 38311104
(2) Lat., Long.: 34 18N, 079 44W*
(3) Elevation 120 ft MSL
(4) Time of Obsn.: 08
(5) Significant Moves: * Before July 1983 the pan evaporation station was located at Lat. 34 13N, and Long. 079 46W. The station moved 6.5 miles from 2 miles north of Florence

to 8 miles northeast of Florence. There is no significant change in soil type or topography between the two stations.

Florence's period of observations are relatively short but correspond nicely with nearby pan evaporation observations. There was a slight increase in annual averages during the period of record, although the average monthly changes were mixed with a few months reporting lower values.

I. HOFMAN FOREST, N.C. (See Table 10)
(1) Number 31414406
(2) Lat., Long., 34 50N 77 18W
(3) Elevation 44ft MSL
(4) Time of Obsn: 19
(5) Significant Moves: none
This station is located in extreme eastern North Carolina. Unfortunately, the records are not long enough to establish any trend.

J. LUMBERTON 3SE, N.C. (See Table #11)
(1) Number 31517706
(2) Lat., Long.: 34 37N 078 59W
(3) Elevation 112ft MSL
(4) Time of Obsn. 08
(5) Significant Moves: During the period 1958-1960 the station was located at Lat. 34 42N, Long. 079 00W. Lumberton's relatively large pan evaporation measurements are more than those made at nearby stations. This is not unexpected, however, due to the location of Lumberton to the Sandhill area of North Carolina. There has been no significant change in Lumberton's annual pan evaporation readings during the period of record.

K. SANDHILL RESEARCH STATION-ELGIN (See Table #12)
(1) Number 38766606
(2) Lat., Long.: 34 08N 080 52W
(3) Elevation 440ft MSL
(4) Time of Obsn.: 08
(5) Significant Moves: none
The pan evaporation records for the Sandhill Research Station were consistently higher than pan evaporation measurements in the upper coastal plain or the lower piedmont. These higher evaporation measurements at the Sandhill Station result from the effect of the sandy terrain. The sandy soils dry out more rapidly than clay or loamy soils and during the summer heat more rapidly with accompanying lower relative humidities and higher evaporation rates. In reviewing the Sandhill records, no definite trend was noted. The average annual decadal pan evaporation decreased in the 1970s, increased in the 1980s but decreased thereafter.

L. SAVANAH WEATHER SERVICE OFFICE AIRPORT (See Table #13)
(1) Number 09784709

(2) Lat., Long.: 32 08N 081 12W
(3) Elevation 046ft MSL
(4) Time of Obsn.: 07
(5) Significant Moves: unk
Observations for the 1965-69 period were slightly larger than the decadal average for 1970-79. There has been, however, a slight upward trend since 1980. This upward trend agrees quite well with the measurements made at Charleston.

M. UNION 7SW (SOUTHEAST FOREST EXPERIMENT STATION, See Table #14)
(1) Number 38878602
(2) Lat., Long.: 34 38N 81 40W
(3) Elevation 500ft MSL
(4) Time of Obsn.: 07
(5) Significant Moves: Station was relocated in 1964 to a new site with different exposure. Evaporation observations were discontinued at the time of relocation. The relatively short period of pan evaporation measurements from Union conform quite well with readings from surrounding stations. The period is too short, however, to confirm any definite trend.

2. VARIATION OF PAN EVAPORATION ACROSS SOUTH CAROLINA

There is considerable variation in the average monthly and annual pan evaporation measurements across South Carolina (Fig 4-8). The largest annual pan evaporation readings during the period of record are in the extreme southeast part of South Carolina where annual totals exceed 60 inches. The average annual 60 inch isoline enters the State south of Myrtle Beach and proceeds southwest into Georgia about 40 miles northwest of Savannah. Pan evaporation elsewhere over the Coastal Plains is between 50 and 60 inches per year. A second area of pan evaporation readings exceeding 60 inches per year is in the Sandhills or the narrow northeast-southwest belt that extends through the central part of the state and corresponds to the location of the Fall Line separating the Coastal Plain from the Piedmont. Moving northwest across the Piedmont, pan evaporation measurements decrease with annual totals of around 40 inches in the higher mountains of northwest South Carolina. The only significant anomaly to the above are the Clark Hill ovservations which are lower than nearby areas. The Clark Hill anomaly merits further study. The Clark Hill evaporation pan is immediately downwind from Thurmond Lake. It is unlikely that this observation station is representative of a large portion of the state.

This pan evaporation data has been summarized for each decade. The Charleston data shows an increase each decade with the greatest increase occurring in the three year period 1990-92. A similar increase was noted at Savannah, Ga. This latter site, although located in Georgia, is the nearest coastal pan evaporation observation site to Charleston.

Pan evaporation observations in northwest South Carolina do not confirm the upward trend noted in southern South Carolina. Clark Hill pan evaporation values have decreased in recent years. Clemson's readings increased through 1979 but have fallen since then.

References:

- National Climatic Data Center, Asheville, N.C. South Carolina Climatological Data, 1950-92.
- Huschke, R.E.. Glossary of Meteorology. American Meteorological Society, 1959.
- Kohler, M.A., T.J. Nordenson, and D.R. Baker. Evaporation Maps for the United States, Technical Paper No. 37. U.S. Weather Bureau. 1959.
- Thornthwaite, C.W. and J.R. Mather. The Water Balance. Publications in Climatology Vol.8 No. 1. Drexel Institute of Technology. 1955
- Lambert, Jerry R. Evaporation Models, Dept of Agricultural Engineering, Clemson University, 1968.
- Kish, Alex J. Estimating Moisture in South Carolina Soils. Circular 176. Clemson University, 1977.
- Linsley, R.K., Kohler, J.L.H. Paulhus. Hydrology for Engineers, 3rd Ed. 1982.

Table #1 Athens University of Georgia
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1953-92)	0.07	0.10	0.15	0.20	0.23	0.24	0.25	0.23	0.19	0.14	0.10	0.07	
DaSDev(1953-92)	0.00	0.03	0.04	0.05	0.06	0.07	0.07	0.06	0.05	0.04	0.03	0.02	
AVMONTHLY(1953-92)	1.98	2.75	4.80	6.34	7.33	8.03	8.02	7.20	5.76	4.38	3.06	2.15	61.79
AVMONTHLY(1953-59)	2.08	2.67	4.88	5.81	8.36	7.51	7.41	7.58	6.52	4.28	2.95	2.14	62.20
AVMONTHLY(1960-69)	2.55	2.95	4.47	5.93	7.04	7.14	7.66	6.61	5.20	4.16	3.01	2.35	59.07
AVMONTHLY(1970-71)	1.18	2.00	3.73	5.74	6.83	7.51	8.62	6.56	5.49	4.14	2.89	2.14	56.81

Table #2 University of Georgia Plant Science Farm
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1971-92)	0.06	0.10	0.15	0.22	0.23	0.28	0.27	0.24	0.19	0.15	0.10	0.07	
DaSDev	0.02	0.03	0.04	0.06	0.07	0.08	0.08	0.07	0.05	0.04	0.03	0.02	
AVMONTHLY(1971-92)	1.86	2.76	4.80	6.74	7.28	8.44	8.37	7.38	5.79	4.53	3.12	2.06	63.14
AVMONTHLY(1971-79)	1.97	3.49	4.88	6.96	6.53	8.38	8.01	7.30	5.44	4.59	3.33	2.12	63.00
AVMONTHLY(1980-89)	1.78	2.39	4.80	6.70	8.01	8.71	8.64	6.82	6.05	4.52	3.00	2.20	63.61
AVMONTHLY(1990-92)	1.94	2.55	4.51	6.22	7.10	7.66	8.57	7.05	5.97	4.41	2.88	1.44	60.31

Table #3 Cataloochee, N.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1965-87)				0.03	0.04	0.04	0.04	0.04	0.03	0.02	0.01		
DaSDev(1965-87)				0.10	0.13	0.14	0.14	0.13	0.10	0.07	0.07		
MEAN(1965-87)				3.23	3.89	4.16	4.22	3.87	3.10	2.15	1.98		
AVMONTHLY(1965-69)				3.38	3.98	4.40	4.31	4.20	3.07	2.04	1.80		
AVMONTHLY(1970-79)				3.75	3.55	3.87	4.02	3.85	2.91	2.11			
AVMONTHLY(1980-87)				2.87	3.83	4.29	4.39	3.70	3.31	2.27	2.07		

Table #4 Chapel Hill, N.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1948-1992)	0.04	0.04	0.11	0.18	0.20	0.23	0.24	0.21	0.17	0.12	0.07	0.05	
DaSDev(1948-1992)	0.01	0.01	0.03	0.05	0.06	0.07	0.07	0.06	0.05	0.03	0.02	0.01	
AVMONTHLY(1948-92)	1.10	1.09	3.42	5.36	6.21	6.91	7.29	6.44	5.10	3.59	2.23	1.68	50.42
AVMONTHLY(1948-49)		1.36	2.56	3.97	5.13	5.22	5.31	4.47	4.05	2.20	1.92	1.15	
AVMONTHLY(1950-59)	1.51	1.90	3.67	5.71	6.27	7.21	7.61	6.75	6.46	3.58	2.17	1.62	54.45
AVMONTHLY(1960-69)	0.79	1.23	3.53	5.41	6.48	6.41	6.65	6.30	5.07	3.87	2.50	1.12	49.34
AVMONTHLY(1970-79)	1.08	0.82	3.73	5.29	5.78	6.64	7.37	6.50	5.17	3.57	2.30	1.52	49.76
AVMONTHLY(1980-89)			2.80	5.21	6.43	7.50	7.54	6.74	5.19	3.62	2.04	1.11	
AVMONTHLY(1990-92)			2.77	7.86	6.04	2.11	7.95	6.01	7.75	3.64			

Table #5 Charleston, S.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1960-92)	0.08	0.114	0.162	0.226	0.246	0.256	0.256	0.225	0.183	0.155	0.1209	0.151	
DaSDev(1960-92)	0.021	0.032	0.047	0.062	0.069	0.07	0.07	0.063	0.05	0.043	0.03	0.023	
AVMONTHLY(1960-92)	2.47	3.22	5.01	6.77	7.63	7.67	7.93	6.98	5.48	4.79	3.26	2.53	63.72
AVMONTHLY(1960-1969)	2.35	2.99	5.19	6.57	7.16	6.95	7.45	6.40	5.16	4.51	3.13	2.40	60.24
AVMONTHLY(1970-79)	2.10	3.11	5.40	6.76	7.17	7.38	7.75	6.88	5.33	4.63	3.20	2.59	62.28
AVMONTHLY(1980-89)	2.31	3.40	5.31	7.25	8.38	8.48	8.33	7.62	5.68	5.04	3.41	2.60	67.82
AVMONTHLY(1990-92)	2.97	4.00	4.11	7.11	8.46	8.64	9.37	7.35	6.68	5.48	3.74	2.75	70.67

Table #6 Clark Hill, S.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1952-92)	0.04	0.07	0.12	0.17	0.2	0.23	0.22	0.2	0.16	0.12	0.07	0.04	
DaSDev(1952-92)	0.012	0.02	0.033	0.036	0.055	0.065	0.063	0.058	0.046	0.033	0.021	0.013	
AVMONTHLY(1952-92)	1.39	1.99	3.67	5.11	6.15	6.95	6.94	6.21	4.88	3.63	2.24	1.36	50.53
AVMONTHLY(1952-59)	1.97	2.47	3.92	5.75	6.93	8.10	7.72	7.92	5.73	4.05	2.78	1.88	59.24
AVMONTHLY(1960-69)	1.60	2.05	3.77	5.29	6.52	6.80	6.96	6.26	5.06	3.99	2.42	1.72	52.42
AVMONTHLY(1970-79)	1.15	1.75	4.31	5.01	5.61	6.67	6.43	5.72	4.42	4.34	2.13	1.10	48.63
AVMONTHLY(1980-89)	0.88	1.53	5.28	4.86	6.27	6.96	7.07	5.89	4.57	4.73	2.00	1.06	51.10
AVMONTHLY(1990-92)	1.10	1.69	3.34	4.20	4.79	5.70	6.36	4.77	4.93	3.03	1.54	0.82	42.26

Table #7 Clemson University, S.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1950-92)	0.048	0.08	0.128	0.178	0.201	0.223	0.223	0.205	0.156	0.121	0.084	0.047	
DaSDev(1950-80)	0.014	0.022	0.034	0.05	0.056	0.061	0.061	0.058	0.041	0.033	0.023	0.014	
AVMONTHLY(1950-92)	1.46	2.27	3.96	5.33	6.22	6.68	6.92	6.34	4.96	3.79	2.54	1.47	51.67
AVMONTHLY(1950-59)	1.81	2.58	3.89	5.65	6.42	6.92	6.98	6.63	4.82	3.78	2.45	1.59	53.52
AVMONTHLY(1960-69)	1.59	2.55	4.34	5.58	6.69	6.76	7.01	6.68	4.79	3.85	2.51	1.52	53.88
AVMONTHLY(1970-79)	1.23	2.35	3.57	5.58	6.28	7.10	7.66	6.95	5.10	3.97	2.79	1.40	53.97
AVMONTHLY(1980-89)	1.47	1.89	3.77	5.31	6.37	6.95	7.12	6.34	4.86	3.83	2.33	1.15	51.39
AVMONTHLY(1990-92)	1.33	2.43	3.49	4.69	5.27	5.83	6.71	5.48	4.33	3.26	2.27	1.06	46.15

Table #8 Edisto Experiment Station (Blackville 3W)
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1963-92)	0.059	0.089	0.138	0.195	0.217	0.243	0.237	0.205	0.173	0.134	0.09	0.13	
DaSDev(1963-92)	0.017	0.025	0.038	0.054	0.06	0.067	0.066	0.057	0.047	0.036	0.025	0.04	
AVMONTHLY(1963-92)	1.87	2.63	4.42	5.93	6.86	7.41	7.52	6.45	5.21	4.06	2.65	2.00	57.01
AVMONTHLY(1963-69)	2.46	2.66	4.65	5.97	6.75	7.07	7.08	6.31	4.97	4.13	2.92	2.33	57.31
AVMONTHLY(1970-79)	1.61	2.67	4.65	6.54	6.92	7.62	7.87	6.65	4.99	4.27	2.74	2.10	58.62
AVMONTHLY(1980-89)	1.70	2.49	4.19	5.79	7.25	7.81	7.69	6.70	5.25	4.06	2.45	1.80	57.17
AVMONTHLY(1990-92)	1.73	2.69	4.19	5.41	6.52	7.16	7.43	6.15	5.61	3.79	2.48	1.77	54.94

Table #9 Florence 8NE, S.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1980-92)	0.054	0.082	0.135	0.2	0.23	0.266	0.278	0.212	0.169	0.127	0.083	0.057	
DaSDev(1980-92)	0.014	0.021	0.038	0.057	0.062	0.072	0.073	0.06	0.046	0.034	0.023	0.014	
AVMONTHLY(1980-92)	1.67	2.32	4.13	5.97	7.18	8.08	8.05	6.49	5.10	3.85	2.47	1.74	57.05
AVMONTHLY(1980-89)	1.58	2.32	4.12	5.93	7.25	8.17	7.93	6.60	5.07	3.86	2.57	1.80	57.18
AVMONTHLY(1990-92)	1.91	2.33	4.16	6.08	6.95	7.64	8.46	6.13	5.28	3.83	2.12	1.61	56.48

Table #10 Hofmann Forest, N.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1960-92)	0.04	0.07	0.12	0.16	0.20	0.22	0.22	0.20	0.15	0.11	0.07	0.05	
DaSDev(1948-92)	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.06	0.04	0.03	0.02	0.01	
AVMONTHLY(1948-92)	1.30	1.96	3.68	4.92	6.16	6.63	6.96	6.22	4.62	3.29	2.01	1.41	49.16
AVMONTHLY(1948-49)	2.05	2.22	3.82	5.42	6.44	6.60	7.40	6.18	4.85	3.23	2.82	3.33	54.34
AVMONTHLY(1980-89)	1.22	1.91	3.70	4.95	6.31	6.66	6.89	6.21	4.65	3.38	1.96	1.29	49.13

Table #11 Lumberton, N.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1962-87)	0.05	0.08	0.14	0.22	0.24	0.26	0.25	0.22	0.18	0.13	0.08	0.05	
DaSDev(1962-87)	0.01	0.02	0.04	0.06	0.07	0.07	0.07	0.06	0.05	0.04	0.02	0.01	
AVMONTHLY(1962-87)	1.49	2.31	4.23	6.47	7.47	7.79	7.83	6.86	5.34	4.16	2.53	1.60	58.08
AVMONTHLY(1960-69)	1.50	2.14	4.95	6.50	7.72	7.27	7.46	7.08	5.46	4.43	2.75	1.59	58.84
AVMONTHLY(1970-79)	1.83	2.63	4.32	6.39	6.82	7.45	7.71	6.68	5.07	4.04	2.52	1.69	57.13
AVMONTHLY(1980-87)	1.06	2.15	3.51	6.55	8.08	8.67	8.29	6.90	5.57	4.07	2.32	1.49	58.64

Table #12 Sandhill Research Station-Elgin
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1963-92)	0.058	0.096	0.153	0.245	0.252	0.274	0.274	0.230	0.196	0.154	0.106	0.064	
DaSDev(1963-92)	0.015	0.025	0.043	0.066	0.07	0.077	0.077	0.065	0.055	0.044	0.0297	0.018	
AVMONTHLY(1963-92)	1.80	2.72	4.76	7.34	7.81	8.23	8.49	7.12	5.88	4.79	3.19	1.98	64.10
AVMONTHLY(1963-69)	2.42	2.91	4.55	6.99	7.98	7.84	7.98	7.14	5.80	4.69	3.40	2.21	63.90
AVMONTHLY(1970-79)	1.56	2.58	4.88	7.35	7.38	7.96	8.22	6.88	5.46	4.72	3.38	2.01	62.37
AVMONTHLY(1980-89)	0.94	2.62	4.26	7.03	8.20	8.87	8.77	7.48	6.28	4.97	2.92	1.8	64.14
AVMONTHLY(1990-92)	2.10	3.00	4.86	6.55	7.60	7.96	9.67	6.61	6.08	4.66	1.93	1.89	62.93

Table #13 Savannah, G.A.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1965-92)	0.072	0.117	0.173	0.243	0.264	0.276	0.281	0.241	0.205	0.165	0.114	0.752	
DaSDev(1965-92)	0.019	0.03	0.48	0.066	0.072	0.078	0.078	0.067	0.058	0.046	0.032	0.019	
AVMONTHLY(1965-92)	2.23	3.29	5.38	7.29	8.18	8.29	8.71	7.47	6.15	5.12	3.43	2.33	67.85
AVMONTHLY(1965-69)	2.53	3.12	6.23	7.94	8.17	7.45	6.48	7.38	6.20	5.12	3.56	2.78	66.95
AVMONTHLY(1970-79)	2.47	3.63	5.32	7.31	7.57	8.04	8.21	7.19	5.73	5.16	3.44	2.42	66.46
AVMONTHLY(1980-89)	1.84	2.99	5.04	7.41	8.62	8.77	8.91	7.75	6.26	4.54	3.41	1.89	67.42
AVMONTHLY(1990-92)	2.60	3.60	5.82	6.42	8.14	8.49	9.43	7.51	6.84	5.23	3.28	2.43	69.77

Table #14 UNION, S.C.
all values in inches

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Daily(1950-64)	0.049	0.075	0.112	0.166	0.202	0.207	0.224	0.207	0.157	0.109	0.07	0.043	
DaSDev(1950-1964)	0.013	0.02	0.031	0.047	0.055	0.06	0.063	0.058	0.044	0.031	0.02	0.013	
AVMONTHL(1950-64)	1.53	2.11	3.48	4.99	6.26	6.21	6.94	6.42	4.7	3.39	2.10	1.34	49.47
AVMONTHLY(1950-59)	1.57	2.28	3.51	5.04	6.15	7.06	7.17	6.64	4.91	3.36	2.11	1.51	51.29
AVMONTHLY(1960-64)	1.46	1.45	2.78	4.37	6.55	6.20	6.45	6.09	4.68	3.69	2.23	0.92	46.85

State Climatology OfficeWelcome ¦ Contact Info ¦ Site Map
Columbia, SC 29202E-mail: mizzellh@dnr.sc.gov
File: pan_evap_tables.php
Last modified: Aug 07 2007 at 13:01

Sec 2.3 Ref 24

www.state.sc.us/dhec/eqc/water/pubs/broad.pdf

downloaded 6/15/00

WATERSHED WATER QUALITY MANAGEMENT STRATEGY

BROAD BASIN

TECHNICAL REPORT NO. 001-98

PREPARED BY

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
BUREAU OF WATER
2600 BULL STREET
COLUMBIA SC 29201
(803) 898-4300

Table of Contents

Introduction

The South Carolina Department of Health and Environmental Control (SCDHEC or the Department) initiated its first watershed planning activities as a result of a U.S. Environmental Protection Agency (USEPA) grant in June of 1972. These activities were soon extended by §303(e), "Federal Water Pollution Control Act Amendments of 1972", U.S. Public Law 92-500. In 1975, the SCDHEC published basin planning reports for the four major basins in South Carolina. The next major planning activity resulted from §208 of the Federal Water Pollution Control Act, which required states to prepare planning documents on an areawide basis. Areawide plans were completed in the late 1970's for the five designated areas of the State and for the nondesignated remainder of the State. To date, these plans or their updated versions have served as information sources and guides for water quality management.

During the past decade, special water quality initiatives and Congressional mandates have diverted attention and resources from comprehensive water quality assessment and protection. The Bureau of Water now emphasizes watershed planning to better coordinate river basin planning and water quality management. Watershed-based management allows the Department to address Congressional and Legislative mandates in a coordinated manner and to better utilize current resources. The watershed approach also improves communication between the Department, the regulated community, and the public on existing and future water quality issues (SCDHEC 1991a).

Purpose of the Watershed Water Quality Management Strategy

By definition, a watershed is a geographic area into which the surrounding waters, sediments, and dissolved materials drain, and whose boundaries extend along surrounding topographic ridges. Watershed-based water quality management recognizes the interdependence of water quality related activities associated with a drainage basin including: monitoring, problem identification and prioritization, water quality modeling, planning, permitting, and other activities. The Bureau of Water's Watershed Water Quality Management Program integrates these activities by watershed, resulting in watershed management plans and implementation strategies that appropriately focus water quality protection efforts. While an important aspect of the strategy is water quality problem identification and solution, the emphasis is on problem prevention.

Five major drainage basins divide the State along hydrologic lines and serve as management units. A Watershed Water Quality Management Strategy (WWQMS) will be created for each of the five basins and will be updated on a five-year rotational basis. This will allow for effective allocation and coordination of water quality activities and efficient use of available resources. The Broad Basin is divided into two watershed management units (WMU) and 32 watersheds or hydrologic units. The hydrologic units used are the USDA Natural Resource Conservation Service (1990) 11-digit codes for South Carolina. All water quality related evaluations will be made at the watershed level. The stream names used are derived from USGS topo maps.

The watershed-based strategy fulfills a number of USEPA reporting requirements including various activities under §305(b), §314, and §319 of the Clean Water Act (CWA). Section 305(b) requires that the

State biennially submit a report that includes a water quality description and analysis of all navigable waters to estimate environmental impacts. Section (§314) requires that the State submit a biennial report that identifies, classifies, describes, and assesses the status and trends in water quality of publicly owned lakes. The watershed plan is also a logical evaluation, prioritization, and implementation tool for nonpoint source (§319) requirements. Nonpoint source best management practices (BMPs) can be selected by identifying water quality impairments and necessary controls, while considering all the activities occurring in the drainage basin.

The Strategy also allows for more efficient issuance of National Pollutant Discharge Elimination System (NPDES) and State wastewater discharge permits. Proposed permit issuances within a watershed will be consolidated and presented to the public in groups, rather than one at a time, allowing the Department to realize a resource savings, and the public to realize an information advantage.

The Watershed Water Quality Management Strategy is a geographically-based document that describes, at the watershed level, all water quality related activities that may potentially have a negative impact on water quality. Each watershed in the Broad Basin is evaluated and a strategy described to address impaired streams.

The Watershed Implementation Staff investigates the impaired and threatened streams mentioned in the WWQMS to determine, where possible, the source of the impairment and recommends solutions to correct the problems. As part of this effort, the watershed staff is forging partnerships with various federal and state agencies, local governments, and community groups. In particular, the Watershed Program and the Natural Resource Conservation Service (NRCS) district offices are working together to address some of the nonpoint source (NPS) concerns in the basin. By combining NRCS's local knowledge of land use and the Department's knowledge of water quality, we are able to build upon NRCS's close relationships with landowners and determine where NPS projects are needed. These projects may include educational campaigns or special water quality studies.

Factors Assessed in Watershed Evaluations

Water Quality

Monitoring Overview

In an effort to evaluate the State's water quality, the Department operates a permanent Statewide network of primary ambient monitoring stations and flexible, rotating secondary and watershed monitoring stations (SCDHEC 1996a). The ambient monitoring network is directed towards determining long-term water quality trends, assessing attainment of water quality standards, identifying locations in need of additional attention, and providing background data for planning and evaluating stream classifications and standards.

The monitoring data are also used in the process of formulating permit limits for wastewater discharges with the goal of maintaining state and federal water quality standards and criteria in the receiving streams in accordance with the goals of the Clean Water Act. These standards and criteria define the instream chemical concentrations which provide for protection and reproduction of aquatic flora and fauna, determine support of the classified uses of each waterbody, and serve as instream limits for the regulation of wastewater discharges or other activities. In addition, these data are used in the preparation of the biennial §305(b) report to Congress (SCDHEC 1996b), which summarizes the State's water quality with respect to attainment of classified uses by comparing the ambient monitoring network data to the state water quality standards.

The SCDHEC Water Quality Monitoring Network is comprised of three station types: primary, secondary, and watershed stations. Primary stations are sampled on a monthly basis year round, and are located in high water-use areas or as background stations upstream of high water-use areas. The static primary station network is operated statewide, and receives the most extensive parameter coverage, thus making it best suited for detecting long term trends. Data for the Broad Basin are analyzed from 1980-1995 for trends in water quality and from 1991-1995 for standards compliance.

Secondary stations are sampled monthly from May through October, a period critical to aquatic life, characterized by higher water temperatures and lower flows. Secondary stations are located in areas where specific monitoring is warranted due to point source discharges, or areas with a history of water quality problems. Secondary station parameter coverage is less extensive and more flexible than primary or watershed station coverages. The number and locations of secondary stations have greater annual variability than do those in the primary station network, and during a basin's target year may have parameter coverage and sampling frequency duplicating that of primary or watershed stations.

Watershed stations are sampled on a monthly basis, year round, during a basin's target year; additional watershed stations may be sampled monthly from May through October to augment the secondary station network. Watershed stations are located to provide more complete and representative coverage within the larger drainage basin, and to identify additional monitoring needs. The parameter coverage of watershed stations includes the same basic parameters as primary stations.

The ambient monitoring network, as a program, has the capability of sampling a wide range of media and analyzing them for the presence or effects of contaminants. Ambient monitoring data from 25 primary stations, 72 secondary stations (16 with increased coverage during the basin monitoring year), 33 watershed stations, and 2 inactive stations were reviewed for the Broad Basin, along with 37 biological sites and 3 consultant sites to assess macroinvertebrate communities.

Monthly, quarterly, or annual water column grab samples (0.3m) are used to establish representative physical conditions and chemical concentrations in the waterbodies sampled. This information is considered to represent "average" conditions, as opposed to extremes, because of the inability to target individual high or low flow events on a statewide basis. The more extreme instream chemical concentrations resulting from nonpoint source inputs from rain events or from point source inputs of a variable nature are frequently missed because routine monthly sampling rarely coincides with the time of release.

Many pollutants may be components of point source discharges, but may be discharged in a discontinuous manner, or at such low concentrations that water column sampling for them is impractical. Some pollutants are also common in nonpoint source runoff, reaching waterways only after a heavy rainfall; therefore, in these situations, the best media for the detection of these chemicals are sediment and fish tissue where they may accumulate over time. Their impact may also affect the macroinvertebrate community.

Regional ambient trend monitoring is conducted to collect data to indicate general biological conditions of state waters which may be subject to a variety of point and nonpoint source impacts. In 1991, the Department began using ambient macroinvertebrate data to support the development of Watershed Water Quality Management Strategies. Ambient sampling is also used to establish regional reference or "least impacted" sites from which to make comparisons in future monitoring. Additionally, special macroinvertebrate studies, in which stream specific comparisons among stations located upstream and downstream from a known discharge or nonpoint source area, are used to assess impact.

Qualitative sampling of macroinvertebrate communities are the primary bioassessment techniques used in ambient trend monitoring. A habitat assessment of general stream habitat availability and a substrate characterization is conducted at each site. Annual trend monitoring is conducted during low flow "worst case" conditions in July - September. This technique may also be used in special studies for the purpose of determining if, and to what extent, a wastewater discharge or nonpoint source runoff is impacting the receiving stream. A minimum of two sample locations, one upstream and one downstream from a discharge or runoff area, is collected. At least one downstream recovery station is also established when appropriate. Sampling methodology essentially follows procedures described in Standard Operating Procedures, Biological Monitoring (NCDEHNR 1995).

Aquatic sediments represent a historical record of chronic conditions existing in the water column. Pollutants bind to particulate organic matter in the water column and settle to the bottom where they become part of the sediment "record". This process of sedimentation not only reflects the impact of point source discharges, but also incorporates nonpoint source pollution washed into the stream during rain events. As a result, contaminant concentrations originating from irregular and highly variable sources are recorded in the sediment. The sediment concentrations at a particular location do not vary as rapidly with time as do the water column concentrations. Thus, the sediment record may be read at a later time, unrelated to the actual release time. Lakes act as settling basins for materials entering the lake system directly from a discharge or indirectly from the land surface washed into streams. Therefore, it is not unusual for lake sediment concentrations to be higher than sediment concentrations found in streams. This is especially true for chromium, copper, and zinc.

Classified Waters, Standards, and Natural Conditions

The waters of the State have been classified in regulation based on the desired uses of each waterbody. State standards for various parameters have been established to protect all uses within each classification. The water-use classifications (SCDHEC 1993) that apply to this basin are as follows.

Class ORW, or "outstanding resource waters", are freshwaters which constitute an outstanding recreational or ecological resource, or those freshwaters suitable as a source for drinking water supply purposes, with treatment levels specified by the Department. Streams that are not currently classified as ORW, but meet certain criteria (ie. absence of dischargers, endangered species, federal lands) will be noted as potential ORW candidates in the watershed evaluations.

Class A were freshwaters which were suitable for primary contact recreation. This class was also suitable for uses listed as Class B. As of April, 1992, Class A and Class B waters were reclassified as Class FW which protects for primary contact recreation.

Class B were freshwaters which were suitable for secondary contact recreation and as a source for drinking water supply, after conventional treatment, in accordance with the requirements of the Department. These waters were suitable for fishing, and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. This class was also suitable for industrial and agricultural uses. The main difference between the Class A and B freshwater was the fecal coliform standard. Class A waters were not to exceed a geometric mean of 200/100ml, based on 5 consecutive samples during any 30 day period; nor were more than 10% of the total samples during any 30 day period to exceed 400/100ml. Class B waters were not to exceed a geometric mean of 1000/100ml, based on 5 consecutive samples during any 30 day period; nor were more than 20% of the total samples during any 30 day period to exceed 2000/100ml. As of April, 1992, Class A and Class B waters were reclassified as Class FW, which protects for primary contact recreation.

Class FW, or "freshwaters", are freshwaters which are suitable for primary and secondary contact recreation and as a source for drinking water supply, after conventional treatment, in accordance with the requirements of the Department. These waters are suitable for fishing, and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. This class is also suitable for industrial and agricultural uses.

The standards are used as instream water quality goals to maintain and improve water quality and also serve as the foundation of the Bureau of Water's program. They are used to determine permit limits for treated wastewater dischargers and any other activities that may impact water quality. Using mathematical Wasteload Allocation Models, the impact of a wastewater discharge on a receiving stream, where flow is unregulated by dams, is predicted using 7Q10 streamflows. These predictions are then used to set limits for different pollutants on the National Pollutant Discharge Elimination System (NPDES) permits issued by the Department. The NPDES permit limits are set so that, as long as a permittee (wastewater discharger) meets the established permit limits, the discharge should not cause a standards violation in the receiving stream. All discharges to the waters of the State are required to have an NPDES permit and must abide by those limits, under penalty of law.

Classifications are based on desired uses, not on natural or existing water quality, and are a legal means to obtain the necessary treatment of discharged wastewater to protect designated uses. Actual water quality may not have a bearing on a waterbody's classification. A waterbody may be reclassified if desired or existing public uses justify the reclassification and the water quality necessary to protect these uses is attainable. A classification change is an amendment to a State regulation and requires public participation, SCDHEC Board approval, and General Assembly approval.

Natural conditions may prevent a waterbody from meeting the water quality goals as set forth in the standards. The fact a waterbody does not meet the standards for a particular classification does not mean the waterbody is polluted or of poor quality. Certain types of waterbodies (ie. swamps, lakes, tidal creeks) naturally have water quality lower than the numeric standards. A waterbody can have water quality conditions below standards due to natural causes and still meet its use classification. A site specific numeric standard may be established by the Department and subjected to public participation and administrative procedures for adopting regulations. Site specific numeric standards apply only to the stream segment described in the water classification listing (SCDHEC 1993, Regulation 61-69), not to tributaries or downstream unspecified waters.

Wetlands

In the Section 401 water quality certification process, applications for wetland alterations may be denied or modified due to the special nature of a wetland or the functions that a wetland provides. Wetland impacts must be compensated through restoration, enhancement, preservation, or creation and protected in perpetuity. Future development would be prohibited in these mitigated and legally protected areas. Knowledge of areas that are restricted from development due to mitigation or special water classification is useful in planning future development in a watershed. In cooperation with the S.C. Department of Natural Resources's Division of Land Resources and Conservation Districts, Landsat Thematic Mapper (TM) satellite image data will provide an inventory of wetlands in the basin and an image-based geographical information system (GIS) for subsequent monitoring and tracking efforts.

Lake Eutrophication Assessment

The trophic condition of South Carolina lakes is monitored through SCDHEC's network of routine sampling stations and through periodic sampling of additional lakes. All lakes of at least 40 acres in area that offer public access are monitored. Large (major) lakes are those greater than 850 acres in surface area. Minor lakes are those less than 850 acres in surface area.

Beginning with the 1989 statewide lake water quality assessment, a multi-parameter percentile index has been used to quantify overall lake trophic state. The index includes the following trophic condition indicators: water clarity, total phosphorus, total inorganic nitrogen, chlorophyll *a*, and dissolved oxygen. The baseline data for this relative index are collected during the 1980-81 statewide lake water quality assessment. Use of a baseline data set permits trend detection in subsequent assessments. Percentiles for major and minor lakes are derived separately. All data, as well as the programs for deriving index values, are maintained in USEPA's STORET database. A high index value indicates a desirable trophic condition, while low values indicate the need for further study or restoration (SCDHEC 1991b).

Recreational Swimming Areas

Although all waters of the State are protected for swimming, some areas are more popular than others and may require closer monitoring. With input from agencies such as the Councils of Government the Department is identifying swimming areas (regularly used beaches and river banks with public access) where water quality monitoring may be needed. Currently monitored and suggested areas are located and discussed in the appropriate watershed evaluations.

Water Quality Indicators

MACROINVERTEBRATE COMMUNITY

Macroinvertebrates are aquatic insects and other aquatic invertebrates associated with the substrates of streams, rivers, and lakes. Macroinvertebrates can be useful indicators of water quality because these communities respond to integrated stresses over time which reflect fluctuating environmental conditions. Community responses to various pollutants (e.g. organic, toxic, and sediment) may be assessed through interpretation of diversity, known organism tolerances, and in some cases, relative abundances and feeding types.

FISH TISSUE

Many pollutants occur in such low concentrations in the water column that they are usually below analytical detection limits. Over time many of these chemicals may accumulate in fish tissue to levels that are easily measured. By analyzing fish tissue it is possible to see what pollutants may be present in waterbodies at very low levels. This information can also be used to determine if consumption of the fish pose any undue human health concerns and to calculate consumption rates that are safe.

DISSOLVED OXYGEN

Oxygen is essential for the survival and propagation of aquatic organisms. If the amount of oxygen dissolved in water falls below the minimum requirements for survival, aquatic organisms or their eggs and larvae may die. A severe example is a fish kill. Dissolved oxygen (DO) varies greatly due to natural phenomena, resulting in daily and seasonal cycles. Different forms of pollution also can cause declines in DO.

Changes in DO levels can result from temperature changes or the activity of microscopic plants (algae or phytoplankton) present in a waterbody. The natural diurnal (daily) cycle of DO concentration is well documented. Dissolved oxygen concentrations are generally lowest in the morning, climbing throughout the day and peaking near dusk, then steadily declining during the hours of darkness. Photosynthesis by phytoplankton releases oxygen during the day, which results in a rise in DO. In the dark, respiration consumes DO and lowers the concentration.

There is also a seasonal DO cycle in which concentrations are greater in the colder, winter months and lower in the warmer, summer months. Secondary stations are only sampled during summer months when water temperatures are elevated and DO concentrations are depressed. Streamflow is lower during the summer and greatly affects flushing and reaeration, which affect dissolved oxygen values.

When comparing the SCDHEC data to DO standards, it is necessary to consider several extenuating circumstances that contribute to apparent noncompliance, such as sampling bias due to season. Samples are collected as a single instantaneous grab sample, which is not truly representative of the daily average used as the criterion for most classifications. Secondary stations are sampled only during summer months and generally result in a higher rate of DO excursions as a result. It is essential to examine the data to ascertain such patterns of excursions before summarily concluding that the indicated violations constitute poor water quality. The impact of biased sampling protocols must also be weighed as a factor in instances of nonsupport of classified uses.

BIOCHEMICAL OXYGEN DEMAND

Five-day biochemical oxygen demand (BOD_5) is a measure of the amount of dissolved oxygen consumed by the decomposition of carbonaceous and nitrogenous matter in water over a five-day period. The BOD_5 test indicates the amount of biologically oxidizable carbon and nitrogen that is present in wastewater or in natural water. Matter containing carbon or nitrogen uses dissolved oxygen from the water as it decomposes, which can result in a dissolved oxygen decline. The quantity of BOD_5 discharged by point sources is limited through the National Pollutant Discharge Elimination System (NPDES) permits issued by the Department so as to maintain the applicable dissolved oxygen standard.

PH

The hydrogen ion concentration in a water sample is defined as "pH", and is used as a measure of the acidity of the water. The pH scale ranges from 0 to 14 standard units (SU). A pH of 7 is considered neutral, with values less than 7 being acidic, and values greater than 7 being basic. pH may vary from the ranges specified in the standards due to a variety of natural causes. Low pH values are found in natural waters rich in dissolved organic matter, especially in Coastal Plain swamps and black water rivers. The tannic acid released from the decomposition of vegetation causes the tea coloration of the water and low pHs.

High pH values in lakes during warmer months may be due to high phytoplankton (algae) levels. Continuous flushing in streams prevents the development of significant phytoplankton populations. Most phytoplankton are dormant during the cold winter months, and populations begin to increase as the water warms in the spring. The relationship between phytoplankton and pH is well established. Daily cycles in pH are common in waters with significant phytoplankton populations. Photosynthesis by phytoplankton consumes carbon dioxide during the day releasing carbonate, which results in a rise in pH. In the dark, respiration releases carbon dioxide and lowers pH. Soft water lakes and ponds may reach a pH of 9-10 SU during periods of intense photosynthesis when large phytoplankton populations are present.

FECAL COLIFORM BACTERIA

Coliform bacteria are present in the digestive tract and feces of all warm-blooded animals, including humans, poultry, livestock, and wild game species. Fecal coliform bacteria are themselves generally not harmful, but their presence in surface waters may be serious due to their association with sewage or animal waste which may contain pathogenic microbes. At present, it is difficult to distinguish between waters contaminated by animal waste and those contaminated by human waste.

Diseases that can be transmitted to humans through water contaminated by improperly treated human or animal waste are the primary concern. Fecal coliform bacteria are able to survive in water and are usually more numerous than waterborne disease producing organisms (pathogens). Therefore, it is best to test for fecal coliform bacteria as an indicator of possible fecal contamination rather than to try to isolate the relatively few pathogens which may be present in water.

Public health studies have established a correlation between fecal coliform numbers in recreational and drinking waters, and the risk of adverse health effects. Based on these relationships, the USEPA and SCDHEC have developed enforceable standards for surface waters to protect against adverse health effects from various recreational or drinking water uses. Proper waste disposal or sewage treatment prior to discharge to surface waters minimizes this type of pollution.

NUTRIENTS

'Nutrients', in terms of environmental water quality, usually refer to phosphorus and nitrogen, which are primary requirements for the growth and reproduction of aquatic plants. Oxygen demanding materials and nutrients are the most common constituents discharged to the environment by man's activities, through wastewater facilities and by agricultural, residential, and stormwater runoff. In general, increasing nutrient concentrations are undesirable due to the potential for accelerated growth of aquatic vegetation and algal blooms which may, in turn, deplete dissolved oxygen and result in fish kills.

The forms of nitrogen routinely analyzed at SCDHEC stations are ammonia (NH_3+NH_4/N), total Kjeldahl nitrogen (TKN), and nitrite-nitrate nitrogen (NO_2/NO_3). TKN assays the amount of organic nitrogen and ammonia in a sample. Nitrate is the product of aerobic decomposition of ammonia, and is a primary aquatic plant nutrient. Total phosphorus (TP) is measured to determine the phosphorus concentration of surface waters. This test includes all of the various forms of phosphorus (organic, inorganic, dissolved, and particulate) present in a sample.

There are no official standards or criteria for nutrients in water. However, the USEPA has issued recommendations for total phosphate phosphorus concentrations in order to limit eutrophication. High densities of phytoplankton can cause fluctuations of pH and dissolved oxygen beyond standards. Since these are only recommendations, and not a true criterion for use in evaluating water quality, it is difficult to determine the significance of elevated TP values. Because TP includes all forms of phosphorus, including that incorporated into algal biomass, it would be necessary to consider biological data to properly assess the implications of observed concentrations.

TURBIDITY

Turbidity is an expression of the scattering and absorption of light through water. The presence of clay, silt, fine organic and inorganic matter, soluble colored organic compounds, and plankton and other microscopic organisms increases turbidity. Increasing turbidity can be an indication of increased runoff from land. It is an important consideration for drinking water as finished water has turbidity limits. State water quality standards address turbidity in waters classified for Trout.

TOTAL SUSPENDED SOLIDS

Total Suspended Solids (TSS) are the suspended organic and inorganic particulate matter in water. Although increasing TSS can also be an indication of increased runoff from land, TSS differs from turbidity in that it is a measure of the mass of material in, rather than light transmittance through, a water sample. High TSS can adversely impact fish and fish food populations and damage invertebrate populations. There are no explicit state standards for TSS.

HEAVY METALS

The analytical procedures used by the Department measure total metal concentration, which is a relatively conservative approach, since the total metal concentration is always greater than the acid-soluble or dissolved fraction. Most heavy metal criteria for freshwater are calculated from formulas using water hardness. The formulas used to calculate criteria values are constructed to apply to the entire United States, including Alaska and Hawaii. As with all the USEPA criteria, there is also a large margin of safety built into the calculations. The applicability of the hardness based criteria derived from the USEPA formulas to South Carolina waters has been a subject of much discussion. Hardness values vary greatly nationwide (from zero into the hundreds), with South Carolina representing the lower end of the range (statewide average value is approximately 20 mg/l).

Representatives of the USEPA Region IV standards group have stated that no toxicity data for hardness values less than 50 mg/l were used in the development of the formulas. They have expressed reservations about the validity of the formulas when applied to hardness values below 50 mg/l. Based on this opinion, South Carolina's state standards for metals are based on a hardness of 50 mg/l for waters where hardness is 50 mg/l or less, resulting in several criteria values below the Department's current analytical detection limits. Therefore, any detectable concentration of cadmium, copper, or lead is an excursion beyond recommended criteria.

The SCDHEC monitoring data have historically indicated that zinc and copper levels in South Carolina waters are elevated relative to USEPA criteria, apparently a statewide phenomenon in both fresh and salt waters, and possibly resulting from natural conditions or nonpoint sources. These levels do not appear to adversely affect state fisheries, which suggests that the levels are the result of long-term local conditions to which the fauna have adapted, as opposed to point source pollution events. It is difficult to assess the significance of heavy metal excursions due to the questionable applicability of the formulas at low hardness values and the occurrence of calculated criteria below present detection limits. Atmospheric inputs are recognized as important sources of metals to aquatic systems. Metals are released to the atmosphere from the burning of fossil fuels (coal, oil, gasoline), wastes (medical, industrial, municipal), and organic materials. The metals are then deposited on land and in waterways from the atmosphere via rainfall.

Assessment Methodology

USE SUPPORT DETERMINATION

At the majority of SCDHEC's monitoring stations, water samples for analysis are collected as surface grab samples once per month, quarter, or year, depending on the parameter. Grab samples collected at a depth of 0.3 meters are considered a surface measurement. At most stations sampled by boat, dissolved oxygen and temperature are sampled as a water column profile, with measurements being made at a depth of 0.3 meters below the water surface and at one-meter intervals to the bottom. At stations sampled from bridges, these parameters are measured only at a depth of 0.3 meters. For the purpose of assessment, only surface samples are used in standards comparisons and trend assessments. All water and sediment samples are collected and analyzed according to standard procedures (SCDHEC 1981, 1994). Macroinvertebrate community structure is analyzed routinely at selected stations as a means of detecting adverse biological impacts on the aquatic fauna due to water quality conditions which may not be readily detectable in the water column chemistry.

Results from water quality samples can be compared to state standards and USEPA criteria, with some restrictions due to time of collection and sampling frequency. The monthly sampling frequency employed in the ambient monitoring network may be insufficient for strict interpretation of the standards. The USEPA does not define the sampling method or frequency other than indicating that it should be "representative". The grab sample method is considered to be representative for the purpose of indicating excursions relative to standards, within certain considerations. A single grab sample is more representative of a one-hour average than a four-day average, more representative of a one-day average than a one-month average, and so on (see also Screening & Additional Considerations for Water Column Metals below); thus, when inferences are drawn from grab samples relative to standards, sampling frequency and the intent of the standards must be weighed. When the sampling method or frequency does not agree with the intent of the particular standard, conclusions about water quality should be considered as only an indication of conditions, not as a proven circumstance.

The time period used to assess standards compliance is the last complete five years of data, in the Broad Basin it is 1991 through 1995. This time period was chosen in light of subsequent basin assessments that will evaluate data collected within the five years prior to the last assessment.

AQUATIC LIFE USE SUPPORT

One important goal of the Clean Water Act and state standards is to maintain the quality of surface waters in order to provide for the survival and propagation of a balanced indigenous aquatic community of fauna and flora. The degree to which aquatic life is protected (aquatic life use support) is assessed by comparing important water quality characteristics and the concentrations of potentially toxic pollutants with numeric standards.

Support of aquatic life uses is based on the percentage of standards excursions and, where data are available, the composition and functional integrity of the biological community.

A dissolved oxygen (DO) criterion of 4 mg/l is used for Class SB, 6 mg/l for TN and TPGT, and 5 mg/l for all other Classes. An excursion is an occurrence of a DO concentration less than the stated criterion. For pH, there are several acceptable ranges applied depending on the Class of water: 6-8 SU for TPGT; 6-8.5 SU for FW; 5-8.5 SU for FW*; and 6.5-8.5 for SFH, SA, and SB. For DO and pH, if 10 percent or less of the samples contravene the appropriate standard, then the standards are said to be fully supported. A percentage of standards excursions between 11-25 is considered partial support of the standard, and a percentage greater than 25 is considered to represent nonsupport of the standard, unless excursions are due to natural conditions.

Care must be taken in interpretation of dissolved oxygen data as they relate to aquatic life support.

A station for which there are 12 samples could have 3 excursions and be considered to partially meet the standard. This could translate into 3 continuous months where the criteria were not met. Depending on the extent of the excursions, this could be a minor stress for the community or a significant stress that would preclude attainment of the goal of maintaining a balanced indigenous population of native flora and fauna. A single month with extremely low dissolved oxygen concentrations could represent a significant stress, while the criteria would indicate the aquatic life use was fully supported.

If the acute aquatic life standard is exceeded for any individual toxicant (heavy metals, priority pollutants, chlorine, ammonia) in more than 10 percent of the samples, the standard is not supported. If the acute aquatic life standard is exceeded more than once, but in less than or equal to 10 percent of the samples, the standard is partially supported. If the conclusion for any single parameter is that the standard is not supported, then it is concluded that aquatic life uses are not supported. If the conclusion for any single parameter is that the standard is partially supported, then it is concluded that aquatic life uses are partially supported. Biological data are the ultimate deciding factor for aquatic life uses, regardless of chemical conditions. The goal of the standards is the protection of a balanced indigenous aquatic community.

Since most toxicants are collected with less frequency than the physical parameters, some judgement must be used in applying this guidance (see also Screening & Additional Considerations for Water Column Metals below). If the sample size is small, as in the case of something sampled only annually, a single sample above the acute standard constitutes more than 10 percent of the samples. In this instance, it is possible for a single sample to result in a conclusion that aquatic life uses are not supported, despite what other data suggest. In such a circumstance it is noted that aquatic life uses may not be fully supported and the site is prioritized for the collection of biological data, or additional monitoring and investigation, to verify the true situation.

MACROINVERTEBRATE DATA INTERPRETATION

Macroinvertebrate community assessments are used, where available, to supplement or verify Aquatic Life Use Support determinations based on water chemistry data and to evaluate potential impacts from the presence of sediment contaminants. Aquatic and semi-aquatic macroinvertebrates are identified to the lowest practical taxonomic level depending on the condition and maturity of specimens collected. The EPT Index and the North Carolina Biotic Index are the main indices used in analyzing macroinvertebrate data (NCDEHNR 1995). To a lesser extent taxa richness and sometimes total abundance may be used to help interpret data.

The EPT Index is a tabulation of taxa richness within the generally pollution-sensitive groups. EPT values are used in a relative way (usually compared with least impacted regional sites) for station comparisons (Plafkin *et al.* 1989). A database is currently being developed to establish significant EPT index levels to be used in conjunction with the biotic index to address aquatic life use support.
The biotic index for a sample is the average pollution tolerance of all organisms collected, based on assigned taxonomic tolerance values (NCDEHNR 1995).

One method of qualitative data analysis is taxa richness. This is the number of distinct taxa collected and is the simplest measure of diversity. High taxa richness is generally associated with high water quality. Increasing levels of pollution progressively eliminate the more sensitive taxa, resulting in lower taxa richness.

Total abundance is the enumeration of all macroinvertebrates collected at a sampling location. This is generally not regarded as a qualitative metric; however, when gross differences in abundance occur between stations this metric may be considered as a potential indicator.

RECREATIONAL USE SUPPORT

The degree to which the swimmable goal of the Clean Water Act is attained (recreational use support) is based on the frequency of fecal coliform bacteria excursions and the occurrence of swimming area closures. For fecal coliform bacteria, an excursion is an occurrence of a bacteria concentration greater than 400/100 ml for all Classes. Comparisons to the bacteria geometric mean standard are not considered appropriate based on sampling frequency and the intent of the standard. If 10 percent or less of the samples are greater than 400/100 ml then recreational uses are said to be fully supported. A percentage of standards excursions between 11-25% is considered partial support of recreational uses, and greater than 25% is considered to represent nonsupport of recreational uses.

FISH CONSUMPTION USE SUPPORT

Fish consumption use support is determined by the occurrence of advisories or bans on consumption for a waterbody. For the support of fish consumption uses, a fish consumption advisory indicates partial use support, a consumption ban indicates nonsupport of uses.

The Department uses a risk-based approach to evaluate mercury concentrations in fish tissue and to issue consumption advisories in affected waterbodies. This approach contrasts the average daily exposure dose to the reference dose (RfD) (ATSDR 1992). Using these relationships, fish tissue data are interpreted by determining the consumption rates that would not be likely to pose a health threat to adult males and nonpregnant adult females. Because an acceptable RfD for developmental neurotoxicity has not been developed, pregnant women, infants, and children were advised to avoid consumption of fish from any waterbody where an advisory was issued.

HUMAN HEALTH STANDARDS

State standards for human health are also evaluated in the preparation of the Watershed Water Quality Management Strategy assessments (SCDHEC 1993). For contaminants with human health standards (ie. heavy metals, pesticides), a potential human health threat is indicated if the median concentration exceeds the standard.

Additional Screening and Prioritization Tools

LONG-TERM TREND ASSESSMENT

As part of the watershed assessments, surface data from each station are analyzed for statistically significant long-term trends using a modification of Kendall's tau, which is a nonparametric test removing seasonal effects (Bauer *et al.* 1984, Hirsch *et al.* 1982, Smith *et al.* 1982, Smith *et al.* 1987). Flows are not available for most stations, and the parametric concentrations are not flow-corrected. Seasonal Kendall's tau analysis is used to test for the presence of a statistically significant trend of a parameter, either increasing or decreasing, usually over a twelve to fifteen year period. It indicates whether the concentration of a given parameter is exhibiting consistent change in one direction over the specified time period. A two sided test at $p=0.1$ is used to determine statistically significant trends, and the direction of trend. An estimate of the magnitude of any statistically significant trend is calculated as in Smith *et al.* (1982).

A rigorous evaluation for trends in time-series data usually includes a test for autocorrelation. The data are not tested for autocorrelation prior to the trend analysis. It is felt that autocorrelation would not seriously compromise a general characterization of water quality trends based on such a long series of deseasonalized monthly samples.

One of the advantages of the seasonal Kendall test is that values reported as being below detection limits (DL) are valid data points in this nonparametric procedure, since they are all considered to be tied at the DL value. When the DL changed during the period of interest, all values are considered to be tied at the highest DL occurring during that period (Hirsch *et al.* 1982). Since it is possible to measure concentrations equal to the value of the DL, values less than DL are reduced by subtraction of a constant so that they remain tied with each other, but are less than the values equal to the DL. Since fecal coliform bacteria detection limits vary with sample dilution, there is no set DL; therefore, for values reported as less than some number, the value of the number is used.

SEDIMENT SCREENING

There are no sediment standards; therefore, in order to identify sediments with elevated metals concentrations, percentiles are constructed using five years of statewide sediment data (SCDHEC 1995a). Only values greater than the detection limit were used for chromium, copper, nickel, lead, and zinc. Because so few concentrations of cadmium and mercury are measured above the detection limit, all samples were pooled for these metals. A sediment metal concentration is considered to be high if it is in the top 10% of the pooled results, and very high if it is in the top 5%. Any analytical result above detection limits is flagged for pesticides, PCBs, and other priority pollutants. Sites with noted high metals concentrations or the occurrence of other contaminants above detection limits are prioritized for the collection of biological data, or additional monitoring and investigation, to verify the true situation.

SCREENING & ADDITIONAL CONSIDERATIONS FOR WATER COLUMN METALS

The USEPA criteria for heavy metals to protect aquatic life are specified as a four-day average and a one-hour average (USEPA 1986), and have been adopted as state standards (SCDHEC 1993). Because of the quarterly sampling frequency for heavy metals, the USEPA advises against comparisons to chronic toxicity standards (four-day average concentration); therefore, only the acute standard (one-hour average) for the protection of aquatic life is used in the water quality assessment (Table 1).

Table 1. Metal Standards in Water (µg/l)				
Metal	Present Detection Level	Freshwater 1Hr. Acute Ave.	Saltwater 1Hr. Acute Ave.	Human Health
*Cadmium	10.0	1.79	43.0	5.000
Chromium (VI)	10.0	16.00	1100.0	50.000
*Copper	10.0	9.22	2.9	
*Lead	50.0	33.78	140.0	50.000
Mercury	0.2	2.40	2.1	0.153
*Nickel	20.0	789.00	75.0	4584.000
*Zinc	10.0	65.00	95.0	
* Freshwater standards based on a hardness of 50 mg/l as $CaCO_3$.				

Zinc and copper are elevated statewide and concentrations are frequently measured in excess of the calculated acute aquatic life standards. To identify areas where zinc, copper, and other metals are elevated in the water column above normal background concentrations, concentrations greater than the detection limit from all SCDHEC monitoring sites statewide for a five year period are pooled and the 90th and 95th percentiles are computed (SCDHEC 1995a). This is done separately for each metal for both fresh and saltwaters. The individual measurements from each monitoring station are then compared to these percentiles. As in sediments, a metal concentration is referred to as "high" if it is in the top 10% of the pooled results, and "very high" if it is in the top 5%. All water column values referred to as "high" or "very high" are also in excess of the acute aquatic life standard listed in Table 1. For chromium, because so few concentrations are above the detection limit, all samples collected are used to generate the percentiles. Sites with noted high metals concentrations are prioritized for the collection of biological data, or additional monitoring and investigation, to verify the true situation.

Point Source Contributions

Wasteload Allocation Process

A wasteload allocation (WLA) is the portion of a stream's assimilative capacity for a particular pollutant which is allocated to an existing or proposed point source discharge. Existing WLAs are updated during the basin review process and included in permits during the normal permit expiration and reissuance process. New WLAs are developed for proposed projects seeking a discharge permit or for existing discharges proposing to increase their effluent loading at the time of application. Wasteload allocations for oxygen demanding parameters are developed by the Water Quality Modeling Section, and WLAs for toxic pollutants and metals are developed by the appropriate permitting division.

The ability of a stream to assimilate a particular pollutant is directly related to its physical and chemical characteristics. Various techniques are used to estimate this capacity. Simple mass balance/dilution calculations may be used for a particular conservative (nondecaying) pollutant while complex models may be used to determine the fate of nonconservative pollutants that degrade in the environment. Waste characteristics, available dilution and the number of discharges in an area may, along with existing water quality, dictate the use of a simple or complex method of analysis. Projects which generally do not require complex modeling include: groundwater remediation, noncontact cooling water, mine dewatering, air washers, and filter backwash.

Streams are designated either effluent limited or water quality limited based on the level of treatment required of the dischargers to that particular portion of the stream. In cases where the USEPA published effluent guidelines, the minimum treatment levels required by law are sufficient to maintain instream water quality standards, and the stream is said to be effluent limited. Streams lacking the assimilative capacity for a discharge at minimum treatment levels are said to be water quality limited. In cases where better than technology limits are required, water quality, not minimum requirements, controls the permit limits. The Department's Water Quality Modeling Section recommends limits for numerous parameters including ammonia nitrogen (NH3-N), dissolved oxygen (DO), total residual chlorine (TRC), and five-day biochemical oxygen demand (BOD5). Limits for other parameters, including metals, toxics, and nutrients are developed by the Water Facilities Permitting Division or the Industrial, Agricultural, and Stormwater Permitting Division in conjunction with support groups within the Department.

Permitting Strategy

The Water Facilities Permitting Division and the Industrial, Agricultural, and Stormwater Permitting Division are responsible for drafting and issuing NPDES permits. All NPDES permits in the Broad Basin are to be drafted and issued, or revoked and reissued by September 30, 1997 and will all be reissued together in 2002. Broad Basin permits that remain unissued after September 30, 1997 will be issued during the first quarter of Fiscal Year 98. These permits will also be reissued in 2002 to coincide with the basin permitting year. Major NPDES reissued permits will be individually public noticed in a newspaper of general circulation and minor NPDES reissued permits will be individually public noticed by posting in accordance with Regulation 61-9. New NPDES permits and modifications of existing NPDES permits will be issued as the need arises. New permits and modifications of existing permits will be public noticed by newspaper advertisement and site posting. The permitting Divisions will coordinate drafting of permits for reissue and public notices in the Broad Basin by watershed management units in 2002.

The permitting Divisions use general permits with statewide coverage for certain categories of minor NPDES permits. Discharges covered under general permits include utility water, potable surface water treatment plants, potable groundwater treatment plants with iron removal, petroleum contaminated groundwater, and mine dewatering activities. Additional activities proposed for general permits include bulk oil terminals, aquacultural facilities, and ready-mix concrete/concrete products. Land application systems for land disposal and lagoons are also permitted, and the municipal, community (private), and industrial land application systems will be included in this document as well as NPDES point source dischargers.

A completed draft permit is sent to the permittee, the SCDHEC District office, and if it is a major permit, to the USEPA for review. When the permit draft is finalized, a public notice is issued. Comments from the public are considered and, if requested, a public hearing may be arranged. Both oral and written comments are collected at the hearing, and after considering all information, the Department staff makes the decision whether to issue the permit as drafted, issue a modified permit, or to deny the permit. Everyone who participated in the process receives a copy of the final staff decision. It is anticipated that minor permits will be grouped by watershed and publicly noticed together; major permits will individually stand public review. Staff decisions may be appealed according to the procedures in Regulation 61-72.

Nonpoint Source Contributions

Nonpoint source pollutants are generally introduced to a waterbody during a storm event and enter the system from diverse sources. Nonpoint source contributions originate from a variety of sources that include agriculture, silviculture, construction, urban stormwater runoff, hydrologic modification, landfills, mining, and residual wastes.

Section 319 of the 1987 Amendments to the Clean Water Act required states to assess the nonpoint source water pollution associated with surface and groundwater within their borders and then develop and implement a management strategy to control and abate the pollution. The first Assessment of Nonpoint Source Pollution in South Carolina (SCDHEC 1989) accomplished this purpose. The NPS Management Program developed strategies and targeted waterbodies for priority implementation of management projects. The priority list has been updated several times since then. The current list appears in the State Nonpoint Source Pollution Management Program (SCDHEC 1995b). Comprehensive projects are currently being implemented in a number of these watersheds. Components of the projects vary depending on the particular NPS impacts in the watershed, but all include BMP demonstrations, education, and monitoring.

The conventional §319 NPS Management Program has typically involved SCDHEC program areas or large institutional cooperators such as The Clemson Extension Service and the Department of Natural Resources undertaking large scale projects. In an effort to diversify the participation in the program, the Department allocated a portion of §319 funds to institute a new grants program known as Minigrants. In keeping with the Department's vision statement "Local Solutions to Local Problems", this program sought to gain the involvement of smaller organizations like local governments, nonprofit organizations, and schools in NPS projects that are locally focused and generally smaller in scale.

The purpose of South Carolina's Nonpoint Source Pollution Management Program is to insure the protection and restoration of the state's waters from nonpoint source water pollution impacts. The Plan document describes programs (both regulatory and voluntary) for NPS abatement, targets watersheds for NPS project implementation, and describes the state's strategy under each of the eight categories of NPS sources identified in South Carolina. In each of the categorical sections, management measures are described. Management measures are defined as "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution". The management measures address the following major categories: agriculture, forestry, urban areas, marinas/recreational boating, hydromodification, mining, land application of wastes, and wetlands. The Nonpoint Source Management Program initiates NPS projects during the implementation phase of a targeted basin.

Landfill Activities

All landfill activities within the State are permitted and regulated by the Department's Bureau of Land and Waste Management. All active and closed industrial and municipal solid waste landfills are identified in the appropriate watershed evaluations.

Mining Activities

Mining activities within the State are permitted by the Mining and Reclamation Division of the Department's Bureau of Land and Waste Management. Resource extraction activities and locations are identified in the appropriate watershed evaluations.

Recreational Camps

The two types of camping facilities permitted by the Department through Regulation 61-39 are Resident Camps and Family Camps. Resident camps are organized camps where one or more buildings are provided for sleeping quarters. These camps are typically operated for educational, recreational, religious, or health purposes. Family camps are organized camps where camp sites are provided for use by the general public or certain groups. The camp sewage is discharged into a public collection, treatment and disposal system if available, or an onsite wastewater treatment and disposal system (septic tank) is used. Camp locations are identified in the appropriate watershed evaluations.

Groundwater Concerns

Groundwater is an important resource for drinking water use, together with agricultural, industrial and commercial usages. Based on USEPA drinking water standards, the overall quality of South Carolina's groundwater is excellent. Contaminated groundwater is expensive and difficult to restore; therefore, groundwater protection for present and future usage is the management emphasis. Localized sources of groundwater contamination can include: septic tanks, landfills (municipal and industrial), surface impoundments, underground storage tanks, above ground storage tanks, hazardous waste sites (abandoned and regulated), salt water intrusion, land application or treatment, agricultural activities, road salting, spills and leaks. For the purposes of this assessment, only groundwater contamination affecting surface waters will be identified. A more detailed accounting of groundwater contamination will be addressed in the Broad Basin update in 2001. The groundwater contamination inventory (SCDHEC 1997a) was used to identify groundwater-related problem areas in the basin. Sites in the inventory are referenced by name and county, and are updated annually.

Water Supply

Water treatment facilities are permitted by the Department for municipal and industrial potable water production. As per the 1983 Water Use Reporting and Coordination Act (Act 282), all water uses over 100,000 gallons per day must report their usage. This includes industrial, agricultural, mining, golf courses, public supply, commercial, recreational, hydro power, thermo power, and nuclear power activities. Intake location and the volume removed from a stream are identified in the watershed evaluations for both municipal (potable) and industrial uses.

Growth Potential and Planning

Land use and management can define the impacts to water quality in relation to point and nonpoint sources. Assessing the potential for an area to expand and grow allows for water quality planning to occur and, if appropriate, increased monitoring for potential impairment of water quality. Indicators used to predict growth potential include water and sewer service, road and highway accessibility, and population trends. These indicators and others were used as tools to determine areas within the Broad Basin having the greatest potential for impacts to water quality as a result of development.

Many counties in the Broad Basin lack county wide zoning ordinances; therefore, there is little local regulatory power to influence the direction or magnitude of regional growth. The majority of municipalities have zoning ordinances in place; however, much of the growth takes place just outside the municipal boundaries, where infrastructure is inadequate. Section 208 of the Clean Water Act serves to encourage and facilitate the development and implementation of areawide waste treatment management plans. The §208 Areawide Water Quality Management Plans were completed in great detail during the 1970's and have recently been updated (SCDHEC 1997b, Appalachian Council of Governments 1997, Central Midlands Council of Governments 1997). Information from the updated reports are used in the individual watershed evaluations.

Watershed boundaries extend along topographic ridges and drain surrounding surface waters. Roads are commonly built along ridge tops, with the best drainage conditions. Cities often develop in proximity to ridges as a result of their plateau terrain. It is not uncommon, then, to find cities or road corridors located along watershed boundaries, and thus influencing or impacting several watersheds.

Implementation Process for Impaired Waters

A Total Maximum Daily Load (TMDL) is the calculated maximum allowable pollutant loading to a waterbody at which water quality standards are maintained. A TMDL is made up of two main components, a load allocation and a wasteload allocation. A load allocation is the portion of the receiving water's loading capacity attributed to existing or future nonpoint sources or to natural background sources. The waste load allocation is the portion of a receiving water's loading capacity allocated to an existing or future point source. A TMDL may also include an unallocated portion of the capacity reserved as a margin of safety or for future development.

A TMDL is a means for recommending controls needed to meet water quality standards in a particular water or watershed. Historically, the typical TMDL has been developed as a wasteload allocation, considering a particular waterbody segment, for a particular point source, to support setting effluent limitations. In order to address the combined cumulative impacts of all sources, broad watershed-based TMDLs will now be developed.

The TMDL process is linked to all other State water quality activities, and water quality impairments are identified through monitoring and assessment. Watershed-based investigations result in source identification and TMDL development. TMDLs form links between water quality standards and point and nonpoint source controls. Where TMDLs are established, they constitute the basis for NPDES permits, and for strategies to reduce nonpoint source pollution. The effectiveness and adequacy of applied controls are evaluated through continued monitoring and assessment.

Broad Basin Description

The ***Broad Basin*** incorporates 32 watersheds within 2 Watershed Management Units (WMU) and some 2.5 million acres within the State of South Carolina (a portion of the basin resides in North Carolina). There are a total of 4,719 stream miles in the Broad Basin. Within the Department's Broad Basin are the Enoree River Basin, the Tyger River Basin, the Pacolet River Basin, and the Broad River Basin.

The ***Enoree River Basin*** encompasses 761.6 square miles extending over the Piedmont region. The Enoree River Basin is described in WMU-0501 and encompasses 5 watersheds, some 487,405 acres of which 9.71% is urban land, 12.25% is agricultural land, 10.64% is scrub/shrub land, 0.73% is barren land, 66.39% is forested land, 0.04% is forested wetland, and 0.24% is water (SCLRCC 1990). The urban land percentage is comprised chiefly of the Greenville Metropolitan area. The Enoree River originates near the City of Travelers Rest and accepts drainage from Beaverdam Creek, Warrior Creek, and Duncan Creek before draining into the Broad River. There are 895.5 stream miles in the Enoree River Basin.

The ***Tyger River Basin*** encompasses 841.6 square miles extending over the Piedmont region. The Tyger River Basin is described in WMU-0501 and encompasses 6 watersheds, some 538,617 acres of which 9.94% is urban land, 13.65% is agricultural land, 8.23% is scrub/shrub land, 0.53% is barren land, 66.98% is forested land, and 0.67% is water (SCLRCC 1990). The urban land percentage is comprised chiefly of the City of Greer and portions of the Cities of Spartanburg and Union. There are a total of 977.1 stream miles in the Tyger River Basin. The Tyger River is formed by the confluence of the South Tyger River, the Middle Tyger River, and the North Tyger River near the City of Woodruff and accepts drainage from Fairforest Creek before flowing into the Broad River.

The ***Pacolet River Basin*** encompasses 489.4 square miles extending over the Piedmont region. The Pacolet River Basin is described in WMU-0502 and encompasses 7 watersheds, some 313,221 acres of which 4.52% is urban land, 18.78% is agricultural land, 5.70% is scrub/shrub land, 0.88% is barren land, 69.06% is forested land, and 1.06% is water (SCLRCC 1990). The urban land percentage is comprised chiefly of a portion of the City of Spartanburg. There are a total of 580.1 stream miles in the Pacolet River Basin. The South Pacolet River flows through Lake William C. Bowen and joins the North Pacolet River, which originates in North Carolina, to form Lake Blalock and the Pacolet river. The Pacolet River accepts drainage from Lawsons Fork Creek before flowing into the Broad River.

The ***Broad River Basin*** is described in Watershed Management Unit 0502 and encompasses 14 watersheds and 1,844.8 square miles excluding the Enoree River, the Tyger River, and the Pacolet River Basins which all drain into the Broad River. The Broad River originates in North Carolina and flows across the Piedmont region of South Carolina. Of the 1,180,693 acres, 8.23% is urban land, 11.93% is agricultural land, 5.28% is scrub/shrub land, 0.40% is barren land, 72.24% is forested land, 0.02% is forested wetland, and 1.90% is water (SCLRCC 1990). The urban land percentage is comprised chiefly of the Cities of Gaffney and Chester, and portions of the Cities of York, Union, and Columbia. There are a total of 2,266.3 stream miles in the Broad River Basin. The portion of the Broad River within South Carolina accepts drainage from Buffalo Creek, Cherokee Creek, Kings Creek, Thicketty Creek, Bullock Creek, the Pacolet

River, Turkey Creek, Browns Creek, the Sandy River, the Tyger River, the Enoree River, the Little River, and Cedar Creek.

Physiographic Regions

The State of South Carolina has been divided into six Major Land Resource Areas (MLRAs) by the USDA Soil Conservation Service (USDA 1982): the Blue Ridge, Piedmont, Sand Hills, Upper Coastal Plain, Lower Coastal Plain, and the Coastal Zone. The MLRAs are physiographic regions that have soils, climate, water resources, and land uses in common. The Broad Basin is entirely within the Piedmont region, which is defined as an area of gently rolling to hilly slopes with narrow stream valleys dominated by forests, farms, and orchards; elevations range from 375 to 1,000 feet.

Land Use/Land Cover

General land use/land cover data for South Carolina was derived from SPOT multispectral satellite images using image mapping software to inventory the State's land classifications (SCLRCC 1990). The classifications describing the Broad Basin are as follows.

Urban land is characterized by man-made structures and artificial surfaces related to industrial, commercial and residential uses, as well as vegetated portions of urban areas.

Agricultural/Grass land is characterized by cropland, pasture and orchards, and may include some grass cover in Urban, Scrub/Shrub and Forest areas.

Scrub/Shrub land is adapted from the western Rangeland classification to represent the "fallow" condition of the land (currently unused, yet vegetated), and is most commonly found in the dry Sandhills region including areas of farmland, sparse pines, regenerating forest lands and recently harvested timber lands.

Forest land is characterized by deciduous and evergreen trees not including forests in wetland settings.

Forested Wetland (swampland) is the saturated bottomland, mostly hardwood forests that are primarily composed of wooded swamps occupying river floodplains and isolated low-lying wet areas, primarily located in the Coastal Plain.

Barren land is characterized by an unvegetated condition of the land, both natural (rock, beaches and unvegetated flats) and man-induced (rock quarries, mines and areas cleared for construction in urban areas or clearcut forest areas).

Water (non-land) is characterized by freshwaters only in this basin.

Soil Types

The dominant soil associations, or those soil series comprising, together, over 40% of the land area, were recorded for each watershed in percent descending order. The individual soil series for the Broad Basin are described as follows (USDA 1963-1990).

Alpin soils are well drained and excessively drained, sandy soils with a loamy or sandy subsoil.

Badin soils are moderately deep, well drained, moderately permeable, clayey soils that formed in material weathered from Carolina Slate or other fine grained rock, on ridgetops and side slopes.

Cataula soils are deep, gently sloping to strongly sloping, well drained soils with a loamy surface layer and a clayey subsoil.

Cecil soils are deep, well drained, gently sloping to sloping soils that have red subsoil.

Davidson soils are deep, gently sloping to strongly sloping, well drained to somewhat poorly drained soils with a loamy surface layer and a clayey subsoil.

Enon soils are well drained to somewhat poorly drained, shallow to deep soils, mainly brownish, firm to extremely firm clay loam to clay in the subsoil, on narrow and medium ridges.

Georgeville soils are gently sloping to sloping, well drained and moderately well drained soils.

Goldston soils are dominantly sloping to steep, well drained to excessively drained soils.

Helena soils are gently sloping to sloping, moderately well drained to well drained soils.

Herndon soils are gently sloping to sloping, well drained and moderately well drained soils.

Hiwassee soils are well drained, moderately sloping soils with clayey subsoil, moderately deep.

Madison soils are well drained, moderately sloping soils, with clayey subsoil, moderately deep.

Pacolet soils are well drained, moderately steep soils with clayey subsoil, moderately deep.

Tatum soils are dominantly sloping to steep, well drained to excessively drained soils, with a loamy subsoil, moderately deep or shallow to weathered rock.

Wilkes soils are dominantly strongly sloping to steep, well drained soils.

Winnsboro soils are well drained, gently sloping to steep, moderately deep to deep clayey soils.

Slope and Erodibility

The slope values used in this strategy are approximate slopes derived by NRCS field personnel conducting soil surveys (USDA 1963-1990). The definition of soil erodibility differs from that of soil erosion. Soil erosion may be more influenced by slope, rainstorm characteristics, cover, and land management than by soil properties. Soil erodibility refers to the properties of the soil itself, which cause it to erode more or less easily than others when all other factors are constant. The soil erodibility factor, K, is the rate of soil loss per erosion index unit as measured on a unit plot (USDA 1978), and represents an average value for a given soil reflecting the combined effects of all the soil properties that significantly influence the ease of soil erosion by rainfall and runoff if not protected. The K values in this assessment were derived from the Nonpoint Source Pollution Assessment (SCLRCC 1988), where values closer to 1.0 represent higher soil erodibility and a greater need for best management practices to minimize erosion and contain those sediments which do erode. The range of K-factor values in the Broad Basin is from 0.15 to 0.39, among the 32 hydrologic units or watersheds.

Watershed Evaluations and Implementation Strategies Within WMU-0501

Watershed Management Unit (WMU) 0501 consists primarily of the ***Enoree River Basin*** and the ***Tyger River Basin***. WMU-0501 encompasses the Piedmont region of the State. There are a total of 11 watersheds in WMU-0501, some one million acres of which 9.83% is urban land, 12.98% is agricultural land, 9.38% is scrub/shrub land, 0.63% is barren land, 66.70% is forested land, 0.02% is forested wetland, and 0.46% is water (SCLRCC 1990). There are a total of 1,872.6 stream miles in WMU-0501.

The Enoree River originates near the City of Travelers Rest and accepts drainage from Beaverdam Creek, Warrior Creek, and Duncan Creek before draining into the Broad River. The Tyger River is formed by the confluence of the South Tyger River, the Middle Tyger River, and the North Tyger River near the City of Woodruff and accepts drainage from Fairforest Creek before flowing into the Broad River.

Climate

Normal yearly rainfall in the WMU-0501 area is 48.83 inches, according to the S.C. historic climatological record (SCWRC 1990). Data compiled from National Weather Service stations in Greenville-Spartanburg, Spartanburg, Woodruff, Union, Laurens, Whitmire, and Newberry were used to determine the general climate information for this portion of the State. The highest level of rainfall occurs in the spring with 13.55 inches; 12.41, 10.37, and 12.50 inches of rain falling in the summer, fall, and winter, respectively. The average annual daily temperature is 60.6°F. Spring temperatures average 60.5°F and summer, fall, and winter temperatures are 77.4°F, 61.4°F, and 43.1°F, respectively.

03050108-010

(Enoree River)

General Description

Watershed 03050108-010 is located in Greenville, Spartanburg, and Laurens Counties and consists primarily of the ***Enoree River*** and its tributaries from its origin to Beaverdam Creek. The watershed occupies 169,597 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Madison series. The erodibility of the soil (K) averages 0.27; the slope of the terrain averages 10%, with a range of 2-25%. Land use/land cover in the watershed includes: 21.64% urban land, 20.52% agricultural land, 5.76% scrub/shrub land, 1.18% barren land, 50.81% forested land, and 0.08% water.

The Enoree River originates near the City of Travelers Rest and accepts drainage from the North Enoree River, Long Branch, Beaverdam Creek, Buckhorn Creek (Buckhorn Lake), Mountain Creek (Mountain Lake), Cane Creek, and Princess Creek. Brushy Creek flows through the City of Greenville to enter the river next followed by Rocky Creek (Oak Grove Lake, Shannon Lake, Little Rocky Creek), Dillard Creek, Abner Creek (Vine Creek, Padgett Creek), another Little Rocky Creek, and Peters Creek. Gilder Creek (Earls Lake) originates near the City of Mauldin and is joined by Bridge Fork Creek, Little Gilder Creek, Graze Branch, Horsepen Creek, and Long Branch before flowing into the river downstream of Peters Creek. Hunter Branch enters the river next followed by Buzzard Spring Branch and Lick Creek. Durbin Creek originates near the City of Simpsonville and accepts drainage from Howard Branch, Wilson Branch, Little Durbin Creek, and South Durbin Creek (Reedy Creek) before draining into the Enoree River. Dildane Creek flows into the river downstream of Durbin Creek and is followed by Brock Page Creek and Boggy Creek. Due to the absence of point source dischargers and the presence of endangered species and other special characteristics, portions of Buckhorn Creek may qualify as a potential ORW (outstanding resource water) candidate. There are several ponds and lakes (12-52 acres) in this watershed used for recreational purposes, and a total of 366.2 stream miles, all classified FW. Paris Mountain State Park is located to the north of the City of Greenville; portions of Buckhorn Creek and Mountain Creek are located within the park. There is a Heritage Trust Preserve along the Enoree River just upstream of its confluence with the North Enoree River.

Water Quality

Enoree River - There are seven monitoring sites along this portion of the Enoree River. Aquatic life uses are not supported at the furthest upstream site **(BE-001)** due to chronic occurrences of zinc in excess of the aquatic life acute standard. Every sample collected during the assessment period fell into either the very high or high concentration range, including 17 very high concentrations and 3 high concentrations. In addition, there is a significantly increasing trend in turbidity. The 1995 sediment sample revealed the pesticides P,P'DDT, P,P'DDD, and P,P'DDE (metabolites of DDT). Although the use of DDT was banned in 1973, it is very persistent in the environment. Significantly decreasing trends in five-day biochemical oxygen demand

and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions.

Aquatic life uses are fully supported at the next site downstream (BE-015), but may be threatened by a significantly increasing trend in pH. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. At the next site downstream **(BE-017)**, aquatic life uses are partially supported due to occurrences of copper in excess of the aquatic life acute standard. Recreational uses are not supported at either BE-015 or BE-017 due to fecal coliform bacteria excursions.

Further downstream **(BE-018)**, aquatic life uses are partially supported based on macroinvertebrate community data. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions. Aquatic life uses are also partially supported at the next site downstream **(BE-019)** based on macroinvertebrate community data.

At the next site downstream **(B-037)**, aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in turbidity. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions. Aquatic life uses are also fully supported at the furthest downstream site (B-040), but recreational uses are partially supported due to fecal coliform bacteria excursions. This river was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Beaverdam Creek (BE-039) - Aquatic life uses are fully supported, and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Mountain Creek (B-186) - Aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in turbidity. A significantly decreasing trend in total phosphorus concentration suggests improving conditions for this parameter. Recreational uses are not supported due to fecal coliform bacteria excursions. In addition, there is a significantly increasing trend in fecal coliform bacteria concentration. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Princess Creek (B-192) - Aquatic life uses are not supported due to pH excursions and occurrences of zinc in excess of the aquatic life acute standard, including a very high concentration measured in 1995. In addition, there are increasing trends in pH and total nitrogen concentrations. A significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for this parameter. Pesticides (dieldrin and phosdrin) were detected in the 1994 sediment sample. Recreational uses are partially supported due to fecal coliform bacteria excursions, compounded by a significantly increasing trend in fecal coliform bacteria concentration.

***Brushy Creek* -** There are two monitoring sites along Brushy Creek. Aquatic life uses are fully supported at both the upstream site **(BE-035)** and the downstream site **(BE-009)**, and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration at the downstream site suggest improving conditions for these parameters. Recreational uses are not supported at either site due to fecal coliform bacteria excursions.

***Rocky Creek (BE-007)* -** Aquatic life uses are fully supported, and a significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentration, and turbidity suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions. In addition, there is a significantly increasing trend in fecal coliform bacteria concentration.

***Gilder Creek* -** There are three monitoring sites along Gilder Creek **(BE-040, B-241, BE-020)**. Aquatic life uses are fully supported at all sites, but may be threatened at the midstream and downstream sites due to a significantly increasing trend in pH. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters at all sites. In addition, a significantly increasing trend in dissolved oxygen concentration at B-241 and BE-020 and decreasing turbidity at BE-040 and B-241 suggest improving conditions. Recreational uses are not supported at any site due to fecal coliform bacteria excursions, and there is a significantly increasing trend in fecal coliform bacteria concentration at all sites.

***Lick Creek (B-038)* -** Aquatic life uses are fully supported, and a significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

***Durbin Creek* -** There are three monitoring sites along Durbin Creek. Aquatic life uses are fully supported at the upstream site **(B-035)** and the midstream site **(B-097)**, but recreational uses are not supported at these sites due to fecal coliform bacteria excursions. In addition, there is a significantly increasing trend in fecal coliform bacteria concentration at the midstream site. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions at both the upstream and midstream sites for these parameters. Aquatic life uses are fully supported at the downstream site **(B-022)** based on macroinvertebrate community data. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

***Buckhorn Lake* -** In an effort to provide access for swimming and fishing, aquatic herbicides were applied in 1994 by the South Carolina Department of Natural Resources.

Recreational Swimming Areas

RECEIVING STREAM	*SWIMMING LOCATION*
BEAVERDAM CREEK TRIBUTARY	PARIS MOUNTAIN

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
ENOREE RIVER CITY OF WOODRUFF PIPE #: 001 FLOW: 1.8	SC0045802 MAJOR MUNICIPAL EFFLUENT
ENOREE RIVER POLYTECH INC. PIPE #: 001 FLOW: M/R	SCG250062 MINOR INDUSTRIAL EFFLUENT
ENOREE RIVER NATIONAL STARCH & CHEMICAL CO. PIPE #: 002 FLOW: 0.12 WQL FOR BOD5,DO,TRC,NH3N	SC0038229 MAJOR INDUSTRIAL WATER QUALITY
ENOREE RIVER JPS AUTOMOTIVE PRODUCTS/TAYLORS PIPE #: 001 FLOW: 0.0707 WQL FOR BOD5	SCG641015; SCG250149 MINOR INDUSTRIAL WATER QUALITY
ENOREE RIVER INMAN MILLS/RAMEY PLANT PIPE #: 001 FLOW: 0.05 WQL FOR BOD5,DO,TRC,NH3N	SC0002496 MINOR INDUSTRIAL WATER QUALITY
ENOREE RIVER WCRSA/TAYLORS AREA PLANT PIPE #: 001 FLOW: 7.5 WQL FOR BOD5,DO,TRC,NH3N	SC0024309 MAJOR MUNICIPAL WATER QUALITY
ENOREE RIVER WCRSA/PELHAM PLANT PIPE #: 001 FLOW: 7.5 WQL FOR BOD5,DO,TRC,NH3N	SC0033804 MAJOR MUNICIPAL WATER QUALITY
ENOREE RIVER WCRSA/GILDER CREEK PIPE #: 001 FLOW: 4.0 WQL FOR BOD5,DO,TRC,NH3N	SC0040525 MAJOR MUNICIPAL WATER QUALITY
ENOREE RIVER GREENWOOD HOLDING CORP./GREER PIPE #: 001 FLOW: 0.03 WQL FOR BOD5,DO	SC0042056 MINOR INDUSTRIAL WATER QUALITY
ENOREE RIVER ENOREE LANDFILL	PROPOSED MINOR INDUSTRIAL

PIPE #: 001 FLOW: 0.0033	EFFLUENT
PRINCESS CREEK CAROLINA PRODUCTS WWTP PIPE #: 001 FLOW: M/R	SCG250047 MINOR INDUSTRIAL EFFLUENT
BEAVERDAM CREEK WCRSA/COACHMAN ESTATES PIPE #: 001 FLOW: 0.025 WQL FOR BOD5,DO,TRC,NH3N	SC0024040 MINOR MUNICIPAL WATER QUALITY
MOUNTAIN CREEK ALTAMONT FOREST PIPE #: 001 FLOW: 0.0124 WQL FOR TRC,NH3N	SC0034398 MINOR COMMUNITY WATER QUALITY
MOUNTAIN CREEK MORTON INTERNATIONAL, INC. PIPE #: 001 FLOW: M/R	SCG250097 MINOR INDUSTRIAL EFFLUENT
PRINCESS CREEK EXIDE/GENERAL BATTERY CORP. PIPE #: 001 FLOW: M/R	SC0042633 MINOR INDUSTRIAL EFFLUENT
BRUSHY CREEK LIBERTY LIFE INSURANCE PIPE #: 001 FLOW: 0.03	SCG250166 MINOR INDUSTRIAL EFFLUENT
ROCKY CREEK NYCOIL COMPANY/DM DIV. PIPE #: 001 FLOW: M/R	SCG250061 MINOR INDUSTRIAL EFFLUENT
ROCKY CREEK METROMONT MATERIALS/ROPER MTN PIPE #: 001 FLOW: M/R	SC0044636 MINOR INDUSTRIAL EFFLUENT
ROCKY CREEK TRIBUTARIES GE/GREENVILLE GAS TURBINE PLT PIPE #: 001 FLOW: 0.45 PIPE #: 010 FLOW: MR PIPE #: 011 FLOW: MR	SC0003484 MINOR INDUSTRIAL EFFLUENT EFFLUENT EFFLUENT
VINE CREEK BECKLEY STONE CO./PELHAM QUARRY PIPE #: 001 FLOW: M/R	SCG730042 MINOR INDUSTRIAL EFFLUENT
BROCK PAGE CREEK PIEDMONT DIELECTRICS PIPE #: 001 FLOW: M/R	SCG250056 MINOR INDUSTRIAL EFFLUENT
PADGETT CREEK SSSD/HIGHWAY 101 BUSINESS PARK PIPE #: 001 FLOW: 0.03-0.04 WQL FOR BOD5,DO,TRC; NH3N IN SUMMER & WINTER	SC0047350 MINOR MUNICIPAL WATER QUALITY
DILLARD CREEK CHEVRON USA, INC. PIPE #: 001 FLOW: M/R	SCG830001 MINOR INDUSTRIAL EFFLUENT

GILDER CREEK RENOSOL CORPORATION PIPE #: 001 FLOW: 0.0002	SC0037966 MINOR INDUSTRIAL EFFLUENT
GILDER CREEK BI-LO INC./MAULDIN WAREHOUSE PIPE #: 001 FLOW: M/R	SCG250063 MINOR INDUSTRIAL EFFLUENT
BRIDGE FORK CREEK METROMONT MATERIALS/MAULDIN PIPE #: 001 FLOW: 0.002	SC0038016 MINOR INDUSTRIAL EFFLUENT
DURBIN CREEK WCRSA/DURBIN CREEK PLT PIPE #: 001 FLOW: 3.3 PIPE #: 001 FLOW: VARIABLE (PROPOSED) WQL FOR BOD5,DO,TRC,NH3N	SC0040002 MAJOR MUNICIPAL WATER QUALITY WATER QUALITY
DURBIN CREEK PARA-CHEM SOUTHERN, INC. PIPE #: 001 FLOW: M/R	SCG250117 MINOR INDUSTRIAL EFFLUENT
LITTLE ROCKY CREEK BROCKMAN CATFISH FARM PIPE #: 001 FLOW: 0.1 WQL FOR BOD5,DO	SC0042030 MINOR INDUSTRIAL WATER QUALITY
ENOREE RIVER TRIBUTARY BUCK-A-ROO RANCH INC. PIPE #: 001 FLOW: 0.0101 WQL FOR TRC,NH3N	SC0026662 MINOR COMMUNITY WATER QUALITY

LAND APPLICATION FACILITY NAME	**PERMIT# TYPE**
SPRAYFIELD 3R, INC. GREER SITE 2-BROCKMAN RD	ND0077399 INDUSTRIAL

Camp Facilities

FACILITY NAME/TYPE RECEIVING STREAM	***PERMIT # STATUS***
CAMP BUCKHORN/RESIDENT BUCKHORN CREEK	23-305-0127 ACTIVE

Landfill Activities

SOLID WASTE LANDFILL NAME FACILITY TYPE	***PERMIT # STATUS***
CRYOVAC DUMP INDUSTRIAL	CERCLA SCD980844021 BEING CLOSED
ENOREE LANDFILL MUNICIPAL	231001-1102 ACTIVE

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
ASHMOORE BROTHERS, INC. 418 SAND PIT	0883-30 SAND

Water Supply

WATER USER (TYPE) *STREAM*	*RATED PUMP. CAPACITY (GPM)* *AMT. TRT./DIV. (MGD)*
JPS AUTOMOTIVE PRODUCTS/TAYLORS PLT 2 (I) ENOREE RIVER	1389.0 2.0

Groundwater Concerns

The groundwater in the vicinity of the property owned by Colonial Pipeline (Site #14828) is contaminated with petroleum products (home fuel oil) due to spills and leaks. The surface water affected by the contamination is Durbin Creek and the area is being monitored. The groundwater in the vicinity of the property owned by Buddy's Inc. (Site #04167) is also contaminated with petroleum products. In this case the contamination is due to underground storage tanks and is considered a risk-based corrective action priority classification 1 (SCDHEC 1997). The contaminated plume is discharging to Brushy Creek.

The groundwater in the vicinity of the property owned by Para-chem Southern, Inc. is contaminated with volatile organic compounds (VOC) resulting from several sources including landfills, pits, ponds, lagoons, and unpermitted disposal. This is an EPA NPL site and is currently in the assessment and remediation phase. The surface water affected by the VOCs is an unnamed tributary of Durbin Creek. Another area with contaminated groundwater is in the vicinity of the property owned by GE Gas Turbine, and it is contaminated with VOCs, petroleum products, and phenol resulting from several sources including spills and leaks, pits, ponds, lagoons, septic tank/tile fields and unknown sources. The facility is currently in the assessment, monitoring, and remediation phases. The groundwater extraction system in the WWTP area has been effective in bringing the stream into compliance. The surface water affected by the contamination is Little Rocky Creek.

Growth Potential

There is a high potential for residential, commercial, and industrial growth in this watershed, which contains the eastern portion of the greater Greenville area. The expansion of the Greenville-Spartanburg Airport and highway improvements around the airport and connecting Greenville to the City of Greer and on to the City of Spartanburg will stimulate continued industrial growth between SC 101, SC 417, the Enoree River, and SC 14. Future industrial development will be prevalent along I-385. The City of Woodruff should also experience industrial, commercial, and residential growth.

Implementation Strategy

This section of the Enoree River is impaired by elevated levels of copper from unknown sources. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible. Biological samples were collected at sites further downstream and will be evaluated to determine the cause of their impairment. The Enoree River, Beaverdam Creek, and Mountain Creek are impaired from elevated levels of fecal coliform bacteria resulting from both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050108-020

(Enoree River)

General Description

Watershed 03050108-020 is located in Spartanburg, Laurens, and Union Counties and consists primarily of the ***Enoree River*** and its tributaries from Beaverdam Creek to Duncan Creek. The watershed occupies 71,546 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Wilkes series. The erodibility of the soil (K) averages 0.25; the slope of the terrain averages 18%, with a range of 2-45%. Land use/land cover in the watershed includes: 0.85% urban land, 6.20% agricultural land, 5.13% scrub/shrub land, 0.44% barren land, 87.34% forested land, and 0.04% water.

This segment of the Enoree River accepts drainage from the upstream reach (03050108-010) together with the Beaverdam Creek Watershed, Twomile Creek (Hannah Creek), Buckhead Creek, the Warrior Creek Watershed, Enoree Creek, and Cedar Shoals Creek. Elishas Creek enters the river next followed by Frenchman Creek, Johns Creek (Wildcat Branch), Sispring Branch, and Hills Creek. There are a few recreational lakes (10-35 acres) in this watershed and a total of 126.5 stream miles, all classified FW. The lower portion of the watershed resides within the Sumter National Forest.

Water Quality

Enoree River - There are three monitoring sites along this section of the Enoree River. Aquatic life uses are fully supported at the upstream site **(BE-024)**, and a significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for this parameter. Recreational uses are partially supported due to fecal coliform bacteria excursions. Aquatic life uses are also fully supported at the midstream **(B-041)** and downstream **(B-053)** sites, but may be threatened by a significantly decreasing trend in pH, a significantly increasing trend in turbidity, and a high concentration of zinc measured in 1991. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported at either B-041 or B-053 due to fecal coliform bacteria excursions. This river was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM	***NPDES#***
FACILITY NAME	***TYPE***
PERMITTED FLOW @ PIPE (MGD)	***LIMITATION***
COMMENT	
ENOREE RIVER	SC0041602
TOWN OF WHITMIRE WTP	MINOR DOMESTIC
PIPE #: 001 FLOW: M/R	EFFLUENT
ENOREE CREEK	SCG730013

CAROLINA VERMICULITE PIPE #: 001 FLOW: M/R	MINOR INDUSTRIAL EFFLUENT
ENOREE RIVER RIVERDALE MILLS W&S DISTRICT PIPE #: 001 FLOW: 0.09 WQL FOR BOD5,DO,TRC,NH3N	SC0035734 MINOR MUNICIPAL WATER QUALITY
ENOREE RIVER WR GRACE/SUMMER MINE PIPE #: 001 FLOW: M/R	SCG730001 MINOR INDUSTRIAL EFFLUENT
TWOMILE CREEK PIEDMONT DIELECTRICS CORP., INC. PIPE #: 001 FLOW: M/R	SCG250056 MINOR INDUSTRIAL EFFLUENT
BUCKHEAD CREEK WR GRACE/ROPER MINE PIPE #: 001 FLOW: M/R	'SCG730089 MINOR INDUSTRIAL EFFLUENT
BUCKHEAD CREEK TRIBUTARY WR GRACE/KEARNEY MILL PIPE #: 001 FLOW: M/R	SC0045811 MINOR INDUSTRIAL EFFLUENT

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
TOWN OF WHITMIRE MUNICIPAL	SCD980558084 CLOSED
NATIONAL STARCH INDUSTRIAL	422433-1601 CLOSED

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
PATTERSON VERMICULITE CO. NUMBER 8 MINE	1034-30 VERMICULITE
WR GRACE & CO. SCHUMACHER MINE	0907-42 VERMICULITE
WR GRACE & CO. BELK MINE	0693-42 VERMICULITE
WR GRACE & CO. WATSON MINE	1023-42 VERMICULITE
WR GRACE & CO. GIDEON MINE	0833-42 VERMICULITE
WR GRACE & CO. SUMMER MINE	0714-30 VERMICULITE

WR GRACE & CO. ROPER MINE	1119-30 VERMICULITE ORE
WR GRACE & CO. DESHIELDS #1 & #2 MINE	1019-42 VERMICULITE ORE
WR GRACE & CO. BOYD-WHITMORE MINE	1118-30 VERMICULITE ORE
RAY BROWN ENTERPRISES BROWN SAND MINE #2	0861-42 SAND
CAROLINA VERMICULITE SUMNER #1 MINE	0754-42 VERMICULITE
CAROLINA VERMICULITE LAURENCE MINE	1048-44 VERMICULITE ORE

Water Supply

WATER USER (TYPE) *STREAM*	*PUMPING CAPACITY (MGD)* *REG. PUMPING CAPACITY (MGD)*
CITY OF CLINTON (M) ENOREE RIVER	3.5 1.7
TOWN OF WHITMIRE (M) ENOREE RIVER	2.2 1.0

Growth Potential

There is a low potential for growth in the upper portion of this watershed associated with industrial development along US 221. The watershed is bisected by I-26 and some growth may be expected around the interstate interchanges. A commercial corridor has developed along US 176 and SC 72 serving the Whitmire community. Public water is available, but little growth is expected.

Implementation Strategy

The Enoree River is impaired by elevated levels of fecal coliform bacteria resulting from both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050108-030

(Beaverdam Creek/Warrior Creek)

General Description

Watershed 03050108-030 is located in Laurens County and consists primarily of ***Beaverdam Creek and Warrior Creek*** and their tributaries. The watershed occupies 34,834 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Madison-Davidson-Pacolet series. The erodibility of the soil (K) averages 0.26; the slope of the terrain averages 14%, with a range of 2-40%. Land use/land cover in the watershed includes: 0.78% urban land, 21.91% agricultural land, 13.72% scrub/shrub land, 1.78% barren land, 61.04% forested land, and 0.77% water.

Beaverdam Creek flows into the Enoree River near the Town of Enoree and further downstream Warrior Creek enters the river. Beaverdam Creek accepts drainage from Wallace Branch and Warrior Creek accepts drainage from Double Branch and Strouds Branch. There are several ponds and lakes (11-183 acres) in this watershed used for recreation, industry, mining, flood control, water supply, and aquaculture. There are a total of 85.3 stream miles, all classified FW.

Water Quality

Beaverdam Creek (B-246) - Aquatic life uses are fully supported based on physical, chemical, and macroinvertebrate community data. Recreational uses are not supported due to fecal coliform bacteria excursions.

Warrior Creek - There are two monitoring sites along Warrior Creek. Aquatic life uses are fully supported at the upstream site **(B-150)**, but may be threatened by the occurrence of chromium in excess of the acute aquatic life standard. Recreational uses are not supported due to fecal coliform bacteria excursions. At the downstream site **(B-742)**, aquatic life uses are fully supported based on macroinvertebrate community data.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
BEAVERDAM CREEK VULCAN MATERIALS CO./GRAY COURT PIPE #: 001 FLOW: M/R	SCG730055 MINOR INDUSTRIAL EFFLUENT
WARRIOR CREEK WR GRACE/KEARNEY MILL PIPE #: 002 FLOW: 0.025 PROPOSED; WQL FOR BOD5,DO,TRC,NH3N	SC0045811 MINOR INDUSTRIAL WATER QUALITY

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
CAROLINA VERMICULITE CHARLES WALDREP	0970-30 VERMICULITE
VULCAN MATERIALS CO. GRAY COURT QUARRY	0061-30 GRANITE
WR GRACE & CO. F. WALDREP MINE	1022-30 VERMICULITE ORE
WR GRACE & CO. WRIGHT NO. 1 & 2	0278-30 VERMICULITE
WR GRACE & CO. DAVIS-DEWITT MINE	1018-30 VERMICULITE ORE

Growth Potential

There is a low to moderate potential for growth in this watershed. I-385 crosses the watershed and some industrial growth may be expected around interstate interchanges.

03050108-040

(Duncan Creek)

General Description

Watershed 03050108-040 is located in Laurens and Newberry Counties and consists primarily of ***Duncan Creek*** and its tributaries. The watershed occupies 92,409 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Wilkes-Madison-Pacolet series. The erodibility of the soil (K) averages 0.26; the slope of the terrain averages 16%, with a range of 2-45%. Land use/land cover in the watershed includes: 4.57% urban land, 7.62% agricultural land, 5.90% scrub/shrub land, 0.63% barren land, 81.02% forested land, and 0.26% water.

Duncan Creek originates near the Town of Ora and accepts drainage from Duncan Creek Reservoir 6B (73 acres), Long Branch, Saxton Branch, Beards Fork Creek, Millers Fork (Sand Creek), and Allisons Branch. Beards Fork Creek and Millers Fork enter Duncan Creek near the City of Clinton. Further downstream near the Town of Whitmire, South Fork Duncan Creek (Ned Wesson Branch) enters Duncan Creek followed by Mulberry Branch and Sandy Branch. There are several ponds and lakes (11-73 acres) in this watershed used for recreational, municipal, and flood control purposes and a total of 142.5 stream miles, all classified FW. The lower portion of the watershed resides within the Sumter National Forest.

Water Quality

Duncan Creek (B-072) - Aquatic life uses are fully supported based on macroinvertebrate community data, but may be threatened by a significantly decreasing trend in dissolved oxygen concentration and by occurrences of zinc in excess of the aquatic life acute standard, including a very high concentration measured in 1995. Significantly decreasing trends in total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Duncan Creek Reservoir 6B (B-735) - Aquatic life uses are fully supported. Although a pH excursion occurred, high pH levels are not uncommon in lakes with significant aquatic plant communities and are considered natural, not standards violations. Duncan Creek Reservoir 6B is a 73-acre impoundment at the headwaters of an unnamed tributary to Duncan Creek at the top of the watershed in Laurens County. The maximum depth is approximately 15 feet (4.5 m) and the average depth is 5.4 feet (1.7 m). The reservoir's watershed comprises approximately 0.8 square miles (2 km2). It is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of this lake's desirable trophic condition is recommended.

Beards Fork Creek (B-231) - Aquatic life uses are partially supported due to dissolved oxygen excursions. In addition, there is a significantly decreasing trend in pH. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions, compounded by a significantly increasing trend in fecal coliform bacteria concentration.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM	***NPDES#***
FACILITY NAME	***TYPE***
PERMITTED FLOW @ PIPE (MGD)	***LIMITATION***
COMMENT	
DUNCAN CREEK	SC0022390
TOWN OF WHITMIRE	MINOR MUNICIPAL
PIPE #: 001 FLOW: 0.6	WATER QUALITY
PIPE #: 001 FLOW: 1.0 (PROPOSED)	WATER QUALITY
WQL FOR TRC	
BEARDS FORK CREEK	SC0041629
JOHNSON'S CHEVRON	MINOR INDUSTRIAL
PIPE #: 001 FLOW: M/R	WATER QUALITY
WQL FOR BOD5	
BEARDS FORK CREEK	SCG250146
CLINTON MILLS/BAILEY	MINOR INDUSTRIAL
PIPE #: 001 FLOW: 0.101	EFFLUENT
PIPE #: 002 FLOW: M/R	EFFLUENT
MILLERS FORK	SCG645004
CITY OF CLINTON/GARY ST. WTP	MINOR MUNICIPAL
PIPE #: 001 FLOW: 0.101	EFFLUENT

Landfill Activities

SOLID WASTE LANDFILL NAME	***PERMIT #***
FACILITY TYPE	***STATUS***
CLINTON MILLS	DWP-019
MUNICIPAL	CLOSED
CITY OF CLINTON	DWP-026; DWP-914
MUNICIPAL	CLOSED MSW; PROPOSED C&D

Mining Activities

MINING COMPANY	***PERMIT #***
MINE NAME	***MINERAL***
WR GRACE & CO.	0692-30
GOODWIN MINE	VERMICULITE
WR GRACE & CO.	1064-30
COOPER #1 & #2	VERMICULITE ORE

Water Supply

WATER USER (TYPE) *STREAM*	*PUMPING CAPACITY (MGD)* *REG. PUMPING CAPACITY (MGD)*
CITY OF CLINTON (M) DUNCAN CREEK	3.5 1.7
TOWN OF WHITMIRE (M) DUNCAN CREEK	1.0 1.0

Growth Potential

There is a high potential for industrial growth in this watershed, which contains the City of Clinton and the intersection of I-26 and I-385. Future industrial development will be prevalent along I-385 to the area south of Clinton. US 221 crosses the watershed connecting the Cities of Laurens and Spartanburg, and US 276 connects the Cities of Clinton and Greenville.

Implementation Strategy

Duncan Creek is impaired from elevated levels of fecal coliform bacteria resulting from both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050108-050

(Enoree River)

General Description

Watershed 03050108-050 is located in Newberry and Laurens Counties and consists primarily of the ***Enoree River*** and its tributaries from Duncan Creek to its confluence with the Broad River. The watershed occupies 119,020 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Pacolet-Wilkes series. The erodibility of the soil (K) averages 0.25; the slope of the terrain averages 13%, with a range of 2-40%. Land use/land cover in the watershed includes: 1.03% urban land, 5.87% agricultural land, 2.42% scrub/shrub land, 0.18% barren land, 90.44% forested land, and 0.07% water.

This segment of the Enoree River accepts drainage from the upstream reaches (03050108-010, 03050108-030) together with Sulphur Spring Branch, Collins Branch, and Indian Creek. Indian Creek originates near the Town of Joanna and accepts drainage from Fort Branch, Loftons Branch, Locust Branch, Long Branch (Buncombe Branch), Headleys Creek (Peges Creek), Pattersons Creek, Asias Branch, Gilders Creek (Johns Mountain Branch, Joshuas Branch), and Hunting Creek. South Fork Kings Creek (Little Kings Creek, Means Branch) enters the river near the City of Newberry followed by Fosters Branch, Quarters Branch, and Subers Creek. There are 175.0 stream miles in this watershed, all classified FW. The entire watershed resides within the Sumter National Forest and the Enoree River Waterfowl Area is located near the confluence with the Broad River.

Water Quality

Enoree River (B-054) - Aquatic life uses are fully supported, but may be threatened by a significantly decreasing trend in dissolved oxygen concentration and a significantly increasing trend in total suspended solids. Sediment samples revealed di-n-butylphthalate in 1995. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Indian Creek (B-071) - Aquatic life uses are fully supported based on macroinvertebrate community data.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM	***NPDES#***
FACILITY NAME	***TYPE***
PERMITTED FLOW @ PIPE (MGD)	***LIMITATION***
COMMENT	
HEADLEYS CREEK	SC0024732
JOANNA KOA	MINOR COMMUNITY
PIPE #: 001 FLOW: 0.010	WATER QUALITY
WQL FOR BOD5,DO,TRC,NH3N	

Growth Potential

There is a low potential for growth in this watershed, with the exception of the City of Woodruff. Woodruff is expected to experience industrial, commercial, and residential growth. The remainder of the watershed is effectively excluded from development by residing in the Sumter National Forest.

03050107-010

(South Tyger River)

General Description

Watershed 03050107-010 is located in Greenville and Spartanburg Counties and consists primarily of the ***South Tyger River*** and its tributaries. The watershed occupies 114,241 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Cataula series. The erodibility of the soil (K) averages 0.29; the slope of the terrain averages 8%, with a range of 2-25%. Land use/land cover in the watershed includes: 9.14% urban land, 22.16% agricultural land, 4.32% scrub/shrub land, 1.21% barren land, 62.09% forested land, and 1.09% water.

Mush Creek (Johnson Creek, Dysort Lake, Meadow Fork), Barton Creek (McKinney Creek also known as Burban Fork Creek, Noe Creek), and Pax Creek join to form the South Tyger River near Pax Mountain. Just downstream of the confluence the South Tyger River is impounded to form Lake Robinson. Downstream of Lake Robinson, the South Tyger River is joined by Beaverdam Creek and forms Lake Cunningham (Clear Creek). Downstream from Lake Cunningham near the City of Greer, the river accepts drainage from Frohawk Creek, Wards Creek, and Maple Creek. The river then flows through Berrys Pond (60 acres) and accepts drainage from 58 acre-Silver Lake (Williams Creek), Brushy Creek (Powder Branch), Bens Creek, Chickenfoot Creek, and Ferguson Creek (Quarter Creek, Big Ferguson Creek, Little Ferguson Creek). There are several ponds and lakes (10-250 acres) in this watershed used for recreation, industry, water supply, and irrigation. There are a total of 248.5 stream miles, all classified FW.

Water Quality

South Tyger River - There are six monitoring sites along the South Tyger River. Aquatic life uses are fully supported at the furthest upstream site **(B-741)** based on macroinvertebrate community data. Aquatic life uses are also fully supported further downstream **(B-149)**, and significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentration, and turbidity suggest improving conditions for these parameters. Recreational uses are fully supported at this site, but may be threatened by a significantly increasing trend in fecal coliform bacteria concentration. Continuing downstream **(B-263)**, aquatic life uses are again fully supported, but may be threatened by a significantly increasing trend in turbidity. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions, but a significantly decreasing trend in fecal coliform bacteria concentrations suggests improving conditions.

Aquatic life uses are partially supported at the next site downstream **(B-005A)** based on macroinvertebrate community data. Further downstream **(B-005)**, aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in turbidity. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions. Aquatic life and recreational uses are fully supported at the furthest downstream site **(B-332)**, but aquatic life uses may be threatened by a high concentration of zinc measured in 1995. This river was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

***Mush Creek (B-317)* -** Aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in turbidity and a high concentration of zinc measured in a 1994 sediment sample. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions.

***Lake John Robinson (CL-100)* -** Lake Robinson is an 802-acre impoundment on the South Tyger River in Greenville County, with a maximum depth of approximately 40 feet (12.3 m) and an average depth of approximately 18 feet (5.4 m). Lake Robinson's watershed comprises 47 square miles (123 km2). The lake is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of Lake Robinson's desirable trophic condition is recommended.

***Lake Cunningham (B-341)* -** Lake Cunningham is a 250-acre impoundment on the South Tyger River in Greenville County, with a maximum depth of approximately 19 feet (5.8 m) and an average depth of 8.9 feet (2.7 m). Lake Cunningham's watershed comprises approximately 48 square miles (124 km2), and includes Lake John Robinson. Historical eutrophication studies indicate that Lake Cunningham's trophic condition is improving. It is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of this lake's desirable trophic condition is recommended. Aquatic life and recreational uses are fully supported.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
SOUTH TYGER RIVER SSSD/S.TYGER REGIONAL WWTP PIPE #:001 FLOW: 1.0-2.0 WQL FOR TRC	PROPOSED MAJOR MUNICIPAL WATER QUALITY
SOUTH TYGER RIVER WR GRACE/CRYOVAC/DUNCAN PLT PIPE #: 001 FLOW: 0.05025 WQL FOR DO,NH3N	SC0002313 MINOR INDUSTRIAL WATER QUALITY
SOUTH TYGER RIVER CITY OF GREER/S.TYGER RIVER WWTP PIPE #: 001 FLOW: 1.75 WQL FOR DO,TRC,NH3N	SC0020770 MAJOR MUNICIPAL WATER QUALITY
SOUTH TYGER RIVER TOWN OF DUNCAN WWTP PIPE #: 001 FLOW: 0.275 WQL FOR DO,TRC,NH3N	SC0021008 MINOR MUNICIPAL WATER QUALITY
SOUTH TYGER RIVER LAKEVIEW STEAK HOUSE PIPE #: 001 FLOW: 0.0158	SC0030465 MINOR COMMUNITY EFFLUENT
SOUTH TYGER RIVER MEMC ELECTRONIC MATERIALS PIPE #: 001 FLOW: 0.9 PIPE #: 001 FLOW: 1.2 (PROPOSED) WQL FOR TRC	SC0036145 MAJOR INDUSTRIAL WATER QUALITY WATER QUALITY
SOUTH TYGER RIVER CITY OF GREER CPW WTP PIPE #: 001 FLOW: M/R WQL FOR TRC	SCG645020 MINOR DOMESTIC WATER QUALITY
SOUTH TYGER RIVER SSSD/RIVER FALLS PLANTATION PIPE #: 001 FLOW: 0.07 (PROPOSED) PIPE #: 001 FLOW: 0.14 (PROPOSED) NOT CONSTRUCTED	SC0043524 MINOR MUNICIPAL EFFLUENT EFFLUENT
SOUTH TYGER RIVER CITY OF GREER/MAPLE CREEK PLT PIPE #: 001 FLOW: 4.5 WQL FOR DO,TRC,NH3N	SC0046345 MAJOR MUNICIPAL WATER QUALITY
BEAVERDAM CREEK DAVIDSON MINERAL/SANDY FLATS PIPE #: 001 FLOW: M/R	SCG730079 MINOR INDUSTRIAL EFFLUENT

BURBAN FORK CREEK LOOKUP LODGE/PM UTILITIES INC. PIPE #: 001 FLOW: 0.03 WQL FOR TRC,NH3N	SC0026379 MINOR COMMUNITY WATER QUALITY
MEADOW FORK NORTH GREENVILLE COLLEGE PIPE #: 001 FLOW: 0.04 WQL FOR TRC,NH3N	SC0026565 MINOR COMMUNITY WATER QUALITY
MEADOW FORK LAUREL VALLEY INC. PIPE #: 001 FLOW: 0.2 WQL FOR TRC,NH3N; NOT CONSTRUCTED	SC0045331 MINOR MUNICIPAL WATER QUALITY
WILLIAMS CREEK CARMET COMPANY PIPE #: 001 FLOW: 0.009 WQL FOR DO,TRC,NH3N	SC0038083 MINOR INDUSTRIAL WATER QUALITY
WILLIAMS CREEK MILLIKEN/ARMITAGE PLT PIPE #: 001 FLOW: 0.36 WQL FOR TRC,NH3N	SC0023451 MINOR INDUSTRIAL WATER QUALITY
WILLIAMS CREEK TRIBUTARY US ALUMOWELD CO., INC. PIPE #: 001 FLOW: 0.003 WQL FOR NH3N,TRC	SC0043982 MINOR INDUSTRIAL WATER QUALITY

LAND APPLICATION **FACILITY NAME**	**PERMIT#** **TYPE**
SPRAYFIELD RD ANDERSON APPLIED TECH. CTR.	ND0067351 MUNICIPAL
SPRAYFIELD 3R, INC./GREER SITE 1-WOFFORD RD	ND0077399 INDUSTRIAL

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
CITY OF GREER-SOUTH TYGER WWTP SLUDGE MONOFIL	421003-1501 ACTIVE

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
DAVIDSON MINERAL PROPERTIES, INC. SANDY FLAT QUARRY	0502-23 GRANITE
KING ASPHALT, INC. THEO	0809-42 SAND

CAROLINA VERMICULITE NUKKER-THOMPSON MINE	0893-42 VERMICULITE

Camp Facilities

FACILITY NAME/TYPE *RECEIVING STREAM*	*PERMIT #* *STATUS*
LOOKUP LODGE/RESIDENT BURBAN FORK CREEK	23-305-0116 ACTIVE

Water Supply

WATER USER (TYPE) *STREAM*	*PUMPING CAPACITY (MGD)* *REG. PUMPING CAPACITY (MGD)*
CITY OF GREER CPW (M) LAKE CUNNINGHAM	18.0 8.0

Groundwater Concerns

The groundwater in the vicinity of the property owned by Elmore Waste Disposal is contaminated with volatile organic compounds (VOC) resulting from unpermitted disposal. The facility is currently in the remediation phase. The surface water affected by the VOCs is Wards Creek.

Growth Potential

There is a high potential for growth in this watershed, which contains the City of Greer. The Greenville-Spartanburg Airport expansion, the development of the BMW automotive plant, and highway improvements in the area surrounding the BMW plant will stimulate continued growth. Growth is also expected around the I-85 and US 29 corridors, which connect the Cities of Greenville, Greer, and Spartanburg. The Town of Duncan is expected to serve as a bedroom community for the Greer-Spartanburg area.

Implementation Strategy

The South Tyger River has an impaired macroinvertebrate community from point sources. A facility is currently under enforcement action for acute toxicity. The river is also impacted by elevated levels of fecal coliform bacteria due to point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050107-020

(North Tyger River)

General Description

Watershed 03050107-020 is located in Spartanburg County and consists primarily of the upper ***North Tyger River*** and its tributaries. The watershed occupies 22,376 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Cataula series. The erodibility of the soil (K) averages 0.27; the slope of the terrain averages 12%, with a range of 2-40%. Land use/land cover in the watershed includes: 10.74% urban land, 32.45% agricultural land, 0.57% scrub/shrub land, 0.37% barren land, 54.14% forested land, and 1.73% water.

Jordan Creek, which was impounded to create Lake Cooley, drains into the North Tyger River along with several unnamed tributaries. There are several ponds and lakes (10-330 acres) in this watershed used for recreational purposes and 44.9 stream miles, all classified FW.

Water Quality

North Tyger River (B-219) - Aquatic life uses are partially supported due to occurrences of zinc, including a high concentration that was in excess of the aquatic life acute standard. In addition, there are significantly decreasing trends in dissolved oxygen concentration and pH, and a significantly increasing trend in turbidity. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions, compounded by a significantly increasing trend in fecal coliform bacteria concentration.

Lake Cooley (B-348) - Lake Cooley is a 330-acre impoundment on Jordan Creek in Spartanburg County, with a maximum depth of approximately 39 feet (12.0 m) and a mean depth of 4.0 feet (1.2 m). Lake Cooley's watershed comprises approximately 10 square miles (27 km2). The lake is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of Lake Cooley's desirable trophic condition is recommended. Aquatic life and recreational uses are fully supported.

Unnamed Tributary to the North Tyger River (B-315) - Aquatic life uses are fully supported, but may be threatened by a significantly decreasing trend in pH. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)***	***NPDES#*** ***TYPE*** ***LIMITATION***
NORTH TYGER RIVER SSSD/BUCKEYE FOREST	SC0000957 MINOR MUNICIPAL

PIPE #: 001 FLOW: 0.06	EFFLUENT
NORTH TYGER RIVER STEVECOKNIT/MICKEL PLT PIPE #: 001 FLOW: M/R	SCG250147 MINOR INDUSTRIAL EFFLUENT
NORTH TYGER RIVER LEIGH FIBERS, INC. PIPE #: 001 FLOW: M/R	SCG250170 MINOR INDUSTRIAL EFFLUENT
LAKE COOLEY VULCAN MATERIALS CO. PIPE #: 001 FLOW: M/R	SCG730056 MINOR INDUSTRIAL EFFLUENT
NORTH TYGER TRIBUTARY JACKSON MILLS/WELLFORD PLT PIPE #: 001 FLOW: 0.05 WQL FOR DO,TRC,NH3N	SC0001716 MINOR MUNICIPAL WATER QUALITY

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
WELLFORD LANDFILL MUNICIPAL	421001-1101 ACTIVE
WELLFORD LANDFILL C&D LANDFILL	421001-1201 ACTIVE
OLD WELLFORD LANDFILL MUNICIPAL	DWP-012 CLOSED
MESSER MIRROR INDUSTRIAL	IWP-196 ACTIVE
PALMETTO LANDFILL MUNICIPAL	422401-1101 ACTIVE

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
VULCAN MATERIAL CO. LYMAN QUARRY	0587-42 GRANITE
GROUND IMPROVEMENT TECHNIQUES, INC. WELLFORD CLAY MINE	1125-42 CLAY

Growth Potential

There is a high potential for growth in this watershed, which connects the Cities of Greer and Spartanburg via the I-85 corridor and major roads with I-85 interchanges. There are also industrial developmental pressures along US 29. The City of Spartanburg is building regional treatment facilities, which should provide for future growth. The City of Wellford is expected to serve as a bedroom community for the Greer-Spartanburg area.

Implementation Strategy

The North Tyger River is impaired by elevated levels of zinc from unknown sources. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible. The North Tyger River is also impaired from elevated levels of fecal coliform bacteria resulting from both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050107-030

(North Tyger River)

General Description

Watershed 03050107-030 is located in Spartanburg County and consists primarily of the lower *North Tyger River* and its tributaries. The watershed occupies 33,797 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Davidson-Pacolet-Enon-Cecil series. The erodibility of the soil (K) averages 0.29; the slope of the terrain averages 8%, with a range of 2-15%. Land use/land cover in the watershed includes: 18.00% urban land, 16.55% agricultural land, 2.52% scrub/shrub land, 0.08% barren land, 62.77% forested land, and 0.08% water.

Frey Creek (Grays Creek) drains into the North Tyger RIver followed by Jimmies Creek, Cub Branch, Ranson Creek, Tim Creek (Montgomery Pond), and Stillhouse Branch. Further downstream the river flows through Ott Shoals and accepts drainage from Wards Creek (Tanyard Branch), Tin Roof Branch, Johnson Branch (Big Branch), and Thomas Branch. There are several ponds and lakes (10-137 acres) in this watershed used for recreational purposes and 75.2 stream miles, all classified FW.

Water Quality

North Tyger River - There are three monitoring sites along this portion of the North Tyger River. Aquatic life uses are fully supported at the upstream site **(B-017)** based on macroinvertebrate community data. Further downstream **(B-162)**, aquatic life uses are also fully supported, but may be threatened by a significantly decreasing trend in pH and a significantly increasing trend in turbidity. A significantly increasing trend in dissolved oxygen concentration and a significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for these parameters. Aquatic life uses are again fully supported at the downstream site **(B-018A)**, but recreational uses are not supported at either downstream location due to fecal coliform bacteria excursions. This river was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)***	***NPDES#*** ***TYPE*** ***LIMITATION***
NORTH TYGER RIVER ABCO INDUSTRIES LTD. PIPE #: 001 FLOW: 0.036	SC0002321 MAJOR INDUSTRIAL EFFLUENT
NORTH TYGER RIVER LAIDLAW ENV. SERVICES PIPE #: 001 FLOW: 0.234	SC0040517 MAJOR INDUSTRIAL EFFLUENT
NORTH TYGER RIVER SSSD/NORTH TYGER RIVER	SC0043532 MAJOR MUNICIPAL

PIPE #: 001 FLOW: 2.0 WQL FOR TRC,NH3N	WATER QUALITY
NORTH TYGER RIVER SSSD/NORTH TYGER RIVER PIPE #: 001 FLOW: 5.5 (PROPOSED) WQL FOR BOD5,DO,TRC,NH3N	SC0043532 MAJOR MUNICIPAL WATER QUALITY
NORTH TYGER RIVER SSSD/REEVES BROS. WWTP PIPE #: 001 FLOW: 0.085 PIPE #: 001 FLOW: 0.1013 (PROPOSED)	SC0047139 MINOR MUNICIPAL EFFLUENT EFFLUENT
CUB BRANCH HARMON'S TRAILER PARK PIPE #: 001 FLOW: 0.03 WQL FOR DO,TRC,NH3N	SC0033308 MINOR MUNICIPAL WATER QUALITY
CUB BRANCH SSSD/FOREST PARK ESTATES PIPE #: 001 FLOW: 0.05 WQL FOR TRC,NH3N	SC0034321 MINOR MUNICIPAL WATER QUALITY
CUB BRANCH SSSD/SHORESBROOK SD PIPE #: 001 FLOW: 0.2 WQL FOR TRC,NH3N	SC0035891 MINOR MUNICIPAL WATER QUALITY
TIM CREEK SSSD/ROEBUCK MIDDLE SCHOOL PIPE #: 001 FLOW: 0.02 WQL FOR DO,TRC,NH3N	SC0037532 MINOR MUNICIPAL WATER QUALITY
TIM CREEK SSSD/TIM CREEK WWTP PIPE #: 001 FLOW: 0.05 WQL FOR TRC,NH3N	SC0041491 MINOR MUNICIPAL WATER QUALITY
JIMMIES CREEK SYBRON CHEMICALS WWTP PIPE #: 001 FLOW: 0.36 WQL FOR DO	SC0003492 MINOR INDUSTRIAL WATER QUALITY
RANSON CREEK MADERA SD PIPE #: 001 FLOW: 0.076 WQL FOR DO,TRC,NH3N	SC0021687 MINOR COMMUNITY WATER QUALITY
RANSON CREEK TRIBUTARY LINVILLE HILLS SD PIPE #: 001 FLOW: 0.12 WQL FOR DO,TRC,NH3N	SC0034169 MINOR MUNICIPAL WATER QUALITY
FREY CREEK MIDWAY PARK INC. PIPE #: 001 FLOW: 0.015 WQL FOR TRC	SC0030571 MINOR COMMUNITY WATER QUALITY

Landfill Activities

SOLID WASTE LANDFILL NAME *FACILITY TYPE*	*PERMIT #* *STATUS*
PALMETTO LANDFILL MUNICIPAL	422401-1101 ACTIVE
BATCHILDER BLASIUS SMELTING SLAG LANDFILL	------ CLOSED
SPRINGS INDUSTRIES/SPARTANBURG COUNTY INDUSTRIAL/MUNICIPAL	------ CLOSED
TINDAL CONCRETE SPECIAL WASTE LANDFILL INDUSTRIAL	423340-1601 ACTIVE

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
WR GRACE & CO. JOHNSON MINE	0834-42 VERMICULITE

Growth Potential

There is a moderate potential for growth in this watershed. I-26 bisects the watershed and growth is expected around the major highway interchanges, along with industrial developmental pressures along US 29 and US 221. The City of Spartanburg is building regional treatment facilities, which should provide for future growth.

Implementation Strategy

The North Tyger River is impaired by elevated levels of zinc from unknown sources. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible. The North Tyger River is also impaired from elevated levels of fecal coliform bacteria resulting from both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050107-040

(Middle Tyger River)

General Description

Watershed 03050107-040 is located in Greenville and Spartanburg Counties and consists primarily of the ***Middle Tyger River*** and its tributaries. The watershed occupies 64,948 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil series. The erodibility of the soil (K) averages 0.28; the slope of the terrain averages 8%, with a range of 2-15%. Land use/land cover in the watershed includes: 9.02% urban land, 23.85% agricultural land, 0.77% scrub/shrub land, 1.08% barren land, 64.32% forested land, and 0.95% water.

The Middle Tyger River accepts drainage from Campbell Creek, Beaverdam Creek (Barnes Creek), and Spencer Creek before flowing into Lyman Lake (Meadow Creek). Downstream of Lyman Lake, another Beaverdam Creek (Foyster Creek, Thompson Branch, Berrys Millpond, Silver Lake) flows into the river followed by Twin Lakes much further downstream. There are several ponds and lakes (16-500 acres) in this watershed used for recreational, industrial, municipal, and irrigational purposes. There are a total of 120.3 stream miles, all classified FW.

Water Quality

Middle Tyger River - There are three monitoring sites along the Middle Tyger River. Aquatic life uses are fully supported at the upstream site **(B-148)** based on macroinvertebrate community, but may be threatened by a significantly increasing trend in turbidity, occurrences of zinc (including a very high concentration) in excess of the aquatic life acute standard, and a very high concentration of cadmium measured in sediment. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Aquatic life uses are fully supported at the midstream site **(B-012)**, but may be threatened by a significantly decreasing trend in pH. A significantly decreasing trend in five-day biochemical oxygen demand concentration suggests improving conditions for this parameter. Aquatic life uses are again fully supported at the downstream site **(B-014)** based on physical, chemical, and macroinvertebrate community data. Recreational uses are not supported at any site due to fecal coliform bacteria excursions and there is a significantly increasing trend in fecal coliform bacteria concentration. This river was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM	***NPDES#***
FACILITY NAME	***TYPE***
PERMITTED FLOW @ PIPE (MGD)	***LIMITATION***
COMMENT	
MIDDLE TYGER RIVER	SC0002453
SPARTAN MILLS/STARTEX MILL	MAJOR INDUSTRIAL

PIPE #: 001 FLOW: 0.9 WQL FOR BOD5,DO,TRC	WATER QUALITY
MIDDLE TYGER RIVER - TOWN OF LYMAN WWTP PIPE #: 001 FLOW: 6.0 WQL FOR BOD5,DO,TRC,NH3N	SC0021300 MAJOR MUNICIPAL WATER QUALITY
MIDDLE TYGER RIVER SJWD/WTP PIPE #: 001 FLOW: M/R	SCG643003 MINOR MUNICIPAL EFFLUENT
MIDDLE TYGER RIVER SSSD/BROOKSIDE VILLAGE PIPE #: 001 FLOW: 0.08	SC0023698 MINOR MUNICIPAL EFFLUENT
MIDDLE TYGER RIVER SSSD/TWIN LAKES SD PIPE #: 001 FLOW: 0.12	SC0035696 MINOR MUNICIPAL EFFLUENT

LAND APPLICATION **FACILITY NAME**	**PERMIT#** **TYPE**
SPRAYFIELD BLUE RIDGE HIGH SCHOOL	ND0064629 MUNICIPAL

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
SPRINGS INDUSTRIES INDUSTRIAL	----- CLOSED

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
CLARK CONSTRUCTION CO. CLARK-TYGER SAND MINE	0886-23 SAND
PANEX-EC RESTER MINE	0880-23 SAND & GRAVEL

Water Supply

WATER USER (TYPE) ***STREAM***	***PUMPING CAPACITY (MGD)*** ***REG. PUMPING CAPACITY (MGD)***
SJWD (M) MIDDLE TYGER RIVER	32.8 14.0

Growth Potential

There is a high potential for growth in this watershed, which connects the Cities of Greer and Spartanburg via the I-85 corridor and major roads with I-85 interchanges. There are also industrial developmental pressures along US 29. The Towns of Lyman and Startex are expected to serve as a bedroom community for the Greer-Spartanburg area.

Implementation Strategy

The Middle Tyger River is impaired by elevated levels of fecal coliform bacteria resulting from both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050107-050

(Tyger River)

General Description

Watershed 03050107-050 is located in Spartanburg and Union Counties and consists primarily of the ***Tyger River*** and its tributaries from its confluence with the South and North Tyger Rivers to its confluence with the Broad River. The watershed occupies 152,393 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Wilkes-Madison series. The erodibility of the soil (K) averages 0.24; the slope of the terrain averages 20%, with a range of 6-45%. Land use/land cover in the watershed includes: 0.70% urban land, 6.74% agricultural land, 5.28% scrub/shrub land, 0.34% barren land, 86.90% forested land, and 0.05% water.

The Tyger River is formed by the confluence of the South Tyger River Watershed and the North Tyger River Watershed. The Tyger River then accepts drainage from Nichol Branch (Kelly Branch), Vise Branch, Harrelson Branch (Wofford Branch, Aiken Branch), Jimmies Creek, Cane Creek (Martha Shands Branch, Williams Branch, Trail Branch), Motley Branch, Hackers Creek, and Dutchman Creek. Dutchman Creek accepts drainage from Harrison Branch, Newman Branch, Smith Creek (Jennings Branch), Powder Spring Branch, Shands Branch (Pennywinkle Branch), Paint Bearden Branch, Bearden Branch, another Wofford Branch, Wiley Fork Creek (Carson Branch), and Dry Branch. Cowdens Creek enters the river next followed by Mill Creek, another Wofford Branch, Holcombe Branch, Isaacs Creek, and Sparks Creek. Further downstream, the Tyger River accepts drainage from the Fairforest Creek Watershed, the Tinker Creek Watershed, Hawkins Creek, Johnsons Creek, Padgetts Creek, Evans Branch, Rennicks Branch, Duffs Branch, Peters Creek, and Cane Creek (Brocks Creek). Due to the absence of point source dischargers and the presence of endangered species and other special characteristics, portions of the Tyger River within the Sumter National Forest may qualify as potential ORW candidates. There are a few ponds and lakes (10-25 acres) in this watershed used for recreational purposes and 234.5 stream miles, all classified FW. The lower half of the watershed resides within the Sumter National Forest. Rose Hill State Park is located near the confluence of the Tyger River and Fairforest Creek.

Water Quality

Tyger River - There are two monitoring sites along the Tyger River. Aquatic life uses are fully supported at the upstream site **(B-008)**, but may be threatened by significantly decreasing trends in dissolved oxygen concentration and pH, and a significantly increasing trend in turbidity. Sediment samples revealed a very high concentration of chromium in 1992 and a high concentration in 1993. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions. In addition, there is a significantly increasing trend in fecal coliform bacteria concentration.

At the downstream site **(B-051)**, aquatic life uses are not supported due to occurrences of zinc in excess of the aquatic life acute standard, including a high concentration in 1993. In addition, there are significantly increasing trends in pH and turbidity. Significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions. This river was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Jimmies Creek (B-019) - Aquatic life uses are fully supported. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Dutchman Creek (B-733) - Aquatic life uses are fully supported based on macroinvertebrate community data.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
TYGER RIVER SC DEPT. CORR./CROSS ANCHOR CORR. INST. PIPE #: 001 FLOW: 0.35	SC0036773 MINOR COMMUNITY EFFLUENT
TYGER RIVER SYNTHETIC IND./SPARTANBURG PLT PIPE #: 001 FLOW: M/R	SCG250074 MINOR INDUSTRIAL EFFLUENT

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
WR GRACE & CO. FOSTER MINE	0460-42 VERMICULITE
WR GRACE & CO. PROVIDENCE MINE	0706-42 VERMICULITE
WR GRACE & CO. C. CASEY MINE	1017-42 VERMICULITE ORE
WR GRACE & CO. MYERS MINE	1021-42 VERMICULITE ORE
KING ASPHALT, INC. JOSEPH W. THEO MINE	1124-42 SAND
PATTERSON VERMICULITE CO. FANNIE YOUNG MINE	0585-42 VERMICULITE

Growth Potential

There is an overall low potential for growth in this watershed. An exception would be the City of Woodruff, which is expected to experience residential, commercial, and industrial growth. The lower portion of the watershed is effectively excluded from development by the Sumter National Forest. The western section of the Town of Carlisle is in this watershed, and two projects have been proposed which could influence its growth. One is to impound the Tyger River to create a public access lake to promote development, and the other is to develop a regional solid waste landfill. Union County is currently developing a feasibility study for a multi-county landfill.

Implementation Strategy

The Tyger River is impaired by elevated levels of zinc from unknown sources. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible. The Tyger River is also impaired from elevated levels of fecal coliform bacteria resulting from both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050107-060

(Fairforest Creek/Tinker Creek)

General Description

Watershed 03050107-060 is located in Spartanburg and Union Counties and consists primarily of ***Fairforest Creek and Tinker Creek*** and their tributaries. Both Fairforest Creek and Tinker Creek flow into the Broad River. The watershed occupies 155,396 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Madison-Wilkes series. The erodibility of the soil (K) averages 0.26; the slope of the terrain averages 13% with a range of 2-40%. Land use/land cover in the watershed includes: 14.57% urban land, 11.42% agricultural land, 3.14% scrub/shrub land, 0.34% barren land, 70.22% forested land, and 0.31% water.

Fairforest Creek originates near the City of Spartanburg and accepts drainage from Goat Pond Creek, Holston Creek, Beaverdam Creek (Reedy Creek), Foster Creek (Underwood Branch), Reedy Branch, Buffalo Creek (Zimmerman Pond), Fleming Branch, Goose Branch, Stillhouse Branch (Smith Branch), and Lancaster Branch (James Branch, Pauline Creek, Dugan Creek). Kelsey Creek flows through Lake Craig (Lake Johnson, Thompson Creek) before entering Fairforest Creek. Black Branch (Whitestone Spring Branch) flows into Fairforest Creek next followed by McElwain Creek (Story Branch, Mineral Spring Branch, Sulphur Spring Branch), Kennedy Creek (Iscons Creek, Cunningham Creek), McClure Creek, Sugar Creek (another Beaverdam Creek, Whitlock Lakes, White Pine Lake), Swink Creek (Bishop Branch), and Rocky Creek. Swink Creek is also known as Mitchell Creek and Bishop Branch is also known as Mill Creek. Further downstream, Fairforest Creek accepts drainage from Mitchell Creek, another Sugar Creek (West Springs Branch), another Buffalo Creek, Dining Creek, Shoal Creek (Toschs Creek), Sand Creek, and Morris Branch.

Tinker Creek flows into the Broad River downstream of Fairforest Creek. Tinker Creek accepts drainage from Henry Creek (Reno Lake), Brushy Creek, and Swift Run. There are several ponds and lakes (11-105 acres) in this watershed used for recreational purposes, and 253.7 stream miles, all classified FW. The lower portion of the watershed resides within the Sumter National Forest, and Croft State Park is located next to Fairforest Creek, just south of the City of Spartanburg.

Water Quality

Fairforest Creek **-** There are five monitoring sites along Fairforest Creek. Aquatic life uses are fully supported at the upstream sites **(B-020, B-164)**, but may be threatened by a significantly increasing trend in turbidity at both sites and a significantly decreasing trend in pH at B-020. A significantly decreasing trend in total phosphorus concentration at both upstream sites suggests improving conditions for this parameter. Recreational uses are not supported at either site due to fecal coliform bacteria excursions. This is compounded at B-164 by a significantly increasing trend in fecal coliform bacteria concentration.

Further downstream **(B-021)**, aquatic life uses are partially supported based on macroinvertebrate community data. In addition, there is a significantly increasing trend in turbidity, and occurrences of chromium and zinc in excess of the aquatic life acute standard, including two high concentrations of zinc.

Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions, compounded by a significantly increasing trend in fecal coliform bacteria concentration.

Aquatic life uses are also partially supported at the next site downstream **(BF-007)** due to dissolved oxygen excursions. In addition, there is a significantly decreasing trend in dissolved oxygen concentration. This is a secondary monitoring station and sampling is purposely biased towards periods with potentially low dissolved oxygen concentrations. Significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentration, and turbidity suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions; however, a significantly decreasing trend in fecal coliform bacteria concentration suggests improving conditions for this parameter. At the furthest downstream site **(BF-008)**, aquatic life uses are fully supported based on physical, chemical, and macroinvertebrate community data. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions.

This creek was Class B until April, 1992. Because of chronically high concentrations of fecal coliform bacteria in the upper portions of this creek, samples were collected from additional sites on upper Fairforest Creek in August of 1995. No obvious point source was identified as concentrations were extremely high at all sampling sites, with the exception of the most upstream site. Even at the upstream site Class FW standards were exceeded. The most likely sources of the elevated fecal coliform bacteria concentrations are stormwater runoff and sewage collection system failures.

Unnamed Tributary to Fairforest Creek (B-321) - Aquatic life uses are not supported due to occurrences of chromium, copper, lead, and zinc in excess of the aquatic life acute standard, including a very high concentration of zinc in 1994, a high concentration of copper in 1994, and a high concentration of zinc in 1995. In addition, there is a significantly decreasing trend in pH and a significantly increasing trend in turbidity. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions, compounded by a significantly increasing trend in fecal coliform bacteria concentration.

Kelsey Creek (B-235) - Aquatic life uses are fully supported, but may be threatened by significantly decreasing trends in dissolved oxygen concentration and pH, and a significantly increasing trend in turbidity. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Lake Johnson (CL-035) - Aquatic life uses are fully supported. Although pH excursions occurred, higher pH levels are not uncommon in lakes with significant aquatic plant communities and are considered natural, not standards violations. Lake Edwin Johnson, in Croft State Park in Spartanburg County, is a 40-acre impoundment on Thompson Creek. Lake Johnson's maximum depth is approximately 28 feet (8.5 m); average depth is approximately 14 feet (4.4 m). The lake's watershed comprises approximately 9.3 square miles (24 km2) and includes Lake Craig. Lake Johnson currently maintains an intermediate trophic condition among small lakes in South Carolina; the lake is managed for fishing and supports high algal biomass.

Lake Craig (CL-033) - Aquatic life uses are fully supported. Lake Tom Moore Craig, in Croft State Park in Spartanburg County, is a 105-acre impoundment on Kelsey Creek. The average depth of Lake Craig is approximately 17 feet (5.2 m); the maximum depth is approximately 20 feet (6.1 m). The lake's watershed comprises approximately 8.1 square miles (21 km2). Historical eutrophication studies indicate that Lake Craig's trophic condition is improving; the impoundment has been reconstructed after being destroyed in 1990 floods. The lake is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of Lake Craig's desirable trophic condition is recommended.

Swink Creek or Mitchell Creek (B-199) - Aquatic life uses are fully supported. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Toschs Creek - There are two monitoring sites along Toschs Creek. Aquatic life uses are fully supported at the upstream site **(B-067A)**, and significantly decreasing trends in five-day biochemical oxygen demand and turbidity suggest improving conditions for these parameters. Aquatic life uses are also fully supported at the downstream site **(B-067B)**, but may be threatened by a significantly increasing trend in pH. Significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentrations, and turbidity suggest improving conditions for these parameters. Recreational uses are not supported at either site due to fecal coliform bacteria excursions, and is compounded at the downstream site by a significantly increasing trend in fecal coliform bacteria concentration. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Tinker Creek - There are three monitoring sites along Tinker Creek. Aquatic life uses are fully supported at the upstream site **(B-286)**. Aquatic life uses are also fully supported at the midstream site **(B-287)**, but may be threatened by a significantly increasing trend in pH. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration at both the upstream and midstream sites suggest improving conditions for these parameters. Aquatic life uses are again fully supported at the downstream site **(B-336)** based on macroinvertebrate community data, but may be threatened by occurrences of copper and zinc in excess of the aquatic life acute standard. Recreational uses are not supported at any site due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
FAIRFOREST CREEK SSSD/FAIRFOREST PLANT PIPE #: 001 FLOW: 14.1 WQL FOR TRC,NH3N	SC0020435 MAJOR MUNICIPAL WATER QUALITY
FAIRFOREST CREEK FAIRWOODS SD/UNITED UTILITIES PIPE #: 001 FLOW: 0.065	SC0035041 MINOR COMMUNITY EFFLUENT
FAIRFOREST CREEK SSSD/CAROLINA COUNTRY CLUB PIPE #: 001 FLOW: 0.25 WQL FOR DO,TRC	SC0039560 MINOR MUNICIPAL WATER QUALITY
FAIRFOREST CREEK CITY OF UNION/TOSCHS CREEK WWTP PIPE #: 001 FLOW: 6.0 PROPOSED; WQL FOR BOD5,DO,TRC,NH3N	SC0047244 MAJOR MUNICIPAL WATER QUALITY
FAIRFOREST CREEK MAYFAIR MILLS/MAYFAIR & BAILEY PIPE #: 001 FLOW: M/R	SCG250015 MINOR INDUSTRIAL EFFLUENT
FAIRFOREST CREEK DITCH ADO CORP. WWTP PIPE #: 001 FLOW: M/R	SCG250071 MINOR INDUSTRIAL EFFLUENT
FAIRFOREST CREEK TRIBUTARY POWDERCRAFT CORP. PIPE #: 001 FLOW: M/R	SCG250159 MINOR INDUSTRIAL EFFLUENT
FAIRFOREST CREEK TRIBUTARY SPARTAN MILLS/SPARTAN DIV. PIPE #: 001 FLOW: M/R	SC0002445 MINOR INDUSTRIAL EFFLUENT
FAIRFOREST CREEK TRIBUTARY STONEHAVEN MHP PIPE #: 001 FLOW: .0225 WQL FOR DO,TRC,NH3N	SC0032409 MINOR COMMUNITY WATER QUALITY
REEDY CREEK SSSD/MARILYNDALE SD PIPE #: 001 FLOW: 0.0415 WQL FOR TRC	SC0030121 MINOR MUNICIPAL WATER QUALITY
GOAT POND CREEK AMOCO FABRICS & FIBERS PIPE #: 001 FLOW: M/R	SC0003107 MINOR INDUSTRIAL EFFLUENT
GOAT POND CREEK	SCG250074

SYNTHETIC IND./SPARTANBURG PLT PIPE #: 001 FLOW: M/R	MINOR INDUSTRIAL EFFLUENT
HOLSTON CREEK EVANS MHP PIPE #: 001 FLOW: 0.0038 WQL FOR TRC,NH3N	SC0029521 MINOR COMMUNITY WATER QUALITY
HOLSTON CREEK MINI MART/SPARTANBURG PIPE #: 001 FLOW: M/R	SCG830017 MINOR INDUSTRIAL EFFLUENT
BEAVERDAM CREEK DAVIDSON MINERAL/SANDY FLATS PIPE #: 001 FLOW: M/R	SCG730079 MINOR INDUSTRIAL EFFLUENT
BEAVERDAM CREEK TRIBUTARY S&S MANUFACTURING PIPE #: 001 FLOW: 0.01 WQL FOR TRC,NH3N	SC0022616 MINOR INDUSTRIAL WATER QUALITY
KELSEY CREEK CITCO PETROLEUM PIPE #: 001 FLOW: M/R	SCG340008 MINOR INDUSTRIAL EFFLUENT
KELSEY CREEK TRIBUTARY COLONIAL PIPELINE/SPARTANBURG PIPE #: 001 FLOW: M/R	SC0040665 MINOR INDUSTRIAL EFFLUENT
MILL CREEK TOWN OF JONESVILLE PIPE #: 001 FLOW: 0.15 PIPE #: 001 FLOW: 0.25 (PROPOSED) WQL FOR DO,TRC,NH3N	SC0024988 MINOR MUNICIPAL WATER QUALITY WATER QUALITY
MINERAL SPRING BRANCH SPARTANBURG BOYS HOME PIPE #: 001 FLOW: 0.0035 WQL FOR TRC	SC0024449 MINOR COMMUNITY WATER QUALITY
ROCKY CREEK MILLIKEN & CO./CEDAR HILL PLT PIPE #: 001 FLOW: 0.0163 PIPE #: 001 FLOW: 0.0170 (PHASE I) PIPE #: 001 FLOW: 0.0198 (PHASE II) WQL FOR TRC,NH3N	SC0000809 MINOR INDUSTRIAL WATER QUALITY WATER QUALITY WATER QUALITY
TOSCHS CREEK TRIBUTARY TORRINGTON CO./UNION BEARINGS PIPE #: 001 FLOW: M/R PIPE #: 002 FLOW: M/R WQL FOR BOD5	SC0038636 MINOR INDUSTRIAL WATER QUALITY WATER QUALITY
ISCONS CREEK TRIBUTARY MILLIKEN & CO./WHITESTONE PIPE #: 001 FLOW: M/R	SC0023370 MINOR INDUSTRIAL EFFLUENT
SUGAR CREEK TRIBUTARY UNION AMOCO STATION	SCG830023 MINOR INDUSTRIAL

PIPE #: 001 FLOW: M/R	EFFLUENT
TINKER CREEK CITY OF UNION/BELTLINE PLANT PIPE #: 001 FLOW: 0.35 WQL FOR BOD5,DO,TRC,NH3N	SC0021202 MINOR MUNICIPAL WATER QUALITY

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
RED HILL LANDFILL INDUSTRIAL	422444-1601 ACTIVE
CROFT LANDFILL MUNICIPAL	421001-1102 ACTIVE
OLD CITY/COUNTY DUMP MUNICIPAL	------- CLOSED
MAXIE COPELAND LANDFILL LONGTERM C&D LANDFILL	442329-1201 ACTIVE

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
FAIRFOREST CREEK SAND CO. FAIRFOREST CREEK SAND MINE	1059-42 SAND

Water Supply

WATER USER (TYPE) ***STREAM***	***RATED PUMP. CAPACITY (GPM)*** ***AMT. TRT./DIV. (MGD)***
MAYFAIR MILLS-BAILY PLT FAIRFOREST CREEK	1000 1.44
AMOCO FABRICS & FIBERS CO. FAIRFOREST CREEK TRIBUTARY	1000 3.00

Groundwater Concerns

The groundwater in the vicinity of the properties owned by Ina Bearing - Holly Mobile Home Park (Site #13493) and Spartanburg Steel Products (Site #00403) is contaminated with volatile organic compounds (VOCs) due to unknown sources. The surface water affected by the contamination from Ina Bearing is Fairforest Creek and the facility is currently in the remediation phase (air sparging system initiated). The surface water affected by the contamination from Spartanburg Steel Products is Goat Pond Creek which drains into Fairforest Creek. The facility is currently in the assessment and monitoring phases.

The groundwater in the vicinity of the property owned by Blackman Uhler Chemical is contaminated with volatile organic compounds (VOC) resulting from pits, ponds, and lagoons. This is a RCRA facility and is currently in the remediation phase. The surface water affected by the VOCs is an unnamed tributary of

Kelsey Creek. Another area with groundwater contaminated by VOCs is the I-85 Site, also resulting from pits, ponds, and lagoons. The area is currently in the assessment phase and the affected surface water is Fairforest Creek.

Growth Potential

There is a high potential for growth in this watershed, which contains portions of the Cities of Spartanburg and Union. Industrial growth in particular is expected along the I-85 corridor and major roads with I-85 interchanges. There are also industrial developmental pressures along I-26, US 29, and US 221. Urban development is evident in the City of Union and in the unincorporated Buffalo Mill Village in the form of residential, commercial, and industrial uses. Growth is most evident along the US 176 Bypass. US 176 north from Union to Spartanburg has recently been widened to four lanes and has generated the development of an industrial park. The lower portion of the watershed is effectively excluded from development by the Sumter National Forest.

Implementation Strategy

Fairforest Creek has an impaired macroinvertebrate community, low dissolved oxygen concentrations, and elevated fecal coliform bacteria concentrations due to point and nonpoint sources. The macroinvertebrate samples will be evaluated to determine the cause of their impairment. Toschs Creek and Tinker Creek are also impaired from elevated levels of fecal coliform from point and nonpoint sources. Permit revisions have been initiated and oxygen and bacterial improvements are expected in the next basin rotation. An enforcement action is also underway for fecal coliform bacteria.

A Fairforest Creek tributary is impaired by elevated levels of zinc, chromium, lead, and copper related to unknown and point sources. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible.

Watershed Evaluations and Implementation Strategies Within WMU-0502

Watershed Management Unit (WMU) 0502 consists of the ***Pacolet River Basin*** and the ***Broad River Basin***. WMU-0502 extends across the Piedmont region of the State and contains 21 watersheds, some 1.5 million acres of which 7.41% is urban land, 13.44% is agricultural land, 5.37% is scrub/shrub land, 0.50% is barren land, 71.54% is forested land, 0.02% is forested wetland, and 1.72% is water (SCLRCC 1990). There are a total of 2,846.4 stream miles in WMU-0502.

The Broad River flows across the North Carolina/South Carolina state line and accepts drainage from Buffalo Creek, Cherokee Creek, Kings Creek, Thicketty Creek, Bullock Creek, the Pacolet River, Turkey Creek, Browns Creek, the Sandy River, the Little River, and Cedar Creek in WMU-0502 and the Enoree River and the Tyger River from WMU-0501.

Fish Consumption Advisory

A fish consumption advisory has been issued by SCDHEC for portions of the Broad River advising people to limit the amount of some types of fish consumed from this river due to mercury contamination. Pregnant women, infants, children, and people with neurologic diseases face the greatest risk of mercury related health problems and should not eat any fish from these waters. The consumption of Largemouth Bass from the Broad River south of Neal Shoals in Union County to the confluence with the Saluda River in Columbia should be restricted to no more than 3.25 pounds per month.

The source of mercury contamination in fish tested by the Department is uncertain. Mercury occurs naturally and may account for a portion of the levels found in fish tissue. Another source is deposition from the air, a result of the combustion of fossil fuels. The Department continues to monitor for mercury in ambient air and precipitation. A precipitation sampler is located at the Congaree Swamp National Monument as part of the National Air Deposition Program, Mercury Deposition Network. Weekly composite samples are collected for mercury analysis to provide background concentrations for application across the State. The continuous monitoring of mercury concentrations in air is also conducted at the site.

There is no data available linking mercury in wastewater discharges as a major source of mercury in fish, nor can mercury levels be traced to any industries. South Carolina is one of 40 states that are seeing high mercury levels in fish and have issued advisories. These states are working together and with the U.S. Environmental Protection Agency to try and identify the cause or causes of mercury in fish.

Climate

Normal yearly rainfall in the WMU-0502 area is 48.25 inches, according to the S.C. historic climatological record (SCWRC 1990). Data compiled from National Weather Service stations in Rainbow Lake, Gaston Shoals, Gaffney, Ninety Nine Islands, Spartanburg, Santuck, Chester, Blair, Winnsboro, Parr, Little Mountain, Columbia at USC, and Columbia Metropolitan Airport were used to determine the general climate information for this portion of the State. The highest level of rainfall occurs in the summer with 13.55 inches; 12.41, 10.37, and 12.50 inches of rain falling in the fall, winter, and spring, respectively. The average annual daily temperature is 62.1°F. Summer temperatures average 78.4°F and fall, winter, and spring temperatures are 63.0°F, 45.0°F, and 62.1°F, respectively.

03050105-050

(Broad River)

General Description

Watershed 03050105-050 is located in Cherokee and Spartanburg Counties and consists primarily of tributaries of the ***Broad River***. This watershed occupies 16,454 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Pacolet series. The erodibility of the soil (K) averages 0.28; the slope of the terrain averages 10%, with a range of 2-45%. Land use/land cover in the watershed includes: 8.95% urban land, 37.39% agricultural land, 1.36% scrub/shrub land, 0.32% barren land, 51.79% forested land, and 0.19% water.

Before the Broad River flows across the South Carolina/North Carolina border it accepts drainage from several streams originating in South Carolina that flow into North Carolina including Arrowood Branch, Big Horse Creek (Little Horse Creek, Jolleys Lake), Suck Creek, and Ashworth Creek. There are several small ponds and lakes in this watershed used for recreational purposes and 26.8 stream miles, all classified FW.

Water Quality

There are no water quality monitoring stations in this watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
LITTLE HORSE CREEK SPARTAN MILLS/MONTGOMERY DIV. PIPE #: 001 FLOW: M/R WQL FOR TRC	SC0002429 MAJOR INDUSTRIAL WATER QUALITY

Growth Potential

There is a low potential for growth in this watershed.

03050105-090

(Broad River)

General Description

Watershed 03050105-090 is located in Cherokee and York Counties and consists primarily of the ***Broad River*** and its tributaries from the North Carolina border to the Pacolet River. The watershed occupies 82,652 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Wilkes-Goldston-Badin series. The erodibility of the soil (K) averages 0.28; the slope of the terrain averages 12%, with a range of 2-45%. Land use/land cover in the watershed includes: 4.54% urban land, 18.42% agricultural land, 0.84% scrub/shrub land, 1.04% barren land, 73.37% forested land, and 1.79% water.

After the river crosses the state line, it accepts drainage from Ross Creek (Sarratt Creek), Mikes Creek, the Bowens River (Wylies Creek), the Buffalo Creek Watershed, and the Cherokee Creek Watershed. Further downstream, Peoples Creek (Furnace Creek, Toms Branch) drains into the river near the City of Gaffney. Doolittle Creek enters the river next, near the Town of Blacksburg, followed by London Creek (Lake Cherokee, Little London Creek), Bear Creek, McKowns Creek, Dry Branch, the Kings Creek Watershed, and Quinton Branch. Mud Creek enters the river next, downstream of Mud Island, followed by Guyonmbore Creek, Mountain Branch, Abingdon Creek (Wolf Branch, Service Branch, Jenkins Branch), the Thicketty Creek Watershed, Beaverdam Creek (McDaniel Branch), the Bullock Creek Watershed, and Dry Creek (Nelson Creek).

There are several ponds and lakes (10-45 acres) in this watershed used for recreation and water supply and 229.3 stream miles, all classified FW. A fifteen mile segment of the Broad River, extending from Ninety Nine Islands Dam to the river's confluence with the Pacolet River is designated as a South Carolina State Scenic River in recognition of it's outstanding natural resources.

Water Quality

Broad River - There are two monitoring sites along this section of the Broad River. Aquatic life uses are fully supported at the upstream site **(B-042)**, but may be threatened by a significantly increasing trend in pH and a high concentration of zinc measured in 1991. Sediment samples revealed P,P'DDT and P,P'DDE (metabolites of DDT) in 1993, together with high concentrations of chromium and nickel. Although the use of DDT was banned in 1973, it is very persistent in the environment. Significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions; however, a significantly decreasing trend in fecal coliform bacteria concentration suggests improving conditions for this parameter.

At the downstream site **(B-044)**, aquatic life uses are not supported due to occurrences of cadmium, chromium, copper, lead, and zinc in excess of the aquatic life acute standards, including a high concentration of zinc in 1992 and a very high concentration in 1995. In addition, there is a significantly increasing trend in pH. Sediment samples revealed P,P'DDT in 1993. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are partially supported at this site due to fecal coliform bacteria excursions.

Canoe Creek - Aquatic life uses are partially supported at the site immediately upstream of the Town of Blacksburg wastewater treatment plant discharge (B-755), and not supported at the site immediately downstream of the discharge (B-756) or further downstream (B-088) based on macroinvertebrate community data (Shealy Environmental Services, Inc., 1996). Department data at B-088 indicates dissolved oxygen excursions, a significantly decreasing trend in dissolved oxygen concentration and a significantly increasing trend in five-day biochemical oxygen demand. A significantly decreasing trend in total phosphorus concentration suggests improving conditions for this parameter. Recreational uses are not supported due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed. In addition, the main discharge to this stream is being relocated to the Broad River, thus improving bacterial conditions.

Peoples Creek (B-211) - Aquatic life uses are fully supported, and significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentration, and turbidity suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions; however, a significantly decreasing trend in fecal coliform bacteria concentration suggests improving conditions for this parameter. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Furnace Creek (B-100) - Aquatic life uses are fully supported, but may be threatened by a significantly decreasing trend in dissolved oxygen concentration and a significantly increasing trend in pH. Sediment samples revealed a high concentration of zinc in 1991, P,P'DDT and O,P'DDT in 1993 and P,P'DDT again in 1994. Although the use of DDT was banned in 1973, it is very persistent in the environment. Significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentration, and turbidity suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Doolittle Creek (B-323) - Aquatic life uses are fully supported, and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Lake Cherokee (B-343) - Lake Cherokee is a 45-acre impoundment at the headwaters of London Creek in Cherokee County, with a maximum depth of approximately 32 feet (9.8 meters) and an average depth of 11 feet (3.4 meters). Lake Cherokee's watershed comprises approximately 0.2 square miles (0.4 km2). Historical eutrophication studies indicate that Lake Cherokee's trophic condition is improving. It is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of this lake's desirable trophic condition is recommended. Aquatic life and recreational uses are fully supported. In an effort to provide access for boating and fishing, 300 triploid grass carp (20/vegetated acre) were stocked in 1991 and aquatic herbicides were applied in 1989, 1991, and 1995.

Guyonmoore Creek (B-330) - Aquatic life uses are fully supported, and recreational uses are partially supported due to fecal coliform bacteria excursions.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
BROAD RIVER SC DISTRIBUTORS INC. PIPE #: 001 FLOW: 0.04	SC0002755 MINOR MUNICIPAL EFFLUENT
BROAD RIVER MILLIKEN & CO./MAGNOLIA PLT PIPE #: 001 FLOW: 3.45 PIPE #: 001 FLOW: 4.879 (PROPOSED)	SC0003182 MAJOR INDUSTRIAL EFFLUENT EFFLUENT
BROAD RIVER CHAMPION PRODUCTS PIPE #: 001 FLOW: 2.0	SC0035947 MAJOR INDUSTRIAL EFFLUENT
BROAD RIVER CITY OF GAFFNEY/PEOPLES CREEK PLT PIPE #: 001 FLOW: 3.5 WQL FOR DO	SC0047091 MAJOR MUNICIPAL WATER QUALITY
BROAD RIVER TOWN OF BLACKSBURG/CANOE CREEK PLT PIPE #: 001 FLOW: 0.68 (PROPOSED) WQL FOR DO,TRC,NH3N	SC0047457 MINOR MUNICIPAL WATER QUALITY
CANOE CREEK TOWN OF BLACKSBURG/CANOE CREEK PLT PIPE #: 001 FLOW: 0.34 WQL FOR DO,TRC,NH3N	SC0026042 MINOR MUNICIPAL WATER QUALITY
BEAVERDAM CREEK G & W INC. PIPE #: 001 FLOW: 0.005 WQL FOR BOD5,DO,TRC,NH3N	SC0027561 MINOR INDUSTRIAL WATER QUALITY
PEOPLES CREEK HAMRICK MILLS PIPE #: 001 FLOW: M/R	SCG250167 MINOR INDUSTRIAL EFFLUENT
PEOPLES CREEK CHEROKEE CO. COGEN PARTNERS PIPE #: 001 FLOW: M/R	SCG250110 MINOR INDUSTRIAL EFFLUENT

LAND APPLICATION FACILITY NAME	PERMIT# TYPE
SPRAYFIELD PEELER RUG COMPANY	ND0070980 INDUSTRIAL
SPRAYFIELD SCREEN PRINTERS	ND0003417 INDUSTRIAL

Landfill Activities

SOLID WASTE LANDFILL NAME *FACILITY TYPE*	*PERMIT #* *STATUS*
CITY OF GAFFNEY CWP INDUSTRIAL/C&D	APPLYING FOR PERMIT ACTIVE

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
SQUAW VALLEY SAND CO. BROAD RIVER PLANT	0042-09 SAND
THOMAS SAND CO. BLACKSBURG PLANT	0869-09 SAND
RAY BROWN ENTERPRISES HIDDEN VALLEY MINE	0123-09 SAND
RAY BROWN ENTERPRISES BROWN #3 SAND MINE	1070-09 SAND

Water Supply

WATER USER (TYPE) *STREAM*	*PUMPING CAPACITY (MGD)* *REG. PUMPING CAPACITY (MGD)*
CITY OF GAFFNEY BPW (M) BROAD RIVER	18.0 12.0

Growth Potential

There is a moderate potential for growth in this watershed, which contains the Town of Blacksburg and a portion of the City of Gaffney. The City of Gaffney is planning for new subdivision growth by considering new regional treatment facilities near the Cherokee Creek-Broad River area. Major growth is expected along the I-85 corridor, particularly in the area north of Gaffney. The potential for industrial growth exists along SC 329 east of Gaffney due to the existing industrial park and the proposal of another park.

Implementation Strategy

The Broad River is impaired by elevated levels of copper, cadmium, lead, and zinc from unknown or possibly point sources. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible. Peoples Creek is impaired from elevated levels of fecal coliform resulting from point sources, and bacteria conditions are expected to improve now that permit revisions have been initiated. Canoe Creek has an impaired macroinvertebrate community and elevated fecal coliform levels due to point sources. The facility is being upgraded and relocated, and conditions should improve.

03050105-100

(Buffalo Creek)

General Description

Watershed 03050105-100 is located in Cherokee County and consists primarily of ***Buffalo Creek*** and its tributaries. The watershed occupies 9,917 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Herndon-Helena-Goldston-Georgeville series. The erodibility of the soil (K) averages 0.34; the slope of the terrain averages 10%, with a range of 2-45%. Land use/land cover in the watershed includes: 7.22% urban land, 21.20% agricultural land, 0.51% scrub/shrub land, 0.84% barren land, 70.23% forested land, and 0.01% water.

Bee Branch flows across the North Carolina border and drains into Buffalo Creek, which flows into the Broad River. There are 19.5 stream miles in this watershed, all classified FW.

Water Quality

Buffalo Creek - There are three monitoring sites along Buffalo Creek. Aquatic life uses are fully supported at the upstream site **(B-740)** based on macroinvertebrate community data. Aquatic life uses are also fully supported at the midstream site **(B-119)**, but may be threatened by a significantly increasing trend in total phosphorus concentration, a high concentration of zinc measured in 1992, and PCB 1260 in 1991. Aquatic life uses are partially supported at the downstream site **(B-057)** due to occurrences of cadmium, chromium, and copper in excess of the aquatic life acute standards, including a very high concentration of copper measured in 1992. In addition, there is a significantly increasing trend in pH and total phosphorus concentration, and the PAH indeno(1,2,3-cd)pyrene was detected in 1995. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total nitrogen concentrations at both the midstream and downstream sites suggest improving conditions for these parameters. Recreational uses are not supported at any site due to fecal coliform bacteria excursions, and there is a significantly increasing trend in bacteria concentrations at the midstream site.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)*** ***COMMENT***	***NPDES#*** ***TYPE*** ***LIMITATION***
BUFFALO CREEK EMRO MARKETING SPEEDWAY #66 PIPE #: 002 FLOW: 0.0075 WQL FOR BOD5,DO,TRC,NH3N	SC0042196 MINOR INDUSTRIAL WATER QUALITY
BUFFALO CREEK TNS MILLS INC./BLACKSBURG PLT PIPE #: 001 FLOW: M/R	SCG250043 MINOR INDUSTRIAL EFFLUENT

BUFFALO CREEK TRIBUTARY BROAD RIVER TRUCK STOP PIPE #: 001 FLOW: 0.01 WQL FOR TRC,NH3N	SC0032433 MINOR COMMUNITY WATER QUALITY
BEE BRANCH TRIBUTARY JM BROWN VEND/MR. WAFFLE PIPE #: 001 FLOW: 0.0092 WQL FOR TRC,NH3N	SC0031968 MINOR MUNICIPAL WATER QUALITY

Water Supply

WATER USER (TYPE) *STREAM*	*RATED PUMP.CAP.(GPM)* *AMT. TRT./DIV. (MGD)*
MILLIKEN & CO.-MAGNOLIA FINISHING (I) BUFFALO CREEK	3400.0 4.896

Growth Potential

There is a moderate potential for growth in this watershed, which contains a portion of the Town of Blacksburg. Major growth is expected along the I-85 corridor, which stretches across the watershed. Commercial growth is also associated with the I-85 corridor near the Town of Blacksburg.

Implementation Strategy

Buffalo Creek is impaired by elevated levels of copper, cadmium, and lead. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible.

03050105-110

(Cherokee Creek)

General Description

Watershed 03050105-110 is located in Cherokee County and consists primarily of ***Cherokee Creek*** and its tributaries. The watershed occupies 14,911 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Goldston-Badin series. The erodibility of the soil (K) averages 0.22; the slope of the terrain averages 10%, with a range of 2-45%. Land use/land cover in the watershed includes: 20.87% urban land, 33.65% agricultural land, 0.56% scrub/shrub land, 0.74% barren land, 42.79% forested land, and 1.38% water.

Cherokee Creek flows through Lake Whelchel (180 acres) near the City of Gaffney and accepts drainage from Allison Creek in the lake and Providence Creek downstream of the lake before flowing into the Broad River. There are several ponds and lakes (10-180 acres) in this watershed used for recreational and municipal purposes. There are 34.5 stream miles, all classified FW.

Water Quality

Cherokee Creek (B-056) - Aquatic life uses are fully supported, and significantly decreasing trends in five-day biochemical oxygen demand and turbidity suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)*** ***COMMENT***	***NPDES#*** ***TYPE*** ***LIMITATION***
CHEROKEE CREEK CITY OF GAFFNEY/PROVIDENCE CREEK PLT PIPE #: 001 FLOW: 1.80 WQL FOR DO,TRC,NH3N	SC0020508 MAJOR MUNICIPAL WATER QUALITY
PROVIDENCE CREEK CITY OF GAFFNEY/WTP PIPE #: 001 FLOW: 1.02 WQL FOR TRC	SC0021121 MINOR DOMESTIC WATER QUALITY

Landfill Activities

SOLID WASTE LANDFILL NAME *FACILITY TYPE*	*PERMIT #* *STATUS*
CHEROKEE COUNTY LANDFILL MUNICIPAL	111001-1101 ACTIVE

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
BOREN BRICK HIGGINS RED CLAY PIT	0113-09 CLAY
BOREN BRICK SHALE PIT	0114-09 SHALE

Water Supply

WATER USER (TYPE) *STREAM*	*PUMPING CAPACITY (MGD)* *REG. PUMPING CAPACITY (MGD)*
CITY OF GAFFNEY BPW (M) LAKE WHELCHEL	---- 18.0

Groundwater Concerns

The groundwater in the vicinity of the property owned by SKF Tools (Site #13699) is contaminated with volatile organic compounds (VOCs). The source of the contamination is spills and leaks. The facility is currently in the remediation phase. The surface water affected by the contamination is Providence Creek.

Growth Potential

There is a moderate potential for growth in this watershed, which contains a portion of the City of Gaffney. The City of Gaffney is planning for new subdivision growth by considering new regional treatment facilities near the Cherokee Creek-Broad River area. Major growth is expected along the I-85 corridor, particularly in the area north of Gaffney. Commercial growth is also associated with the I-85 corridor near the SC 11 interchange north of Gaffney and at the SC 105 interchange with the new outlet center. The potential for industrial growth exists along SC 329 east of Gaffney due to the existing industrial park and the proposal of another park.

Implementation Strategy

Cherokee Creek is impaired from elevated levels of fecal coliform resulting from point sources, and bacteria conditions are expected to improve now that permit revisions have been initiated. An enforcement action is currently underway for fecal coliform bacteria.

03050105-120

(Kings Creek)

General Description

Watershed 03050105-120 is located in Cherokee and York Counties and consists primarily of ***Kings Creek*** and its tributaries. The watershed occupies 33,018 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Goldston-Badin series. The erodibility of the soil (K) averages 0.15; the slope of the terrain averages 13%, with a range of 2-45%. Land use/land cover in the watershed includes: 1.10% urban land, 14.48% agricultural land, 0.30% scrub/shrub land, 0.48% barren land, 83.41% forested land, and 0.23% water.

Kings Creek originates in North Carolina and flows across the state line to accept drainage from Modlin Branch, Dixon Branch, Ponders Branch, Stonehouse Branch, Dellingham Branch, Mill Creek, and Jumping Branch. Further downstream, Garner Branch flows into Kings Creek followed by Manning Branch, Bells Branch, Beech Branch, Wolf Creek, and Nells Branch before draining into the Broad River. There are several recreational ponds and lakes in this watershed and 77.1 stream miles, all classified FW. Kings Mountain National Military Park and Kings Mountain State Park are additional natural resources in the watershed.

Water Quality

Kings Creek (B-333) - Although there were occurrences of copper in excess of the aquatic life acute standard, based on macroinvertebrate community data, aquatic life uses are fully supported. Recreational uses are partially supported due to fecal coliform bacteria excursions.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM
FACILITY NAME
PERMITTED FLOW @ PIPE (MGD)
COMMENT

NPDES#
TYPE
LIMITATION

KINGS CREEK DITCH
COMPRESSOR STATION/GROVER
PIPE #: 001 FLOW: 0.22

SC0047783
MINOR INDUSTRIAL
EFFLUENT

MILL CREEK TRIBUTARY
VULCAN MATERIALS CO.
PIPE #: 001 FLOW: M/R

SCG730068
MINOR INDUSTRIAL
EFFLUENT

Mining Activities

MINING COMPANY
MINE NAME

PERMIT #
MINERAL

BOREN BRICK
SERICITE PIT

0115-09
SERICITE

VULCAN MATERIALS CO. BLACKSBURG QUARRY	0354-09 LIMESTONE
BORAL BRICKS, INC.-ASHE DIV. ROBERTS MINE	0221-09 SHALE
TAYLOR CLAY PRODUCTS CO. GROVER MINE	0199-09 MANGANESE SCHIST
INDUSTRIAL MINERALS, INC. KINGS CREEK MINE	0162-09 SERICITE

Growth Potential

There is a low potential for growth in this watershed due to the absence of public utilities.

03050105-130

(Thicketty Creek)

General Description

Watershed 03050105-130 is located in Cherokee County and consists primarily of ***Thicketty Creek*** and its tributaries. The watershed occupies 98,730 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Pacolet-Wilkes-Herndon-Madison series. The erodibility of the soil (K) averages 0.30; the slope of the terrain averages 16%, with a range of 2-45%. Land use/land cover in the watershed includes: 5.04% urban land, 19.53% agricultural land, 0.59% scrub/shrub land, 0.92% barren land, 73.51% forested land, and 0.41% water.

Thicketty Creek joins with Macedonia Creek to form Lake Thicketty at the top of the watershed. Thicketty Creek then accepts drainage from Thicketty Mountain Creek (Linder Creek), Clary Creek, Allgood Branch, and Irene Creek (Cole Creek) near the City of Gaffney. Little Thicketty Creek (Rocky Ford Creek, Cowpens Creek) enters Thicketty Creek next followed by Limestone Creek (Mill Creek, Skelton Creek) and Big Blue Branch (Blue Branch). North Goucher Creek and South Goucher Creek join in Hammett Lake to form Goucher Creek (Gum Root Creek), which flows into Thicketty Creek, downstream of Big Blue Creek. Jones Creek (Martin Lake) enters Thicketty Creek next followed by Timber Ridge Branch, Minkum Creek (Polecat Creek), Crocker Branch, Lusts Mill Creek, and Gilkey Creek. Gilkey Creek accepts drainage from Gaffney Country Club Lake, Blanton Creek, Peeler Branch, Spencer Branch (also known as Cartum Branch), Dry Fork Creek, Martin Branch, and Rocky Branch. Thicketty Creek drains into the Broad River. There are several ponds and lakes (10-100 acres) in this watershed used for recreation, irrigation, and flood control. There are a total of 213.9 stream miles, all classified FW.

Water Quality

Thicketty Creek **-** There are three monitoring sites along Thicketty Creek. Aquatic life uses are fully supported at the upstream site **(B-095)**, the midstream site **(B-133)** based on macroinvertebrate community data, and the downstream site **(B-062)**. A significantly decreasing trend in five-day biochemical oxygen demand at the midstream and downstream sites suggest improving conditions for this parameter. Recreational uses are not supported at any site due to fecal coliform bacteria excursions, which is compounded at the downstream site by a significantly increasing trend in fecal coliform bacteria concentrations. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Lake Thicketty (B-342) **-** Lake Thicketty is a 100-acre impoundment on Thicketty and Macedonia Creeks in Cherokee County, with a maximum depth of approximately 20 feet (6.1 m), and an average depth of 10 feet (3.1 m). Lake Thicketty's watershed comprises 6.9 square miles (18 km2). Historical eutrophication studies indicate that Lake Thicketty's trophic condition is improving. It is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of this lake's desirable trophic condition is recommended. Aquatic life and recreational uses are fully supported.

Irene Creek (B-059) - Aquatic life uses are fully supported, and a significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentrations, and turbidity suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Limestone Creek (B-128) - Aquatic life uses are fully supported, and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Gilkey Creek (B-334) - Aquatic life uses are fully supported based on physical, chemical, and macroinvertebrate community data. Recreational uses are not supported due to fecal coliform bacteria excursions.

Recreational Swimming Areas

RECEIVING STREAM	*SWIMMING LOCATION*
LAKE RUFUS	CAMP LEA

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
THICKETTY CREEK CITY OF GAFFNEY/CLARY WWTP PIPE #: 001 FLOW: 3.6 WQL FOR BOD5,DO,TRC,NH3N	SC0031551 MAJOR MUNICIPAL WATER QUALITY
LITTLE THICKETTY CREEK JIM'S TRAILER PARK PIPE #: 001 FLOW: 0.01 WQL FOR TRC,NH3N	SC0030503 MINOR COMMUNITY WATER QUALITY
ALLGOOD BRANCH PINECONE CAMPGROUND PIPE #: 001 FLOW: 0.018 WQL FOR TRC,NH3N	SC0034002 MINOR COMMUNITY WATER QUALITY
IRENE CREEK NESTLE FROZEN FOODS CORP. PIPE #: 001 FLOW: 0.066 WQL FOR TRC	SC0037664 MINOR INDUSTRIAL WATER QUALITY
IRENE CREEK TIMKEN CO./GAFFNEY BEARING PIPE #: 001 FLOW: 0.013	SC0000949 MINOR INDUSTRIAL EFFLUENT
MILL CREEK HAMRICK MILLS/MUSGROVE MILLS	SCG250168 MINOR INDUSTRIAL

PIPE #: 001 FLOW: M/R	EFFLUENT
SPENCERS BRANCH TRIBUTARY BRIARCREEK SD I/UNITED UTILITIES PIPE #: 001 FLOW: 0.0228 WQL FOR TRC,NH3N	SC0023736 MINOR COMMUNITY WATER QUALITY
SPENCERS BRANCH BRIARCREEK SD II/UNITED UTILITIES PIPE #: 001 FLOW: 0.020 WQL FOR TRC,NH3N	SC0026409 MINOR COMMUNITY WATER QUALITY
JONES CREEK MEDLEY FARMS NPL SITE PIPE #: 001 FLOW: 0.041	SC0046469 MINOR INDUSTRIAL EFFLUENT

Growth Potential

There is a moderate potential for growth in this watershed associated with I-85 and the City of Gaffney. Major growth is expected along the I-85 corridor, which stretches across the watershed, particularly in the area north of Gaffney. US 29 and a rail line also stretches across the watershed from Spartanburg to Gaffney.

Implementation Strategy

Thicketty Creek is impaired by elevated levels of fecal coliform bacteria resulting from point and nonpoint sources. Permit revisions have been initiated and conditions are expected to improve.

03050105-140

(Bullock Creek)

General Description

Watershed 03050105-140 extends through York County and consists primarily of ***Bullock Creek*** and its tributaries. The watershed occupies 76,376 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Wilkes-Cecil-Goldston-Badin series. The erodibility of the soil (K) averages 0.22; the slope of the terrain averages 13%, with a range of 2-45%. Land use/land cover in the watershed includes: 0.22% urban land, 15.88% agricultural land, 0.36% scrub/shrub land, 0.68% barren land, 82.74% forested land, and 0.12% water.

Bullock Creek originates near the South Carolina/North Carolina border and accepts drainage from Gin Branch, Rocky Branch, Buckhorn Creek (Silver Creek), and Clark Fork. Clark Fork also originates near the state line and flows through Lake Crawford to join Jennings Branch and forms Lake York before accepting drainage from Biggers Branch and Saltlick Branch. Downstream of Clark Fork, Bullock Creek accepts drainage from Thompson Branch, Berry Branch, Purgatory Branch, Mitchell Branch, Plexico Branch, Loves Creek, and Bells Creek (Prater Branch, Dowdle Branch). There are a few ponds and lakes (10-50 acres) in this watershed used for recreation and irrigation and 138.8 stream miles, all classified FW. Kings Mountain State Park extends over the upper portion of the watershed along with Kings Mountain National Military Park.

Water Quality

Bullock Creek - There are two monitoring sites along Bullock Creek. Aquatic life uses are fully supported at the upstream site **(B-739)** based on macroinvertebrate community data. Aquatic life uses are also fully supported at the downstream site **(B-159)**, and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported at this site due to fecal coliform bacteria excursions.

Lake York (B-737) - Aquatic life uses are fully supported. Lake York, located in Kings Mountain State Park in York County, is a 50-acre impoundment on Clark Fork. Lake York's maximum depth is approximately 13 feet (4.0 m); average depth is 9 feet (2.7 m). The lake's watershed comprises approximately 0.8 square miles (2 km2) in North and South Carolina. Lake York is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of this lake's desirable trophic condition is recommended. In an effort to provide access for swimming and boating, 600 triploid grass carp (20/vegetated acre) were stocked in 1993 and aquatic herbicides were applied in 1995.

Long Branch (B-326) - Aquatic life uses are fully supported, and significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentrations, and turbidity suggest improving conditions for these parameters. Recreational uses are partially supported at this site due to fecal coliform bacteria excursions.

***Clark Fork* -** There are two monitoring sites along Clark Fork. Aquatic life uses are fully supported at the site upstream of Crawford Lake **(B-325)**, but may be threatened by a significantly decreasing trend in pH. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are partially supported at this site due to fecal coliform bacteria excursions. Aquatic life uses are also fully supported at the site downstream of Crawford Lake **(B-157)** based on macroinvertebrate community data. In an effort to provide access for swimming and boating in Crawford Lake, 200 triploid grass carp (20/vegetated acre) were stocked in 1992 and aquatic herbicides were applied in 1990-1996.

Recreational Swimming Areas

RECEIVING STREAM	*SWIMMING LOCATION*
LAKE CRAWFORD	KINGS MTN STATE PARK

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
LONG BRANCH US PARK SERVICE/KINGS MTN NATL MIL PARK PIPE #: 001 FLOW: 0.023 WQL FOR DO,TRC,NH3N	SC0025275 MINOR INDUSTRIAL WATER QUALITY

Growth Potential

There is a low potential for growth in this watershed, which contains the Towns of Hickory Grove and Sharon, and public water service is limited to these towns. Although the area is largely rural, residential activity is increasing as a result of the close proximity to the Town of Clover, the City of York, and the Greater Charlotte Metropolitan Area.

03050105-150

(North Pacolet River)

General Description

Watershed 03050105-150 is located in Spartanburg County and consists primarily of the ***North Pacolet River*** and its tributaries. The watershed occupies 30,145 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Hiwassee series. The erodibility of the soil (K) averages 0.28; the slope of the terrain averages 10%, with a range of 2-25%. Land use/land cover in the watershed includes: 8.57% urban land, 22.87% agricultural land, 0.97% scrub/shrub land, 0.13% barren land, 66.92% forested land, and 0.54% water.

The North Pacolet River originates in North Carolina and accepts drainage from Vaughn Creek (Lake Lanier) and Wolfe Creek, which originate in South Carolina. After flowing across the state line, the river accepts drainage from Page Creek. Hooper Creek, Collinsville Creek, and Bear Creek enter the river next; all originating in North Carolina. Obed Creek drains into the river at the base of the watershed. There are a few recreational ponds and lakes (10-90 acres) in this watershed and a total of 71.6 stream miles, all classified FW with the exception of Vaughn Creek which is classified ORW. Due to the absence of point source dischargers and the presence of endangered species and other special characteristics, portions of a Vaughn Creek tributary may qualify as a potential ORW candidate.

Water Quality

North Pacolet River **-** There are three monitoring sites along the North Pacolet River. Aquatic life uses are fully supported at the upstream site **(B-719)** based on macroinvertebrate community data.
Aquatic life uses are also fully supported at the midstream site **(B-026)**, but may be threatened by a significantly decreasing trend in pH and a significantly increasing trend in turbidity. Significantly decreasing trends in five-day biochemical oxygen demand and total nitrogen concentration suggest improving conditions for these parameters. At the downstream site **(B-126)**, aquatic life uses are again fully supported, but may be threatened by an occurrence of lead in excess of the aquatic life acute standard. Recreational uses are not supported at any site due to fecal coliform bacteria excursions.

Vaughn Creek (B-099-7) **-** Aquatic life uses are fully supported based on macroinvertebrate community data.

Lake Lanier **-** There are two monitoring sites along Lake Lanier. Aquatic life uses are fully supported at the uplake site **(B-099A)**, but may be threatened by significantly decreasing trends in dissolved oxygen concentration and pH, and a significantly increasing trend in turbidity. Recreational uses are partially supported at this site due to fecal coliform bacteria excursions. Aquatic life uses are also fully supported at the downlake site **(B-099B)**, but may be threatened by a significantly decreasing trend in pH and a significantly increasing trend in turbidity. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are fully supported.

Page Creek (B-301) - Aquatic life uses are fully supported, and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
NORTH PACOLET RIVER ONEITA INDUSTRIES/FINGERVILLE PIPE #: 001 FLOW: 0.50	SC0035157 MINOR INDUSTRIAL EFFLUENT
NORTH PACOLET RIVER SSSD/FINGERVILLE PIPE #: 001 FLOW: 0.020	SC0047759 MINOR MUNICIPAL EFFLUENT
NORTH PACOLET RIVER MILLIKEN/NEW PROSPECT MILL PIPE #: 001 FLOW: 0.47 WQL FOR DO,TRC,NH3N	SC0023540 MINOR INDUSTRIAL WATER QUALITY
OBED CREEK HB SWOFFORD VOCATIONAL CENTER PIPE #: 001 FLOW: 0.0045 WQL FOR NH3N	SC0028037 MINOR MUNICIPAL WATER QUALITY
PAGE CREEK CITY OF LANDRUM/PAGE CREEK PLT PIPE #: 001 FLOW: 0.3 WQL FOR BOD5,TRC,NH3N	SC0026875 MINOR MUNICIPAL WATER QUALITY
WOLFE CREEK CITY OF LANDRUM/PLANT #1 PIPE #: 001 FLOW: 0.1 WQL FOR TRC,NH3N	SC0021636 MINOR MUNICIPAL WATER QUALITY

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
LITTLE ACRES SAND CO. NORTH PACOLET RIVER MINE	1037-42 SAND

Water Supply

WATER USER (TYPE) *STREAM*	*PUMPING CAPACITY (MGD)* *REG. PUMPING CAPACITY (MGD)*
CITY OF LANDRUM (M) VAUGHN CREEK TRIBUTARY	0.0 0.0
CITY OF LANDRUM (M) LAKE LANIER - VAUGHN CREEK	2.0 1.0

Growth Potential

There is a low potential for growth in this watershed, which contains the Town of Fingerville.

03050105-160

(South Pacolet River)

General Description

Watershed 03050105-160 is located in Spartanburg County and consists primarily of the ***South Pacolet River*** and its tributaries. The watershed occupies 59,585 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil series. The erodibility of the soil (K) averages 0.28; the slope of the terrain averages 9%, with a range of 2-25%. Land use/land cover in the watershed includes: 8.00% urban land, 25.85% agricultural land, 0.71% scrub/shrub land, 0.44% barren land, 61.90% forested land, and 3.11% water.

The South Pacolet River originates near Glassy Mountain and accepts drainage from Green Creek, Belue Creek, Jamison Mill Creek, Spivey Creek (Clear Branch), and Motlow Creek (Easley Creek, Holston Creek) before forming Lake Bowen (Alexander Creek, Turkey Creek). The South Pacolet River flows out of Lake Bowen to then form the South Pacolet River Reservoir #1 (Mud Creek) which is also known as Spartanburg Reservoir #1 (301 acres). There are 146.4 stream miles in this watershed, all classified FW. Due to the absence of point source dischargers and the presence of endangered species and other special characteristics, portions of a Green Creek tributary, Belue Creek, and Jamison Mill Creek may qualify as potential ORW candidates.

Water Quality

South Pacolet River **-** There are two monitoring sites along the South Pacolet River. Aquatic life uses are fully supported at the upstream site **(B-720)** based on macroinvertebrate community data. Aquatic life uses are also fully supported at the downstream site **(B-302)**, but may be threatened by an occurrence of lead in excess of the aquatic life acute standard. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Spivey Creek (B-103) **-** Aquatic life uses are fully supported, and a significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for this parameter. Recreational uses are partially supported at this site due to fecal coliform bacteria excursions.

Lake Bowen **-** Lake William C. Bowen is a 1600-acre impoundment on the South Pacolet River in Spartanburg County, with a maximum depth of approximately 41 feet (12.5 m) and an average depth of 15 feet (4.7 m). Lake Bowen's watershed comprises 82 square miles (212.6 km2). In 1991, NRCS, in cooperation with SCDHEC, began an educational project to reduce watershed pollutant loads. Historical eutrophication assessments indicate that Lake Bowen's trophic condition is improving. It is currently one of the least eutrophic large lakes in South Carolina, characterized by low nutrient concentrations. Preservation of this lake's desirable trophic condition is recommended.

There are two monitoring sites along Lake Bowen. Aquatic life uses are fully supported at the uplake site **(B-340)**. Sediment samples revealed P,P'DDT and O,P'DDT, and P,P'DDD, O,P'DDD, P,P'DDE (metabolites of DDT) in 1991. Although the use of DDT was banned in 1973, it is very persistent in the environment. Aquatic life uses are also fully supported at the downlake site **(B-339)**, but may be threatened by a very high concentration of cadmium detected in the 1992 sediment sample. Recreational uses are fully supported at both sites.

Spartanburg Reservoir #1 (B-113) - Aquatic life uses are fully supported, but may be threatened by a significantly decreasing trend in dissolved oxygen concentration and a significantly increasing trend in turbidity. A significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for this parameter. Recreational uses are fully supported, but may be threatened by a significantly increasing trend in fecal coliform bacteria concentrations.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)*** ***COMMENT***	***NPDES#*** ***TYPE*** ***LIMITATION***
MOTLOW CREEK LINKS O TRYON PIPE #: 001 FLOW: 0.024 WQL FOR DO,TRC,NH3N	SC0042684 MINOR COMMUNITY WATER QUALITY
SOUTH PACOLET RIVER SPARTANBURG WATER SYSTEM WWTP/SIMMS PLT PIPE #: 001 FLOW: 0.004 PIPE #: 001 FLOW: 0.012 (PROPOSED)	SC0030279 MINOR MUNICIPAL EFFLUENT EFFLUENT
SOUTH PACOLET RIVER SPARTANBURG WATER SYSTEM/SIMMS PLT PIPE #: 001 FLOW: 1.17 WQL FOR TRC	SCG643002 MINOR DOMESTIC WATER QUALITY
SPIVEY CREEK CITY OF LANDRUM/WTP PIPE #: 001 FLOW: 0.032 WQL FOR TRC	SCG645029 MINOR DOMESTIC WATER QUALITY

LAND APPLICATION **FACILITY NAME**	**PERMIT#** **TYPE**
SPRAYFIELD CAMPOBELLO-GRAMBLING SCHOOL	ND0067342 MUNICIPAL

Landfill Activities

SOLID WASTE LANDFILL NAME / *FACILITY TYPE*	*PERMIT #* / *STATUS*
BILLY JACKSON C&D LANDFILL	------
C&D LANDFILL	CLOSED

Mining Activities

MINING COMPANY / *MINE NAME*	*PERMIT #* / *MINERAL*
LITTLE ACRES SAND CO.	0805-42
SOUTH PACOLET RIVER MINE	SAND

Water Supply

WATER USER (TYPE) / *STREAM*	*PUMPING CAPACITY (MGD)* / *REG. PUMPING CAPACITY (MGD)*
SPARTANBURG WATER SYSTEM (M)	----
SOUTH PACOLET RIVER RES.#1	64.0

Growth Potential

There is a low to moderate potential for growth in this watershed, which contains the City of Landrum and the Town of Campobello.

03050105-170

(Pacolet River)

General Description

Watershed 03050105-170 is located in Spartanburg and Cherokee Counties and consists primarily of the ***Pacolet River*** and its tributaries from its origin at the confluence of the North and South Pacolet Rivers to Lawsons Fork Creek. The watershed occupies 84,046 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Pacolet series. The erodibility of the soil (K) averages 0.28; the slope of the terrain averages 11%, with a range of 2-45%. Land use/land cover in the watershed includes: 11.15% urban land, 33.26% agricultural land, 0.92% scrub/shrub land, 0.29% barren land, 53.08% forested land, and 1.31% water.

The Pacolet River is formed by the confluence of the North Pacolet River Watershed and the South Pacolet River Watershed. Downstream from the confluence, the Pacolet River accepts drainage from Thompson Creek and forms Lake Blalock (760 acres). Streams draining into Lake Blalock include Buck Creek, Little Buck Creek (Ezell Branch, Cudds Creek, Greenes Lake), and Casey Creek (Carlisle Branch). Downstream from the lake, the Pacolet River accepts drainage from Cherokee Creek (Little Cherokee Creek), Island Creek (Zekial Creek, Double Branch), Pole Bridge Branch, Peters Creek, Cinder Branch, Turkey Hen Branch, Quinn Branch, and Mill Branch. There are several ponds and lakes (10-760 acres) in this watershed used for recreational, municipal, and water supply purposes. There are a total of 156.7 stream miles, all classified FW. Cowpens National Battlefield Site is located between Island Creek and Zekial Creek.

Water Quality

Pacolet River - There are three monitoring sites along the Pacolet River. Aquatic life uses are fully supported at the upstream site **(B-028)**, but may be threatened by significantly increasing trends in total phosphorus concentration and turbidity. A significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for this parameter. Aquatic life uses are also fully supported at the midstream site **(B-163A)**, but may be threatened by decreasing trends in dissolved oxygen concentration and pH. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. At the downstream site **(B-331)**, aquatic life uses are again fully supported. Recreational uses are not supported at the upstream and downstream sites and are partially supported at the midstream site due to fecal coliform bacteria excursions.

Little Buck Creek (B-259) - Aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in turbidity. A significantly decreasing trend in total phosphorus concentrations suggests improving conditions for this parameter. Recreational uses are not supported due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Lake Taylor Blalock (B-347) - Lake Blalock in Spartanburg County is a 760-acre impoundment on the Pacolet River, with a maximum depth of approximately 49.5 feet (15 m) and an average depth of 5.6 feet (1.7 m). Lake Blalock's watershed comprises 273 square miles (707 km2), which includes Spartanburg Reservoir #1 and Lake Bowen, and extends into North Carolina. Eutrophication assessments indicate that Lake Blalock is one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of this lake's desirable trophic condition is recommended. Aquatic life and recreational uses are fully supported.

Potter Branch (B-191) - Aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in turbidity. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
PACOLET RIVER SSSD/CLIFTON WWTP PIPE #: 001 FLOW: 0.29	SC0042668 MINOR MUNICIPAL EFFLUENT
PACOLET RIVER HOECHST CELANESE CORP. PIPE #: 002 FLOW: 0.800 PIPE #: 004 FLOW: 0.061 PIPE #: 010 FLOW: 0.216 WQL FOR DO,TRC	SC0002798 MAJOR INDUSTRIAL EFFLUENT EFFLUENT WATER QUALITY
PACOLET RIVER SSSD/TOWN OF COWPENS-WASH. RD PIPE #: 001 FLOW: 1.5 WQL FOR TRC	SC0045624 MAJOR MUNICIPAL WATER QUALITY
PACOLET RIVER CITY OF SPARTANBURG/LAKE BLALOCK/CHESNEE WTP PIPE #: 001 FLOW: 1.12 NOT CONSTRUCTED	SCG641006 MINOR DOMESTIC EFFLUENT
PACOLET RIVER TRIBUTARY OMEGA CHEMICALS, INC. PIPE #: 001 FLOW: 1.12	SCG250055 MINOR INDUSTRIAL EFFLUENT
CHEROKEE CREEK SAXONIA-FRANKE OF AMERICA, INC. PIPE #: 001 FLOW: 0.003	SC0046353 MINOR INDUSTRIAL EFFLUENT
LITTLE BUCK CREEK CITY OF CHESNEE/MAIN PLANT WWTP	SC0025763 MINOR MUNICIPAL

PIPE #: 001 FLOW: 0.500 | WATER QUALITY
WQL FOR NH3N

PETERS CREEK | SC0036102
RR DONNELLEY & SONS CO. | MINOR INDUSTRIAL
PIPE #: 001 FLOW: 0.1202 | WATER QUALITY
WQL FOR TRC; NH3N IN SUMMER & WINTER

PETERS CREEK | SC0037826
SPECIALTY INDUSTRIAL PRODUCTS | MINOR INDUSTRIAL
PIPE #: 001 FLOW: 0.0097 | WATER QUALITY
WQL FOR TRC

PETERS CREEK | SC0030554
SSSD IDLEWOOD SD | MINOR MUNICIPAL
PIPE #: 001 FLOW: 0.08 | WATER QUALITY
WQL FOR TRC,NH3N

PETERS CREEK TRIBUTARY | SCG250046
LIQUID AIR CORP. | MINOR INDUSTRIAL
PIPE #: 001 FLOW: M/R | EFFLUENT

ISLAND CREEK | SC0031577
TALL TALES FISH CAMP | MINOR COMMUNITY
PIPE #: 001 FLOW: 0.0136 | EFFLUENT

CINDER BRANCH | SC0035424
SSSD/CINDER BRANCH PLT | MINOR MUNICIPAL
PIPE #: 001 FLOW: 0.03 | WATER QUALITY
WQL FOR DO,TRC; NH3N IN SUMMER & WINTER

CINDER BRANCH | SC0029718
SSSD/HILLBROOK FOREST SD | MINOR MUNICIPAL
PIPE #: 001 FLOW: 0.15 | WQL FOR DO,TRC,NH3N

LAND APPLICATION SYSTEM FACILITY NAME	PERMIT # TYPE
SPRAYFIELD SPARTANBURG WATER SYSTEM/SIMMS WTP	ND0074101 DOMESTIC
SPRAYFIELD SPARTANBURG WATER SYSTEM/LAKE BLALOCK WTP	ND0077135 DOMESTIC

Landfill Activities

SOLID WASTE LANDFILL NAME *FACILITY TYPE*	*PERMIT #* *STATUS*
IRENE BISHOP SHORT TERM C&D LANDFILL	422904-1301 ACTIVE
DAVID STOLTZ SHORT TERM C&D LANDFILL	422422-1301 ACTIVE
JAMES LANCASTER LAND CLEARING DEBRIS LANDFILL	422460-1701 ACTIVE

HASKELL SEXTON SHORT TERM C&D LANDFILL	422484-7301 ACTIVE
HOECHST CELANESE CORP. INDUSTRIAL C&D LANDFILL	423312-1201 ACTIVE

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
CHAPMAN GRADING & CONCRETE CO., INC. CHAPMAN SAND PLANT #6	1081-42 SAND

Groundwater Concerns

The groundwater in the vicinity of the property owned by Freedom Chemical is contaminated with volatile organic compounds (VOC) resulting from spills and leaks. The facility is currently in the assessment phase. The surface water affected by the VOCs is an unnamed tributary of the Pacolet River.

Growth Potential

There is a low to moderate potential for growth in this watershed associated primarily with the City of Chesnee and the Town of Cowpens, both having sewer infrastructure. Industrial growth in particular is expected along the I-85 corridor and major roads with I-85 interchanges.

Implementation Strategy

Little Buck Creek is impaired from elevated levels of fecal coliform bacteria due to point and nonpoint sources. Permit revisions have been initiated and conditions are expected to improve.

03050105-180

(Lawsons Fork Creek)

General Description

Watershed 03050105-180 is located in Spartanburg County and consists primarily of ***Lawsons Fork Creek*** and its tributaries. The watershed occupies 59,348 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil series. The erodibility of the soil (K) averages 0.28; the slope of the terrain averages 8%, with a range of 2-15%. Land use/land cover in the watershed includes: 43.80% urban land, 20.47% agricultural land, 0.35% scrub/shrub land, 0.26% barren land, 35.02% forested land, and 0.10% water.

Lawsons Fork Creek originates near and flows past the City of Spartanburg before draining into the Pacolet River. Lawsons Fork Creek accepts drainage from Greene Creek (Meadow Creek), Camp Creek, Fawn Branch, Big Shoally Creek (Little Shoally Creek, Flatwood Lake, Fairview Lake), Betty Green Creek (Waldrops Lake), Chinquapin Creek, and Fourmile Branch. There are several ponds and lakes (10-20 acres) in this watershed used for recreation, irrigation, and power supply. There are a total of 103.6 stream miles, all classified FW.

Water Quality

Lawsons Fork Creek - There are five monitoring sites along Lawsons Fork Creek. Aquatic life uses are partially supported at the upstream site **(B-221)** based on macroinvertebrate community data, and fully supported at the next site downstream **(B-277)**. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration at these upstream sites suggest improving conditions for these parameters. Further downstream **(B-278)**, aquatic life uses are also fully supported, but may be threatened by a significantly increasing trend in turbidity. A significantly increasing trend in dissolved oxygen concentration and a significantly decreasing trend in five-day biochemical oxygen demand suggest improving conditions for these parameters.

Aquatic life uses are again fully supported at the next site downstream **(BL-005)**, but may be threatened by a significantly decreasing trend in pH. At the furthest downstream site **(BL-001)**, aquatic life uses are partially supported based on macroinvertebrate community data. In addition, there is a significantly decreasing trend in pH and a significantly increasing trend in turbidity. Sediment samples revealed a very high concentration of zinc in 1992, and high concentrations of PAHs anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, benzo(ghi)perylene, and benzo(a)anthracene in 1994. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration at the downstream sites suggest improving conditions for these parameters. Recreational uses are not supported at any site due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
LAWSONS FORK CREEK MILLIKEN & CO./DEWEY PLT PIPE #: 001 FLOW: 0.374 WQL FOR DO,TRC,NH3N	SC0003581 MAJOR INDUSTRIAL WATER QUALITY
LAWSONS FORK CREEK AMOCO OIL/SPARTANBURG TERMINAL PIPE #: 001 FLOW: M/R PIPE #: 002 FLOW: M/R	SC0003549 MINOR INDUSTRIAL EFFLUENT EFFLUENT
LAWSONS FORK CREEK SSSD/LAWSONS FORK PLANT PIPE #: 001 FLOW: 9.0-15.5 WQL FOR DO,TRC,NH3N	SC0020427 MAJOR MUNICIPAL WATER QUALITY
LAWSONS FORK CREEK SPARTAN MILLS/WHITNEY PIPE #: 001 FLOW: M/R	SCG250115 MINOR INDUSTRIAL EFFLUENT
LAWSONS FORK CREEK CITY OF INMAN PIPE #: 001 FLOW: 0.477 PIPE #: 001 FLOW: 1.000 (PROPOSED) WQL FOR DO,TRC,NH3N	SC0021601 MINOR MUNICIPAL WATER QUALITY WATER QUALITY
LAWSONS FORK CREEK CITGO PETROLEUM CORP. PIPE #: 001 FLOW: M/R	SCG340005 MINOR INDUSTRIAL EFFLUENT
LAWSONS FORK CREEK INMAN MILLS WATER DISTRICT PIPE #: 001 FLOW: 0.175 WQL FOR DO,TRC,NH3N	SC0024414 MINOR MUNICIPAL WATER QUALITY
LAWSONS FORK CREEK SOUTHEAST TERMINAL/SPARTANBURG PIPE #: 001 FLOW: M/R	SCG340002 MINOR INDUSTRIAL EFFLUENT
LAWSONS FORK CREEK BORDEN INC. PIPE #: 001 FLOW: M/R	SCG250113 MINOR INDUSTRIAL EFFLUENT
LAWSONS FORK CREEK TRIBUTARY DRAPER CORPORATION PIPE #: 001 FLOW: M/R PIPE #: 002 FLOW: M/R	SCR001582 MINOR INDUSTRIAL EFFLUENT EFFLUENT
GREENE CREEK HUDSON INTERNATIONAL CONDUCTORS PIPE #: 001 FLOW: M/R	SCG250039 MINOR INDUSTRIAL EFFLUENT

CAMP CREEK STONECREEK SD/UNITED UTILITIES PIPE #: 001 FLOW: 0.084 WQL FOR DO,TRC,NH3N	SC0031763 MINOR COMMUNITY WATER QUALITY
MEADOW CREEK INMAN STONE COMPANY, INC. PIPE #: 001 FLOW: M/R	SCG730084 MINOR INDUSTRIAL EFFLUENT
CHINQUAPIN CREEK SPARTAN MILLS/BEAUMONT PLT PIPE #: 001 FLOW: M/R	SC0002437 MINOR INDUSTRIAL EFFLUENT
CHINQUAPIN CREEK SPARTAN IRON & METAL PIPE #: 001 FLOW: 0.002	SC0046515 MINOR INDUSTRIAL EFFLUENT
CHINQUAPIN CREEK NORTHSIDE ROBO CAR WASH PIPE #: 001 FLOW: M/R	SCG750002 MINOR INDUSTRIAL EFFLUENT
FOURMILE BRANCH CROWN CENTRAL PETROLEUM CORP. PIPE #: 001 FLOW: M/R	SCG340007 MINOR INDUSTRIAL EFFLUENT
FOURMILE BRANCH CONOCO INC./SPARTANBURG TERMINAL PIPE #: 001 FLOW: M/R PIPE #: 002 FLOW: M/R PIPE #: 003 FLOW: M/R	SCG340006 MINOR INDUSTRIAL EFFLUENT EFFLUENT EFFLUENT

LAND APPLICATION SYSTEM **FACILITY NAME**	**PERMIT #** **TYPE**
SPRAYFIELD KOHLER CO.	ND0000892 INDUSTRIAL

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
MILLIKEN & CO. INDUSTRIAL	—— CLOSED
PAR GRADING SHORT TERM C&D LANDFILL	422421-1301 ACTIVE
DRAPER LANDFILL INDUSTRIAL	IWP-103 ACTIVE

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
INMAN STONE COMPANY., INC. INMAN QUARRY	0630-42 GRANITE

Groundwater Concerns

The groundwater in the vicinity of the properties owned by Conoco Inc. (Site #13389), Plantation Pipeline (Site #13652), Exxon Inc. (Site #13432), Fina Oil & Chemical Company (Site #13438), Texaco-Star Enterprises (Site #13726), and Shell Oil Company (Site #13694) are contaminated with petroleum products. Sources of contamination include above ground storage tanks and spills and leaks. The facilities are currently in the assessment and remediation phases, and are participating in a 'community plume agreement'. The surface water affected by the contamination is Fourmile Branch.

The groundwater in the vicinity of the property owned by Milliken & Co. is contaminated with volatile organic compounds (VOC) resulting from pits, ponds, and lagoons. This is a RCRA facility and remedial action has been initiated. The surface water affected by the VOCs is Lawsons Fork Creek.

Growth Potential

There is a high potential for growth in this watershed, which contains a portion of the City of Spartanburg. Industrial growth in particular is expected along the I-85 corridor and major roads with I-85 interchanges. There are also industrial developmental pressures along I-26, US 29, and US 221.

Implementation Strategy

Lawsons Fork Creek has an impaired macroinvertebrate community and elevated levels of fecal coliform bacteria due to both point and nonpoint sources. The biological samples will be evaluated to determine the cause of their impairment. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050105-190

(Pacolet River)

General Description

Watershed 03050105-190 is located in Union, Cherokee, and Spartanburg Counties and consists primarily of the ***Pacolet River*** and its tributaries from Lawsons Fork Creek to the Broad River. The watershed occupies 80,098 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Madison-Cecil-Pacolet series. The erodibility of the soil (K) averages 0.27; the slope of the terrain averages 10%, with a range of 2-25%. Land use/land cover in the watershed includes: 2.12% urban land, 11.77% agricultural land, 3.49% scrub/shrub land, 0.88% barren land, 81.57% forested land, and 0.18% water.

This section of the Pacolet River accepts drainage from its upper reach (03050105-170), together with Richland Creek, Harvey Branch, Browns Branch, Plum Branch, and Mill Branch. Further downstream, Mill Creek (Jumping Run Creek, Eison Branch) enters the river followed by Sandy Run Creek, Peter Hawks Creek, Gault Creek, another Mill Creek, another Gault Creek, Big Creek, Kendrick Branch, and Reedy Branch. The Pacolet River drains into the Broad River. There are a few ponds and lakes (25-40 acres) in this watershed used for recreational, municipal, and industrial purposes. There are a total of 101.8 stream miles in this watershed, all classified FW.

Water Quality

Pacolet River - There are two monitoring sites along this section of the Pacolet River. Aquatic life uses are fully supported at both the upstream **(BP-001)** and the downstream **(B-048)** sites, but may be threatened by a significantly decreasing trend in pH at both sites and a very high concentration of cadmium measured in sediment in 1993 at the downstream site. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentrations at both sites and total nitrogen concentrations at the downstream site suggest improving conditions for these parameters. Recreational uses are not supported at either site due to fecal coliform bacteria excursions, but a significantly decreasing trend in fecal coliform bacteria concentrations suggests improving conditions for this parameter at the downstream site.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM	***NPDES#***
FACILITY NAME	***TYPE***
PERMITTED FLOW @ PIPE (MGD)	***LIMITATION***
COMMENT	
PACOLET RIVER	SC0044717
SSSD/PACOLET MILLS WWTP	MINOR MUNICIPAL
PIPE #: 001 FLOW: 0.3	EFFLUENT
PACOLET RIVER TRIBUTARY	SC0038326
SSSD/PACOLET ELEM. SCHOOL	MINOR MUNICIPAL

PIPE #: 001 FLOW: 0.035 WQL FOR TRC; NH3N IN SUMMER & WINTER	WATER QUALITY
PACOLET RIVER TRIBUTARY FMC CORP/SPARTAN MINERALS PIPE #: 001 FLOW: 0.018 PIPE #: 002 FLOW: 0.257 PIPE #: 02a FLOW: 0.120 PIPE #: 003 FLOW: 0.159 WQL FOR METALS	SC0002411 MINOR INDUSTRIAL WATER QUALITY WATER QUALITY WATER QUALITY WATER QUALITY
PACOLET RIVER TRIBUTARY VULCAN MATERIALS CO. PIPE #: 001 FLOW: M/R	SC0002941 MINOR INDUSTRIAL EFFLUENT
MILL CREEK SPARTAN MILLS/ROSEMONT MILL PIPE #: 001 FLOW: 0.0122	SC0037371 MINOR INDUSTRIAL EFFLUENT

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
KOHLER LANDFILL INDUSTRIAL	422442-1601 ACTIVE

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
DEATON SAND COMPANY DEATON SAND PIT	1016-42 SAND
VULCAN MATERIALS CO. PACOLET QUARRY	0062-42 GRANITE

Growth Potential

There is a low to moderate potential for growth in this watershed, which contains a portion of the Town of Jonesville. Public water and sewer services are available in Jonesville, and residential and commercial uses center around the town and along SC 9.

03050106-010

(Broad River)

General Description

Watershed 03050106-010 is located in Union, Chester, and Fairfield Counties and consists primarily of the ***Broad River*** and its tributaries from the Pacolet River to the Tyger River. The watershed occupies 79,889 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Wilkes-Pacolet-Winnsboro series. The erodibility of the soil (K) averages 0.24; the slope of the terrain averages 21%, with a range of 6-40%. Land use/land cover in the watershed includes: 0.49% urban land, 10.74% agricultural land, 3.70% scrub/shrub land, 0.51% barren land, 82.93% forested land, and 1.63% water.

This section of the Broad River accepts drainage from its upper reach (03050105-094), together with Robertson Branch, Fanning Creek (Sharps Creek), George Branch, Osborn Branch, and the Turkey Creek Watershed. Hughes Creek (Lake John D. Long, Vanderford Branch) enters the river next followed by the Browns Creek Watershed, McCluney Creek, Little Turkey Creek, Clarks Creek, Neals Creek (Hobsons Creek), Mineral Creek, Coxs Creek, and the Sandy River Watershed. There are 156.1 stream miles in this watershed, all classified FW. The lower three-quarters of the watershed, below Turkey Creek, resides within the Sumter National Forest.

Water Quality

A fish consumption advisory has been issued by the Department for mercury and includes portions of the Broad River in this watershed (see Watershed Evaluations and Implementation Strategies Within WMU-0502).

Broad River (B-046) - Aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in pH, a very high concentration of zinc measured in 1993, and di-n-butylphthalate detected in 1991. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus and total nitrogen concentrations suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions.

Lake John D. Long (B-344) - Lake John D. Long is a 78-acre impoundment on Hughes Creek in Union County, with a maximum depth of approximately 31 feet (9.4 m) and an average depth of 16 feet (4.9 m). Lake Long's watershed comprises approximately 1.9 square miles (5.0 km). The lake is currently one of the least eutrophic small lakes in South Carolina, characterized by low nutrient concentrations. Preservation of Lake Long's desirable trophic condition is recommended.

Aquatic life and recreational uses are fully supported. Although pH excursions occurred, higher pH levels are not uncommon in lakes with significant aquatic plant communities and are considered natural, not standards violations. In an effort to provide access for boating and fishing, 300 triploid grass carp (30/vegetated acre) were stocked in 1991 and aquatic herbicides were applied in 1991 and 1994-1996.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
BROAD RIVER CONE MILLS/CARLISLE PLT PIPE #: 001 FLOW: 2.0 PIPE #: 002 FLOW: 0.04 PIPE #: 003 FLOW: 0.12 WQL FOR TRC	SC0001368 MAJOR INDUSTRIAL EFFLUENT WATER QUALITY EFFLUENT
BROAD RIVER SCE&G/NEAL SHOALS HYDRO PIPE #: 001 FLOW:M/R	SC0002186 MINOR INDUSTRIAL EFFLUENT
BROAD RIVER LOCKHART UTIL. CO. PIPE #: 001 FLOW: 0.169 WQL FOR BOD5,DO,TRC,NH3N	SC0003051 MINOR COMMUNITY WATER QUALITY
BROAD RIVER LOCKHART UTIL. CO. PIPE #: 001 FLOW: 0.169 PROPOSED; DISCHARGE BELOW POWER PLANT	SC0003051 MINOR COMMUNITY EFFLUENT
BROAD RIVER CLARIANT CORP./LEEDS PLT PIPE #: 001 FLOW: M/R	SC0022756 MINOR INDUSTRIAL EFFLUENT

LAND APPLICATION **FACILITY NAME**	**PERMIT#** **TYPE**
SPRAYFIELD HOECHST CELANESE CORP.	ND0000091 INDUSTRIAL

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
MCINTYRE SAND CO., INC. MULLINS MINE	0825-44 SAND
MCINTYRE SAND CO., INC. CUDD SAND MINE	0909-44 SAND
SLOAN CONSTRUCTION CO., INC. LOCKHART MINE	0471-44 SAND
UNION COUNTY CARLISLE PIT	0311-10 SAND

Camp Facilities

FACILITY NAME/TYPE ***RECEIVING STREAM***	***PERMIT #*** ***STATUS***
LEEDS HUNT CAMP/FAMILY BROAD RIVER TRIBUTARY	12-307-0008 ACTIVE
WOODS FERRY/FAMILY BROAD RIVER	12-307-0005 ACTIVE

Water Supply

WATER USER (TYPE) ***STREAM***	***PUMPING CAPACITY (MGD)*** ***REG. PUMPING CAPACITY (MGD)***
CITY OF UNION (M) BROAD RIVER	28.5 8.0
CARLISLE CONE MILLS (M) BROAD RIVER	8.1 5.7
LOCKHART MILLS (M) BROAD RIVER	2.0 1.0

WATER USER (TYPE) ***STREAM***	***RATED PUMP. CAP. (GPM)*** ***AMT. TRT./DIV. (MGD)***
HOECHST CELANESE CORP. (I) BROAD RIVER	200 0.288
HOECHST CELANESE CORP. (I) MINERAL CREEK	694.4 0.576

Growth Potential

There is a low potential for future growth in this watershed. A large portion of the watershed is effectively excluded from development by the Sumter National Forest. Public water service is available in the Towns of Santuck, Lockhart, and Carlisle, and sewer service is available in Lockhart and Carlisle.

03050106-020

(Turkey Creek)

General Description

Watershed 03050106-020 is located in York and Chester Counties and consists primarily of ***Turkey Creek*** and its tributaries. The watershed occupies 96,488 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Wilkes-Cecil-Madison series. The erodibility of the soil (K) averages 0.26; the slope of the terrain averages 12%, with a range of 2-40%. Land use/land cover in the watershed includes: 1.09% urban land, 11.31% agricultural land, 1.48% scrub/shrub land, 0.54% barren land, 85.47% forested land, and 0.11% water.

Turkey Creek originates near the City of York, flowing out of Caldwell Lake (37 acres) and accepting drainage from Ross Branch (Lake Carolyn), Dry Fork, Little Turkey Creek (McClures Branch, Lindsey Creek), and Bryson Creek. Further downstream, Blue Branch enters Turkey Creek followed by Rainey Branch (Palmer Branch), Susybole Creek (Little Susybole Creek), Mill Creek (Rodens Creek), and McKelvy Creek. There are a few ponds and lakes (10-37 acres) in this watershed used for recreational, municipal, and irrigational purposes. There are a total of 142.3 stream miles in this watershed, all classified FW. The lower tip of the watershed resides within the Sumter National Forest.

Water Quality

Turkey Creek (B-136) - Aquatic life uses are fully supported based on physical, chemical, and macroinvertebrate community data. Recreational uses are fully supported.

Ross Branch (B-086) - Aquatic life uses are fully supported, and a significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for this parameter. Recreational uses are not supported due to fecal coliform bacteria excursions.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)*** ***COMMENT***	***NPDES#*** ***TYPE*** ***LIMITATION***
LITTLE SUSYBOLE CREEK BECKER MINERALS/LOWRY QUARRY PIPE #: 001 FLOW: M/R	SCG730085 MINOR INDUSTRIAL EFFLUENT
SUSYBOLE CREEK TRIBUTARY MACK ESTATES PIPE #: 001 FLOW: 0.02 WQL FOR DO,TRC,NH3N; NOT CONSTRUCTED	SC0043095 MINOR MUNICIPAL WATER QUALITY

Mining Activities

MINING COMPANY *MINE NAME*	*PERMIT #* *MINERAL*
REA CONSTRUCTION CO. SAND PIT #123 - TURKEY CREEK MINE	0177-46 SAND
REA CONSTRUCTION CO. SAND PIT #124 - SUSYBOLE CREEK MINE	0180-10 SAND

Water Supply

WATER USER (TYPE) *STREAM*	*PUMPING CAPACITY (MGD)* *REG. PUMPING CAPACITY (MGD)*
CITY OF YORK (M) CALDWELL LAKE	4.1 2.2
CITY OF YORK (M) ROSS BRANCH TRIBUTARY - LAKE CAROLYN	4.0 2.2

Growth Potential

There is a low to moderate potential for growth in this watershed, which contains the Town of Lowrys and portions of the City of York, and the Towns of Sharon and McConnells. The City of York is located at the top of the watershed, and extends water and sewer service in and around the city. Residential and commercial development are expected to grow in these areas.

03050106-030

(Browns Creek)

General Description

Watershed 03050106-030 is located in Union County and consists primarily of ***Browns Creek*** and its tributaries. The watershed occupies 34,729 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Madison-Cecil-Wilkes series. The erodibility of the soil (K) averages 0.26; the slope of the terrain averages 13%, with a range of 2-40%. Land use/land cover in the watershed includes: 5.67% urban land, 18.59% agricultural land, 3.09% scrub/shrub land, 0.32% barren land, 72.20% forested land, and 0.13% water.

Big Browns Creek (Knox Creek, Bethlehem Creek, Meng Creek) originates near the City of Union and merges with Little Browns Creek to form Browns Creek. Gregorys Creek flows into Browns Creek just prior to its confluence with the Broad River. There are 59.6 stream miles in this watershed, all classified FW. The lower portion of the watershed resides within the Sumter National Forest.

Water Quality

Browns Creek (B-155) - Aquatic life uses are fully supported based on macroinvertebrate community data, but may be threatened by a very high concentration of zinc measured in 1995 and occurrences of copper in excess of the aquatic life acute standard. Recreational uses are partially supported due to fecal coliform bacteria excursions.

Meng Creek (B-064) - Aquatic life uses are fully supported, and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Unnamed tributary to Meng Creek (B-243) - Aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in pH. Significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus concentration, and turbidity suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Gregorys Creek (B-335) - Aquatic life uses are fully supported, but may be threatened by a very high concentration of zinc measured in 1995. Recreational uses are fully supported.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
BIG BROWNS CREEK CITY OF UNION/MENG CREEK PLANT PIPE #: 001 FLOW: 1.0 WQL FOR DO,TRC,NH3N	SC0047236 MAJOR MUNICIPAL WATER QUALITY
BIG BROWNS CREEK TRIBUTARY SONOCO PRODUCTS/PINCKNEY PLT PIPE #: 001 FLOW: 0.001 WQL FOR BOD5,DO,TRC,NH3N	SC0028789 MINOR INDUSTRIAL WATER QUALITY
MENG CREEK CITY OF UNION/WTP PIPE #: 001 FLOW: 0.062 WQL FOR TRC	SCG645028 MINOR DOMESTIC WATER QUALITY

Landfill Activities

SOLID WASTE LANDFILL NAME *FACILITY TYPE*	*PERMIT #* *STATUS*
UNION COUNTY LANDFILL MUNICIPAL	441001-1101 ACTIVE

Growth Potential

There is a low to moderate potential for growth in this watershed, which contains a portion of the City of Union and the unincorporated Monarch Mill Village. Water service is available in most of the watershed, and the area should continue to experience scattered residential development.

Implementation Strategy

Meng Creek and a tributary to Meng Creek are impaired by elevated levels of fecal coliform bacteria due to both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050106-040

(Sandy River)

General Description

Watershed 03050106-040 is located in Chester County and consists primarily of the ***Sandy River*** and its tributaries. The watershed occupies 102,351 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Wilkes-Madison series. The erodibility of the soil (K) averages 0.26; the slope of the terrain averages 14%, with a range of 2-40%. Land use/land cover in the watershed includes: 3.41% urban land, 9.12% agricultural land, 3.28% scrub/shrub land, 0.22% barren land, 83.58% forested land, and 0.40% water.

The Sandy River accepts drainage from Chapel Branch and flows through Chester Reservoir (80 acres) near the City of Chester. Downstream from the reservoir, Dry Fork enters the river followed by Caney Fork Creek (Chester State Park Lake, Twomile Branch, Threemile Branch), Carter Branch, Bear Branch (Mountain Lakes), and Seely Creek (Julies Fork, Walkers Mill Branch, Rock Branch, Bond Branch, Long Branch, Gum Spring Branch). Further downstream, the river accepts drainage from Rocky Branch, Brushy Fork Creek (Smith Creek, Starne Branch), the Little Sandy River (Mobley Creek, Coon Creek), and Johns Creek. Chester State Park is located in this watershed and extends over Twomile Branch and Threemile Branch near the City of Chester. There are several ponds and lakes (10-138 acres) in this watershed used for recreational and municipal purposes, and a total of 156.2 stream miles all classified FW. The lower tip of the watershed resides within the Sumter National Forest.

Water Quality

Sandy River (B-075) - Aquatic life uses are fully supported based on physical, chemical, and macroinvertebrate community data. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Chester State Park Lake (CL-023) - Aquatic life uses are fully supported. Chester State Park Lake is a 138-acre impoundment on Twomile Branch and Threemile Branch located within Chester State Park in Chester County. The maximum depth is approximately 17 feet (5.2 m) and the average depth is 8.9 feet (2.7 m). The lake's watershed comprises approximately 9.2 square miles (23.8 km2). Eutrophication assessments indicate that Chester State Park Lake maintains an intermediate trophic condition among small lakes in South Carolina. Valued for fishing, although not intensively managed, the lake can support high algal biomass.

Dry Fork (B-074) - Aquatic life uses may not be supported due to the occurrence of a high concentration of copper and both high and very high concentrations of chromium and nickel in sediments. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
SANDY RIVER HILLTOP MOBILE HOME PARK PIPE #: 001 FLOW: 0.01125 WQL FOR DO,TRC,NH3N	SC0031224 MINOR COMMUNITY WATER QUALITY
SANDY RIVER CITY OF CHESTER/SANDY RIVER WWTP PIPE #: 001 FLOW: 2.133 WQL FOR BOD5,DO,TRC,NH3N	SC0036081 MAJOR MUNICIPAL WATER QUALITY

LAND APPLICATION **FACILITY NAME**	**PERMIT#** **TYPE**
SPRAYFIELD OWENS LAUNDROMAT	ND0001023 INDUSTRIAL
SPRAYFIELD ESSEX INTER INC.	ND0001015 INDUSTRIAL

Landfill Activities

SOLID WASTE LANDFILL NAME *FACILITY TYPE*	*PERMIT #* *STATUS*
CITY OF CHESTER MUNICIPAL	DWP-069 CLOSED

Camp Facilities

FACILITY NAME/TYPE *RECEIVING STREAM*	*PERMIT #* *STATUS*
CHESTER STATE PARK/FAMILY CHESTER STATE PARK LAKE	12-307-0001 ACTIVE
B&S FAMILY CAMPGROUND/FAMILY SEELY CREEK	12-307-0007 ACTIVE

Growth Potential

There is a low to moderate potential for growth in this watershed, which contains the City of Chester. Water and sewer services are provided in and around Chester and will promote modest residential, commercial, and industrial growth. The majority of the watershed is rural in nature with a high degree of forestry activities.

Implementation Strategy

Dry Fork is impaired by elevated levels of chromium, copper, and nickel from nonpoint sources. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible.

03050106-050

(Broad River)

General Description

Watershed 03050106-050 is located in Newberry and Fairfield Counties and consists primarily of the ***Broad River*** and its tributaries from the Tyger River to the Parr Shoals dam. The watershed occupies 156,544 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil-Pacolet-Wilkes series. The erodibility of the soil (K) averages 0.24; the slope of the terrain averages 15%, with a range of 2-40%. Land use/land cover in the watershed includes: 0.73% urban land, 11.17% agricultural land, 3.86% scrub/shrub land, 0.34% barren land, 76.86% forested land, and 7.03% water.

This section of the Broad River accepts drainage from its upper reaches (03050105-094, 03050106-010) together with the Tyger River Watershed, the Enoree River Watershed, Beaver Creek (McClures Creek, Chicken Creek, Storm Branch, Reedy Branch, Sandy Fork), Rocky Creek, and Terrible Creek. The Parr Shoals dam impounds the Broad River to form Parr Reservoir, which accepts drainage from Hellers Creek (Second Creek, Buck Branch) and Cannons Creek (Rocky Branch, Kerr Creek, Charles Creek, Mud Creek). Monticello Reservoir (7100 acres) is connected to Parr Reservoir by Frees Creek. There are a few ponds and lakes (10-7100 acres) in this watershed used for recreation, industry, and power supply. There are a total of 294.9 stream miles, all classified FW. The Sumter National Forest and the Broad River Waterfowl Area are natural resources in the watershed.

Water Quality

A fish consumption advisory has been issued by the Department for mercury and includes portions of the Broad River in this watershed (see Watershed Evaluations and Implementation Strategies Within WMU-0502).

Broad River (B-047) - Aquatic life uses are fully supported, but may be threatened by a significantly increasing trend in total phosphorus concentration. A significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for this parameter. Recreational uses are partially supported due to fecal coliform bacteria excursions. This river was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Beaver Creek (B-143) - Aquatic life uses are fully supported based on macroinvertebrate community data.

Cannons Creek (B-751) - Aquatic life uses are fully supported based on macroinvertebrate community data.

Monticello Reservoir - Monticello Reservoir is a 7100-acre divided impoundment flooding most of the Frees Creek watershed in Fairfield County. The upper impoundment is a small recreational lake. The lower impoundment is linked with Parr Reservoir on the Broad River via a pumped storage hydroelectric facility.

Overall, the average depth of Monticello Reservoir is 59 feet (17.9 m) and the maximum depth in the lower impoundment is approximately 126 feet (38.4 m). The lake's watershed comprises approximately 17 square miles (44 km2). Historical eutrophication studies indicate that Monticello Reservoir's trophic condition is improving. It is currently one of the least eutrophic large lakes in South Carolina, characterized by low nutrient concentrations. Preservation of Monticello Reservoir's desirable trophic condition is recommended.

There are two monitoring sites along Monticello Reservoir. Aquatic life uses are fully supported at the upper impoundment site **(B-328)**. Recreational uses are fully supported, but may be threatened by a significantly increasing trend in fecal coliform bacteria concentration. Aquatic life uses are also fully supported at the lower impoundment site **(B-327)**, but may be threatened by a significantly increasing trend in pH and a very high concentration of copper measured in the 1992 sediment sample. Although pH excursions occurred, higher pH levels are not uncommon in lakes with significant aquatic plant communities and are considered natural, not standards violations. Significantly decreasing trends in total phosphorus and total nitrogen concentration, and turbidity at both lake sites suggest improving conditions for these parameters. Recreational uses are fully supported, but may be threatened by a significantly increasing trend in fecal coliform bacteria concentration.

Parr Reservoir **-** Parr Reservoir is a 4400-acre impoundment on the Broad River in Fairfield and Newberry Counties, linked with Monticello Reservoir via a pumped storage hydroelectric facility. Parr Reservoir's maximum depth is approximately 25 feet (7.6 m) and the average depth is 15 feet (4.6 m). The reservoir's watershed comprises approximately 4750 square miles (12,302 km2) in North and South Carolina. Currently, Parr Reservoir maintains an intermediate trophic condition among large lakes in South Carolina; a short retention time (average approximately four days) results in both high dissolved oxygen concentrations and high turbidity.

There are two monitoring sites along Parr Reservoir. Aquatic life and recreational uses are fully supported at both the uplake site **(B-346)** and the downlake site **(B-345)**. Although a pH excursion occurred at the downlake site, aquatic life uses are considered to be fully supported due to the small number of samples collected.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)*** ***COMMENT***	***NPDES#*** ***TYPE*** ***LIMITATION***
BROAD RIVER SCE&G/PARR HYDRO STA. PIPE #: 001 FLOW: M/R	SC0001864 MINOR INDUSTRIAL EFFLUENT
MONTICELLO RESERVOIR SCE&G/SUMMER NUCLEAR STA. PIPE #: 014 FLOW: 0.12 WQL DO,TRC; NH3N IN SUMMER & WINTER	SC0030856 MAJOR INDUSTRIAL WATER QUALITY

PARR RESERVOIR SCE&G/FAIRFIELD PUMPED STORAGE PIPE #: 001 FLOW: M/R	SC0035904 MINOR INDUSTRIAL EFFLUENT
CANNONS CREEK NEWBERRY INN/BEST WESTERN PIPE #: 001 FLOW: 0.0255 WQL FOR TRC,NH3N	SC0026921 MINOR COMMUNITY WATER QUALITY
CHARLES CREEK FOREST HILLS SD/ELBO INC. PIPE #: 001 FLOW: 0.02 WQL FOR DO,TRC,NH3N	SC0024571 MINOR MUNICIPAL WATER QUALITY
KERR CREEK TOWN OF PROSPERITY PIPE #: 001 FLOW: 0.17 WQL FOR DO,TRC,NH3N	PROPOSED MINOR MUNICIPAL WATER QUALITY
ROCKY CREEK TARMAC MID-ATLANTIC, INC. PIPE #: 001 FLOW: M/R	SCG730053 MINOR INDUSTRIAL EFFLUENT

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
NEWBERRY COUNTY LANDFILL MUNICIPAL	DWP-117 CLOSED
NEWBERRY COUNTY COMPOSTING MUNICIPAL	361001-3001 ACTIVE
NEWBERRY COUNTY TRANSFER STATION MUNICIPAL	361001-6007 ACTIVE
SHAKESPEARE CO. LANDFILL INDUSTRIAL	IWP-159 CLOSED

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
TARMAC MID-ATLANTIC, INC. BLAIR QUARRY	0130-20 GRANITE
NEWBERRY COUNTY WICKER ESTATE PIT	0299-36 SAND/CLAY

Water Supply

WATER USER (TYPE) ***STREAM***	***PUMPING CAPACITY (MGD)*** ***REG. PUMPING CAPACITY (MGD)***
VC SUMMER NUCLEAR STATION WTP (M) MONTICELLO RESERVOIR	3.1 1.5

Growth Potential

There is a low to moderate potential for growth in this watershed, primarily associated with residential development around the reservoirs, the Town of Jenkinsville, and the City of Newberry. The upper portion of the watershed is effectively excluded from development by the Sumter National Forest, and the overall lack of adequate utilities to serve the remaining area will limit growth.

Implementation Strategy

The Broad River is impaired by elevated levels of fecal coliform bacteria due to point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

03050106-060

(Broad River)

General Description

Watershed 03050106-060 is located in Richland, Newberry, and Fairfield Counties and consists primarily of the ***Broad River*** and its tributaries from the Parr Shoals dam to its confluence with the Saluda River. The watershed occupies 160,922 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Tatum-Alpin-Herndon-Pacolet series. The erodibility of the soil (K) averages 0.29; the slope of the terrain averages 13%, with a range of 2-25%. Land use/land cover in the watershed includes: 15.47% urban land, 5.62% agricultural land, 1.89% scrub/shrub land, 0.46% barren land, 74.96% forested land, and 1.57% water.

This section of the Broad River accepts drainage from its upper reaches (03050105-094, 03050106-010, 03050106-050) together with Mayo Creek, Crims Creek (Rocky Creek, Summers Branch), Wateree Creek (Risters Creek), Boone Creek, Freshley Branch, Mussel Creek, and the Little River Watershed. Hollingshead Creek (Boyd Branch, Wildhorse Branch, Metz Branch, Hope Creek, Bookman Creek) enters the river next followed by the Cedar Creek Watershed, Nipper Creek, Nicholas Creek (Swygert Branch, Moccasin Branch), Slatestone Creek, and Burgess Creek. Crane Creek and Smith Branch enter the river at the base of the watershed near the City of Columbia. Sorghum Branch, Dry Branch (Crescent Lake, Stevensons Lake), Elizabeth Lake (60 acres), and Cumbess Creek drain into Crane Creek followed by North Crane Creek. North Cane Creek accepts drainage from Beasley Creek (Robertson Branch, Lot Branch, Hawkins Branch), Swygert Creek, Dry Fork Creek, and Long Branch. There are several ponds and lakes (10-60 acres) in this watershed used for recreational and irrigational purposes, and a total of 311.6 stream miles, all classified FW. The Harbison State Forest is located next to the Broad River just downstream of Nicholas Creek and a Heritage Trust Preserve is located along Nipper Creek.

Water Quality

A fish consumption advisory has been issued by the Department for mercury and includes portions of the Broad River in this watershed (see Watershed Evaluations and Implementation Strategies Within WMU-0502).

Broad River - There are three monitoring sites along this section of the Broad River. Aquatic life uses may not be supported at the upstream site **(B-236)** due to the occurrence of pesticides (P,P'DDT, P,P'DDE, endrin) and high concentrations of the PAHs benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene in sediment samples. Recreational uses are partially supported due to fecal coliform bacteria excursions. Aquatic life and recreational uses are fully supported at the midstream site **(B-337)**. At the downstream site **(B-080)**, aquatic life uses are not supported due to occurrences of copper and zinc in excess of the aquatic life acute standard. In addition, there is a significantly decreasing trend in dissolved oxygen concentration. Significantly decreasing trends in five-day biochemical oxygen demand, total phosphorus and total nitrogen concentration at both the upstream and downstream sites suggest improving conditions for these parameters.

Recreational uses are partially supported due to fecal coliform bacteria excursions. This river was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Elizabeth Lake (B-110) - Aquatic life uses are fully supported. Although pH excursions occurred, they were typical of values seen in blackwater, sandhills systems and were considered natural, not standards violations. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are partially supported due to fecal coliform bacteria excursions. In addition, there is a significantly increasing trend in fecal coliform bacteria concentration.

Crane Creek - There are two monitoring sites along Crane Creek. Aquatic life uses are partially supported at the upstream site **(B-081)** based on macroinvertebrate community data. Aquatic life uses are not supported at the downstream site **(B-316)** due to occurrences of copper and zinc in excess of the aquatic life acute standard. In addition, there is a significantly increasing trend in turbidity. A significantly decreasing trend in total phosphorus concentration suggests improving conditions for this parameter. Recreational uses are not supported due to fecal coliform bacteria excursions, and there is a significantly increasing trend in fecal coliform bacteria concentration. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Smith Branch (B-280) - Aquatic life uses are not supported based on macroinvertebrate community data. A significantly increasing trend in dissolved oxygen concentration and significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentrations suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)***	***NPDES#*** ***TYPE*** ***LIMITATION***
BROAD RIVER MARTIN MARIETTA/N. COLUMBIA PIPE #: 001 FLOW: M/R	SCG730066 MINOR INDUSTRIAL EFFLUENT
BROAD RIVER RAINTREE ACRES SD/MIDLANDS UTILITIES PIPE #: 001 FLOW: 0.14	SC0039055 MINOR COMMUNITY EFFLUENT
BROAD RIVER TOWN OF CHAPIN PIPE #: 001 FLOW: 1.2 PIPE #: 001 FLOW: 2.4 (PROPOSED)	SC0040631 MAJOR MUNICIPAL EFFLUENT EFFLUENT

BROAD RIVER
RICHLAND COUNTY REGIONAL WWTP
PIPE #: 001 FLOW: 2.5

SC0046621
MAJOR MUNICIPAL
EFFLUENT

BROAD RIVER
AMERADA HESS #40231
PIPE #: 001 FLOW: MR
NOT CONSTRUCTED

SC0045187
MINOR INDUSTRIAL
EFFLUENT

MAYO CREEK
SCE&G/SUMMER NUCLEAR TRAINING CTR
PIPE #: 001 FLOW: 0.004
WQL FOR TRC

SC0038407
MINOR INDUSTRIAL
WATER QUALITY

CRANE CREEK
ATLANTIC SOFT DRINK
PIPE #: 001 FLOW: M/R

SCG250021
MINOR INDUSTRIAL
EFFLUENT

CRANE CREEK
RICHTEX BRICK CORP.
PIPE #: 001 FLOW: 0.008
WQL FOR DO,TRC,NH3N

SC0031640
MINOR INDUSTRIAL
WATER QUALITY

CRANE CREEK DITCH
COLUMBIA I-20 AUTO TRUCK CTR
PIPE #: 001 FLOW:M/R

SC0035416
MINOR INDUSTRIAL
EFFLUENT

CRANE CREEK TRIBUTARY
PRESCOTT TERRACE WWTP
PIPE #: 001 FLOW: ----

SC0030899
MINOR MUNICIPAL
EFFLUENT

RISTERS CREEK
MUNN OIL CO/MUNN-E-S
PIPE #: 001 FLOW: M/R
NEVER CONSTRUCTED

SCG830006
MINOR INDUSTRIAL
EFFLUENT

SMITH BRANCH
CROWN SC 17
PIPE #: 001 FLOW: M/R

SC0043681
MINOR INDUSTRIAL
EFFLUENT

SMITH BRANCH
CHEVRON USA/COLUMBIA
PIPE #: 001 FLOW: M/R

SCG830003
MINOR INDUSTRIAL
EFFLUENT

NIPPER CREEK
TARMAC AMERICA/DREYFUS QUARRY
PIPE #: 001 FLOW: M/R

SCG730052
MINOR INDUSTRIAL
EFFLUENT

Landfill Activities

SOLID WASTE LANDFILL NAME
FACILITY TYPE

PERMIT #
STATUS

GIST BACKHOE & GRINDING SERVICE
MUNICIPAL

402445-3001
ACTIVE

WHALES TAIL
INERT

CLOSED

RICHLAND COUNTY MSW MUNICIPAL	DWP-065 CLOSED
RICHLAND COUNTY C&D LANDFILL	401002-1201 ACTIVE
RICHARDSON CONSTRUCTION CO., INC. C&D LANDFILL	— CLOSED
RICHTEX BRICK CORP. INDUSTRIAL	IWP-147 ACTIVE
CITY OF COLUMBIA-NORTH LANDFILL MUNICIPAL	SCD981-028-699 CLOSED
CAROLINA WRECKING C&D LANDFILL	402451-1301 CLOSED
CAROLINA WRECKING C&D LANDFILL	APPLYING FOR PERMIT ACTIVE
RICHLAND WRECKING CO., INC. C&D LANDFILL (3 SITES)	— CLOSED
NORTH COLUMBIA DEVELOPMENT C&D LANDFILL	— CLOSED
OSS METALS C&D LANDFILL	— CLOSED

Mining Activities

MINING COMPANY ***MINE NAME***	***PERMIT #*** ***MINERAL***
MARTIN MARIETTA MATERIALS NORTH COLUMBIA QUARRY	0099-40 GRANITE
TRIP CONSTRUCTION CO. TRIP CONSTRUCTION MINE	0081-40 SAND
RICHTEX CORP. BROAD RIVER MINE	0187-40 SHALE
TARMAC MID-ATLANTIC, INC. DREYFUS QUARRY	0129-40 GRANITE

Camp Facilities

FACILITY NAME/TYPE ***RECEIVING STREAM***	***PERMIT #*** ***STATUS***
WOODSMOKE CAMPGROUND/FAMILY WILDHORSE BRANCH	40-307-0011 ACTIVE
CAPITAL CITY CAMPGROUND/FAMILY CRANE CREEK TRIBUTARY	40-307-0003 ACTIVE

Water Supply

WATER USER (TYPE) *STREAM*	*PUMPING CAPACITY (MGD)* *REG. PUMPING CAPACITY (MGD)*
CITY OF COLUMBIA (M) BROAD RIVER CANAL	90.0 72.0

Groundwater Concerns

The groundwater in the vicinity of the property owned by Southern Bell is contaminated with petroleum products due to underground storage tanks. The contamination is considered a risk-based corrective action priority classification 1 (SCDHEC 1997). The contaminated plume is discharging to Smith Branch.

Growth Potential

There is a high potential for growth in this watershed, which contains the northwest portion of the City of Columbia and ample water and sewer service. The I-26 and I-77 corridors, which cross the watershed, together with the US 321, US 21, and US 176 corridors will serve to increase residential, commercial, and industrial growth in the Greater Columbia Area. The northwest portion of the city (St. Andrews, Irmo, and Harbison) will continue to develop as a regional commercial hub for the area. Industrial development along the I-77 corridor is expected to remain strong due to the aggressive economic development policy by the City of Columbia and Richland County. The Killian and Blythwood areas in particular are expected to see increased construction activity.

Implementation Strategy

The Broad River is impaired by elevated levels of pesticides, PAHs, zinc, copper, and fecal coliform bacteria from point and nonpoint sources. Biological community data are needed to determine the ecological significance of the metal excursions and should be acquired where feasible. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation. Crane Creek has an impaired macroinvertebrate community and elevated levels of zinc, copper, and fecal coliform bacteria from point and nonpoint sources. Smith Branch also has an impaired macroinvertebrate community and elevated levels of fecal coliform. The biological data will be evaluated to determine the cause of their impairment. Permit revisions have been initiated in Crane Creek and bacterial improvements are expected in the next basin rotation.

03050106-070

(Little River)

General Description

Watershed 03050106-070 is located in Fairfield, Chester, and Richland Counties and consists primarily of the ***Little River*** and its tributaries. The watershed occupies 117,685 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Wilkes-Cecil series. The erodibility of the soil (K) averages 0.26; the slope of the terrain averages 14%, with a range of 2-40%. Land use/land cover in the watershed includes: 0.39% urban land, 3.92% agricultural land, 4.54% scrub/shrub land, 0.19% barren land, 90.87% forested land, and 0.10% water.

Big Creek and Little Creek join to form the headwaters of the Little River near the Town of Blackstock. Downstream of the confluence, the Little River accepts drainage from Camp Branch, Brushy Fork Creek (Dumpers Creek), the West Fork Little River (Weir Creek, Spring Branch, Williams Creek, Opossum Branch), Lick Branch, and Harden Branch. The Jackson Creek Watershed drain into the river next followed by Crumpton Creek, the Mill Creek Watershed, Morris Creek, Gibson Branch (Manns Branch, Russell Creek), and Home Branch. The Little River drains into the Broad River. There are a few ponds and lakes (10-16 acres) in this watershed used for recreational and industrial purposes. There are a total of 186.4 stream miles in this watershed, all classified FW.

Water Quality

Little River (B-145) - Although a very high concentration of zinc was measured in 1995, based on macroinvertebrate community data, aquatic life uses are fully supported. Significantly decreasing trends in five-day biochemical oxygen demand and total phosphorus concentration suggest improving conditions for these parameters. Recreational uses are not supported due to fecal coliform bacteria excursions, compounded by a significantly increasing trend in fecal coliform bacteria concentration.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)*** ***COMMENT***	***NPDES#*** ***TYPE*** ***LIMITATION***
MORRIS CREEK MARTIN MARIETTA/RION QUARRY PIPE #: 001 FLOW: M/R	SCG730060 MINOR INDUSTRIAL EFFLUENT

Camp Facilities

FACILITY NAME/TYPE ***RECEIVING STREAM***	***PERMIT #*** ***STATUS***
GLENN'S 6-10 CAMPGROUND/FAMILY LITTLE RIVER TRIBUTARY	20-307-0012 ACTIVE

Growth Potential

There is a low potential for growth in this watershed due to the absence of public utilities.

03050106-080

(Jackson Creek/Mill Creek)

General Description

Watershed 03050106-080 is located in Fairfield County and consists primarily of ***Jackson Creek and Mill Creek*** and their tributaries. The watershed occupies 37,523 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Madison-Cecil-Wilkes series. The erodibility of the soil (K) averages 0.26; the slope of the terrain averages 12%, with a range of 2-40%. Land use/land cover in the watershed includes: 9.33% urban land, 8.62% agricultural land, 2.57% scrub/shrub land, 0.37% barren land, 78.41% forested land, and 0.70% water.

Jackson Creek is created by the confluence of Winnsboro Branch and Moore Creek near the Town of Winnsboro. Jackson Creek accepts drainage from Jordan Branch, Kennedy Creek, Sand Creek, Stitt Branch, and Gladney Branch before flowing into the Little River. Mill Creek drains into the Little River downstream of Jackson Creek. There are a few ponds and lakes (10-192 acres) in this watershed used for recreational, municipal, and flood control purposes. There are a total of 69.3 stream miles in this watershed, all classified FW.

Water Quality

Jackson Creek (B-102) - Aquatic life uses are partially supported based on macroinvertebrate community data. In addition, there is an occurrence of chromium and copper in excess of the aquatic life acute standard. Recreational uses are not supported due to fecal coliform bacteria excursions.

Winnsboro Branch - There are two monitoring sites along Winnsboro Branch. Aquatic life uses are fully supported at the upstream site **(B-123)**, but may be threatened by a significantly increasing trend in turbidity. A significantly decreasing trend in five-day biochemical oxygen demand suggests improving conditions for this parameter. Recreational uses are not supported due to fecal coliform bacteria excursions.

Aquatic life uses are also fully supported at the downstream site **(B-077)**, but may be threatened by a significantly decreasing trend in dissolved oxygen concentration and the occurrence of chromium, copper, and zinc in the water column in excess of the aquatic life acute standard, and the detection of PCB-1242 and PCB-1254 in the 1993 sediment sample. A significantly decreasing trend in total phosphorus concentration suggests improving conditions for this parameter. Recreational uses are not supported due to fecal coliform bacteria excursions. This is compounded by a significantly increasing trend in fecal coliform bacteria concentration.

Mill Creek (B-338) - Although pH excursions occurred, aquatic life uses are considered to be fully supported due to the small number of samples collected. Recreational uses are not supported due to fecal coliform bacteria excursions.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM ***FACILITY NAME*** ***PERMITTED FLOW @ PIPE (MGD)*** ***COMMENT***	***NPDES#*** ***TYPE*** ***LIMITATION***
JACKSON CREEK TOWN OF WINNSBORO PIPE #: 001 FLOW: 1.6 WQL FOR BOD5,DO,TRC,NH3N	SC0020125 MAJOR MUNICIPAL WATER QUALITY
JACKSON CREEK TRIBUTARY UNIROYAL GOODRICH TIRE MFG. PIPE #: 001 FLOW: M/R	SCG250148 MINOR INDUSTRIAL EFFLUENT
JORDAN BRANCH ROYAL HILL SD/MIDLAND UTILITIES PIPE #: 001 FLOW: 0.04 PROPOSED; WQL FOR BOD5,DO,TRC,NH3N	SC0031046 MINOR COMMUNITY WATER QUALITY

Landfill Activities

SOLID WASTE LANDFILL NAME ***FACILITY TYPE***	***PERMIT #*** ***STATUS***
CHAMBERS FAIRFIELD COUNTY SW TRANSFER STA. MUNICIPAL	—— ACTIVE
FAIRFIELD COUNTY LANDFILL MUNICIPAL	DWP-090 CLOSED

Water Supply

WATER USER (TYPE) ***STREAM***	***PUMPING CAPACITY (MGD)*** ***REG. PUMPING CAPACITY (MGD)***
TOWN OF WINNSBORO (M) SAND CREEK	0.7 0.5
TOWN OF WINNSBORO (M) MILL CREEK - 192 ACRE LAKE	— ---

Growth Potential

There is a low potential for growth in this watershed except for in and around the City of Winnsboro, where water and sewer services exist.

Implementation Strategy

Jackson Creek has an impaired macroinvertebrate community from unknown sources. The biological data will be evaluated to determine the cause of their impairment.

03050106-090

(Cedar Creek)

General Description

Watershed 03050106-090 is located in Fairfield and Richland Counties and consists primarily of ***Cedar Creek*** and its tributaries. The watershed occupies 61,189 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Herndon-Helena-Georgeville series. The erodibility of the soil (K) averages 0.39; the slope of the terrain averages 11%, with a range of 2-25%. Land use/land cover in the watershed includes: 0.66% urban land, 7.17% agricultural land, 1.40% scrub/shrub land, 0.05% barren land, 0.02% forested wetland, 90.35% forested land, and 0.34% water.

Big Cedar Creek originates near the Town of Ridgeway and accepts drainage from Center Creek (Rock Dam Creek), Persimmon Fork, Horse Creek, Williams Branch (Big Branch), and Little Cedar Creek (Crooked Run Creek, Bethel Pond, Smith Branch, Chappel Branch). Big Cedar Creek merges with Harmon Creek (Little Horse Branch, Elkins Creek) to form Cedar Creek which flows into the Broad River. There are a few recreational ponds and lakes (10-20 acres) in this watershed and a total of 150.0 stream miles, all classified FW.

Water Quality

Big Cedar Creek (B-320) - Aquatic life uses are fully supported based on physical, chemical, and macroinvertebrate community data. Recreational uses are partially supported due to fecal coliform bacteria excursions. This creek was Class B until April, 1992 and bacterial conditions may show improvement as the NPDES permits are reissued in the watershed.

Activities Potentially Affecting Water Quality

Point Source Contributions

RECEIVING STREAM *FACILITY NAME* *PERMITTED FLOW @ PIPE (MGD)* *COMMENT*	*NPDES#* *TYPE* *LIMITATION*
CEDAR CREEK TRIBUTARY TOWN OF RIDGEWAY WWTP PIPE #: 001 FLOW: 0.12 WQL FOR BOD5,DO,TRC,NH3N	SC0022900 MINOR MUNICIPAL WATER QUALITY
CENTER CREEK KINGS LABORATORY PIPE #: 001 FLOW: M/R	SC0038474 MINOR INDUSTRIAL EFFLUENT

Growth Potential

There is a low to moderate potential for growth in this watershed. Water and sewer services are available in the Blythewood area.

Implementation Strategy

Big Cedar Creek is impaired from elevated levels of fecal coliform bacteria resulting from both point and nonpoint sources. Permit revisions have been initiated and bacterial improvements are expected in the next basin rotation.

Summary of Water Quality and Implementation Strategies

This summary details both impaired and unimpaired waters. Waters are considered impaired if they are unable to fully meet classified uses for aquatic life, recreation or fish consumption based on the corresponding standards (see Methodology section for interpretation). Noteworthy long-term trends are identified for unimpaired waters. The actions indicated should occur prior to updating this assessment in 2001. (* See text for additional information.)

PS=Partially Supported; NS=Not Supported

WATERSHED WATERBODY	IMPAIRED USE	CAUSE	POSSIBLE SOURCE	RECOMMENDED ACTION
03050108-010 Enoree River* (7 Sites)	Aquatic Life	NS-Zinc (Site 1); PS-Copper (Site 3); PS-Macroinvertebrate Community (Sites 4,5)	Unknown	Monitor the Area for Groundwater; Further Evaluate the Macroinvertebrate Data
	Recreation	PS-Fecal Coliform (Sites 1,6,7); NS-Fecal Coliform (Sites 2,3,4)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Beaverdam Creek	Recreation	NS-Fecal Coliform	Point Source	Facility May Be Eliminated
			Nonpoint Source	Further Evaluation
Mountain Creek*	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Princess Creek*	Aquatic Life	NS-pH, Zinc	Point Source	Evaluate Macroinvertebrate Community
	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation
Brushy Creek (2 Sites)	Recreation	NS-Fecal Coliform (Both Sites)	Nonpoint Source	Further Evaluation
	—	Groundwater - Petroleum Products	Nonpoint Source	Facility in Monitoring Phase
Rocky Creek*	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Little Rocky Creek	—	Groundwater - Petroleum Products, Phenol, Volatile Organic Compounds	Nonpoint Source	Currently in Assessment, Monitoring, & Remediation Phases.
Gilder Creek* (3 Sites)	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Lick Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation

PS=Partially Supported; NS=Not Supported

WATERSHED WATERBODY	IMPAIRED USE	CAUSE	POSSIBLE SOURCE	RECOMMENDED ACTION
Durbin Creek* (3 Sites)	Recreation	NS-Fecal Coliform (Upstream & Midstream Sites)	Point and/or Nonpoint Sources	Further Evaluation
	—	Groundwater - Petroleum Products	Nonpoint Source	A Risk-Based Corrective Action Priority Classification I Underway
Durbin Creek Tributary	—	Groundwater - Volatile Organic Compounds	Nonpoint Source	Facility Currently in Assessment & Remediation Phase
03050108-020 Enoree River* (3 Sites)	Recreation	PS-Fecal Coliform (Upstream Site); NS-Fecal Coliform (Midstream & Downstream Sites)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
03050108-030 Beaverdam Creek	Recreation	NS-Fecal Coliform	Nonpoint Sources	Further Evaluation
Warrior Creek* (2 Sites)	Recreation	NS-Fecal Coliform (Upstream Site)	Nonpoint Source	Further Evaluation
03050108-040 Duncan Creek*	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Beards Fork Creek*	Aquatic Life	PS-Dissolved Oxygen	Nonpoint Source	Further Evaluation
	Recreation	PS-Fecal Coliform		
03050108-050 Enoree River*	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050107-010 South Tyger River* (6 Sites)	Aquatic Life	PS-Macroinvertebrate Community (Site 4)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation. An Enforcement Action is also Underway. (Proposal to Eliminate and Tie in Point Source)
	Recreation	NS,PS-Fecal Coliform (Sites 3,5)		
Wards Creek	—	Groundwater - Volatile Organic Compounds	Nonpoint Source	Facility Currently in Remediation Phase
Mush Creek*	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation

PS=Partially Supported; NS=Not Supported

WATERSHED WATERBODY	IMPAIRED USE	CAUSE	POSSIBLE SOURCE	RECOMMENDED ACTION
03050107-020 North Tyger River*	Aquatic Life	PS-Zinc	Unknown	Evaluate Macroinvertebrate Community
	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
North Tyger River Tributary	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050107-030 North Tyger River* (3 Sites)	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
03050107-040 Middle Tyger River* (3 Sites)	Recreation	NS-Fecal Coliform (All Sites)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
03050107-050 Tyger River* (2 Sites)	Aquatic Life	NS-Zinc (Upstream Site)	Unknown	Evaluate Macroinvertebrate Community
	Recreation	NS-Fecal Coliform (Both Sites)	Point Sources	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Jimmies Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050107-060 Fairforest Creek* (5 Sites)	Aquatic Life	PS-Metals & Macroinvertebrate Community (Site 3); PS-Dissolved Oxygen (Site 4)	Point and Nonpoint Sources	Permit Actions Initiated & Improvements Expected in Next Basin Rotation.
	Recreation	NS,PS-Fecal Coliform (Sites 1,2,3; Sites 4,5)	Point Source	Permit Actions Initiated & Improvements Expected in Next Basin Rotation. An Enforcement Action is also Underway.
			Nonpoint Source	Further Evaluation
	----	Groundwater - Volatile Organic Compounds	Nonpoint Sources	Facilities Currently in Assessment & Remediation Phases
Fairforest Creek Tributary*	Aquatic Life	NS-Chromium, Copper, Lead, Zinc	Unknown/Point Source	Evaluate Macroinvertebrate Community & Groundwater
	Recreation	NS-Fecal Coliform	Unknown/Nonpoint Source	Further Evaluation

PS=Partially Supported; NS=Not Supported

WATERSHED WATERBODY	IMPAIRED USE	CAUSE	POSSIBLE SOURCE	RECOMMENDED ACTION
Goat Pond Creek	——	Groundwater - Volatile Organic Compounds	Nonpoint Sources	Facility Currently in Assessment & Monitoring Phase
Kelsey Creek*	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Kelsey Creek Tributary	——	Groundwater - Volatile Organic Compounds	Nonpoint Source	RCRA Facility in Remediation Phase
Mitchell Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Toschs Creek* (2 Sites)	Recreation	NS-Fecal Coliform (Both Sites)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation. An Enforcement Action is also Underway.
Tinker Creek* (3 Sites)	Recreation	NS-Fecal Coliform (All Sites)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
03050105-090 Broad River* (2 Sites)	Aquatic Life	NS-Cadmium, Lead, Copper, Zinc (Downstream Site)	Point Source/Unknown (Possibly from N.C.)	Evaluate Macroinvertebrate Community
	Recreation	NS,PS-Fecal Coliform (Both Sites)	Nonpoint Source	Further Evaluation
Canoe Creek* (3 Sites)	Aquatic Life	PS,NS-Macroinvertebrate Community	Point Source	Facility to be Upgraded
	Recreation	NS-Fecal Coliform (Downstream Site)	Point Source	Facility to be Upgraded
Peoples Creek	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Doolittle Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Guyonmoore Creek	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation
Furnace Creek*	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050105-100 Buffalo Creek* (3 Sites)	Aquatic Life	PS-Cadmium, Copper, Chromium (Downstream Site)	Point Source/Unknown (Possibly from N.C.)	Evaluate Macroinvertebrate Community & Groundwater
	Recreation	NS-Fecal Coliform (All Sites)	Nonpoint Source	Further Evaluation

PS=Partially Supported; NS=Not Supported

WATERSHED WATERBODY	IMPAIRED USE	CAUSE	POSSIBLE SOURCE	RECOMMENDED ACTION
03050105-110 Cherokee Creek	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation; An Enforcement Action is also Underway
Providence Creek	—	Groundwater - Volatile Organic Compounds	Nonpoint Source	Facility Currently in Remediation Phase
03050105-120 Kings Creek*	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050105-130 Thicketty Creek* (3 Sites)	Recreation	NS-Fecal Coliform (All Sites)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Irene Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Limestone Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Gilkey Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050105-140 Bullock Creek	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation
Long Branch	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation
Clark Fork* (2 Sites)	Recreation	PS-Fecal Coliform (Upstream Site)	Nonpoint Source	Further Evaluation
03050105-150 North Pacolet River* (3 Sites)	Recreation	NS-Fecal Coliform (2 Downstream Sites)	Nonpoint Source	Further Evaluation
Lake Lanier* (2 Sites)	Recreation	PS-Fecal Coliform (Upstream Site)	Nonpoint Source	Further Evaluation
Page Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050105-160 South Pacolet River (2 Sites)	Recreation	NS-Fecal Coliform (Downstream Site)	Nonpoint Source	Further Evaluation
Spivey Creek	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050105-170 Pacolet River* (3 Sites)	Recreation	NS-Fecal Coliform (All Sites)	Nonpoint Source	Further Evaluation
	—	Groundwater - Volatile Organic Compounds	Nonpoint Source	Facility in Assessment Phase

PS=Partially Supported; NS=Not Supported

WATERSHED WATERBODY	IMPAIRED USE	CAUSE	POSSIBLE SOURCE	RECOMMENDED ACTION
Little Buck Creek*	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Potter Branch*	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050105-180 Lawsons Fork Creek* (5 Sites)	Aquatic Life	PS-Macroinvertebrate Community (Sites 1,5)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source (Urban Runoff from Spartanburg)	Further Evaluation
	Recreation	NS-Fecal Coliform (All Sites)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source (Urban Runoff from Spartanburg)	Further Evaluation
	—	Groundwater - VOCs	Nonpoint Source	Remedial Action has been Initiated for RCRA Facility
Fourmile Branch	—	Groundwater - Petroleum Products	Nonpoint Source	Facilities Currently in Assessment & Remediation Phase, & are Participating in a Community Plume Agreement
03050105-190 Pacolet River* (2 Sites)	Recreation	NS-Fecal Coliform (Both Sites)	Nonpoint Source	Further Evaluation
03050106-010 Broad River*	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050106-020 Ross Branch	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050106-030 Meng Creek	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Meng Creek Tributary*	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
Browns Creek*	Recreation	PS-Fecal Coliform	Nonpoint Source	Further Evaluation

PS=Partially Supported; NS=Not Supported

WATERSHED WATERBODY	IMPAIRED USE	CAUSE	POSSIBLE SOURCE	RECOMMENDED ACTION
03050106-040 Sandy River	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Dry Fork*	Aquatic Life	NS-Copper, Chromium, Nickel	Nonpoint Source (Urban Runoff from Chester)	Evaluate Macroinvertebrate Community & Possibly Groundwater
	Recreation	NS-Fecal Coliform	Nonpoint Source (Urban Runoff from Chester)	Further Evaluation
03050106-050 Broad River*	Recreation	PS-Fecal Coliform Upstream Site (Enoree & Tyger Rivers)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation
03050106-060 Broad River* (3 Sites)	Aquatic Life	NS-Pesticides, PAHs (Upstream Site); Copper, Zinc (Downstream Site)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source (Urban Runoff from Columbia)	Further Evaluation
	Recreation	PS-Fecal Coliform (Upstream & Downstream Site)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source (Urban Runoff from Columbia)	Further Evaluation
Crane Creek* (2 Sites)	Aquatic Life	PS-Macroinvertebrate Community (Upstream Site); NS-Copper, Zinc (Downstream Site)	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source (Urban Runoff from Columbia)	Further Evaluation
	Recreation	NS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source (Urban Runoff from Columbia)	Further Evaluation

PS=Partially Supported; NS=Not Supported

WATERSHED WATERBODY	IMPAIRED USE	CAUSE	POSSIBLE SOURCE	RECOMMENDED ACTION
Smith Branch	Aquatic Life	NS-Macroinvertebrate Community	Nonpoint Source (Urban Runoff from Columbia)	Further Evaluation
	Recreation	NS-Fecal Coliform	Nonpoint Source (Urban Runoff From Columbia)	Further Evaluation
	—	Groundwater - Petroleum Products	Nonpoint Source (Underground Storage Tank Leakage)	Risk-Based Corrective Action Priority Class I is Underway
Elizabeth Lake*	Recreation	PS-Fecal Coliform	Nonpoint Source (Urban Runoff from Columbia)	Further Evaluation
03050106-070 Little River*	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050106-080 Jackson Creek*	Aquatic Life	PS-Macroinvertebrate Community	Unknown	Evaluate Macroinvertebrate data
	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
Winnsboro Branch* (2 Sites)	Recreation	NS-Fecal Coliform (Both Sites)	Nonpoint Source	Further Evaluation
Mill Creek	Recreation	NS-Fecal Coliform	Nonpoint Source	Further Evaluation
03050106-090 Big Cedar Creek	Recreation	PS-Fecal Coliform	Point Source	Permit Actions Initiated & Improvements are Expected in Next Basin Rotation.
			Nonpoint Source	Further Evaluation

UNIMPAIRED WATERS WITH NOTABLE TRENDS

The waters listed in this table are not impaired, but rather display long-term trends that bear following, primarily with continued monitoring.

WATERSHED WATERBODY	CONCERN	POSSIBLE SOURCE	RECOMMENDED ACTION
03050105-160 Lake Bowen	Very High Levels of Cadmium	Unknown	Continue Evaluation
Spartanburg Reservoir #1	Declining Trends in Dissolved Oxygen; Increasing Trend in Turbidity and Fecal Coliform Bacteria	Unknown	Continue Evaluation
03050106-030 Gregorys Creek	Very High Levels of Zinc	Unknown	Continue Evaluation
03050106-050 Monticello Reservoir	Increasing Trends in Fecal Coliform, pH; Very High Levels of Copper	High Geese Population	Continue Evaluation

References

Agency for Toxic Substances Disease Registry. 1992. Toxicological Profile of Mercury. U.S. Department of Health and Human Services, U.S. Public Health Service.

Appalachian Council of Governments. 1997. Appalachian Regional Water Quality Management Plan. Greenville, S.C.

Bauer, K.M., W.M. Glauz and J.D. Flora. 1984. Methodologies for Determining Trends in Water Quality Data. Draft copy of Appendix III in USEPA Guidance for Determining Trends in Water Quality Data.

Central Midlands Council of Governments. 1997. The 208 Water Quality Management Plan for the Central Midlands Region. Columbia, S.C.

Hirsch, R.M., J.R. Slack and R.A. Smith. 1982. Techniques of Trend Analysis for Monthly Water Quality Data. Water Resources Research 18:107-121.

North Carolina Department of Environmental Health and Natural Resources. 1995. Standard Operating Procedures: Biological Monitoring. Division of Environmental Management, Water Quality Section, Raleigh, NC.

Plafkin, James L., M.T. Barbour, K. D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA/444/4-89-001, Washington, D.C.

Shealy Environmental Services, Inc. 1996. Macroinvertebrate Assessment of Canoe Creek Near the Town of Blacksburg's Canoe Creek Wastewater Treatment Plant, Cherokee County, South Carolina.

Smith, R.A., R.M. Hirsch and J.R. Slack. 1982. A Study of Trends in Total Phosphorus Measurements as NASQAN Stations. U.S. Geological Survey Water Supply Paper 2190, Reston, VA.

Smith, R.A., R.B. Alexander, and M.G. Wolman. 1987. Water Quality Trends in the Nation's Rivers. Science 235:1607-1615.

South Carolina Department of Health and Environmental Control. 1981. Procedures and Quality Control Manual for Chemistry Laboratories. Bureau of Environmental Quality Control Laboratories, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1989. Assessment of Nonpoint Source Pollution for the State of South Carolina. Bureau of Water Pollution Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1991a. Watershed Water Quality Management Strategy in South Carolina: Program description. Bureau of Water Pollution Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1991b. South Carolina Lake Classification Survey 1991. Technical Report No. 006-91. Bureau of Water Pollution Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1993. Water Classifications and Standards (Regulation 61-68) and Classified Waters (Regulation 61-69) for the State of South Carolina. Office of Environmental Quality Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1994. Standard Operating and Quality Control Procedures for Ambient Water Quality and Wastewater Facility Monitoring. Technical Report 029-83. Bureau of Water Pollution Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1995a. Summary of Heavy Metals Concentrations in South Carolina Waters and Sediments January 1, 1989 - December 31, 1993. Technical Report 006-94. Bureau of Water Pollution Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1995b. State Nonpoint Source Pollution Management Program. Bureau of Water Pollution Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1996a. State of South Carolina Monitoring Strategy for Fiscal Year 1996. Tech. Rep. 002-95. Bureau of Water Pollution Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1996b. Statewide Water Quality Assessment FY 1993-1994: A Report to Congress Pursuant to Section 305(b) of the Federal Water Quality Act. Bureau of Water Pollution Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1997a. South Carolina Groundwater Contamination Inventory. Office of Environmental Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 1997b. 208 Water Quality Management Plan - Plan Update for the Non-designated Area of South Carolina. Bureau of Water, Columbia, S.C.

South Carolina Land Resources Conservation Commission. 1988. Nonpoint Source Pollution Assessment for South Carolina, Columbia, S.C.

South Carolina Land Resources Conservation Commission. 1990. SPOT Satellite Image Based Land Use/Land Cover data.

South Carolina Water Resources Commission, State Climatology Office. 1990. General Characteristics of South Carolina's Climate. Climate Report No.G5.

United States Environmental Protection Agency. 1986. Quality Criteria for Water 1986. Publication No. EPA 440/5-86-001. Office of Water Regulations and Standards, Washington, D.C.

United States Department of Agriculture, Soil Conservation Service. 1963-1990. Soil Surveys for selected Counties of South Carolina, Columbia, S.C.

United States Department of Agriculture and Purdue Agricultural Experiment Station. 1978. Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. USDA, Agriculture Handbook Number 537.

United States Department of Agriculture, Soil Conservation Service. 1982. South Carolina Resources Inventory: A Summary Report From the 1982 National Resources Inventory. SCS, Columbia, S.C.

APPENDIX A. WMU-0501

Monitoring Station Descriptions

STATION TYPES (P=PRIMARY, S=SECONDARY, W=WATERSHED, BIO=BIOLOGICAL, I=INACTIVE)
CLASS (FW=FRESHWATER, SA=SALTWATER)

03050108-010

BE-001	P	FW	ENOREE RIVER AT UNNUMBERED ROAD W OF US 25, N OF TRAVELERS REST
BE-039	S	FW	BEAVERDAM CREEK AT ROAD 1967
B-186	S	FW	MOUNTAIN CREEK AT S-23-335
B-192	P	FW	PRINCESS CREEK AT SUBER MILL RD, SECOND ROAD S OF US 29 OFF S-23-540
BE-015	S	FW	ENOREE RIVER AT COUNTY ROAD 164
BE-035	S	FW	BRUSHY CREEK AT HOWELL ROAD, APPROXIMATELY 5 MI NE OF GREENVILLE
BE-009	S	FW	BRUSHY CREEK AT S-23-164
BE-007	S	FW	ROCKY CREEK AT BATESVILLE BRIDGE, 1 MI ABOVE CONFLUENCE WITH ENOREE R.
BE-017	P	FW	ENOREE RIVER AT SC 296, 7.5 MI NE OF MAULDIN
BE-040	S	FW	GILDER CREEK AT SC 14, ABOVE GILDERS CREEK PLANT
B-241	S	FW	GILDER CREEK AT S-23-142, 2.75 MI ENE OF MAULDIN
BE-020	S	FW	GILDER CREEK AT S-23-143, 1/4 MI ABOVE CONFLUENCE WITH ENOREE RIVER
BE-018	S/BIO	FW	ENOREE RIVER AT S-30-75
BE-019	BIO	FW	ENOREE RIVER AT SC 418
B-037	S	FW	ENOREE RIVER AT S-42-118, SW OF WOODRUFF
B-038	S	FW	LICK CREEK AT S-42-118, 1 1/4 MI SW WOODRUFF
B-035	S	FW	DURBIN CREEK ON S-23-160, 3 MI E OF SIMPSONVILLE
B-097	P	FW	DURBIN CREEK AT SC 418
BE-022	BIO	FW	DURBIN CREEK AT SC 101
B-040	W	FW	ENOREE RIVER AT S-30-112

03050108-020

BE-024	I	FW	ENOREE RIVER AT US 221
B-041	P	FW	ENOREE RIVER AT SC 49, SE OF WOODRUFF
B-053	W	FW	ENOREE RIVER AT SC 72, 121, & US 176, 1 MI NE WHITMIRE

03050108-030

B-246	W/BIO	FW	BEAVERDAM CREEK AT S-30-97, 7 MI NE OF GRAY COURT
B-150	W	FW	WARRIOR CREEK AT US 221, 8 MI NNE OF LAURENS
B-742	BIO	FW	WARRIOR CREEK AT SC 49

03050108-040

B-735	W	FW	DUNCAN CREEK RESERVOIR 6B
B-231	S	FW	BEARDS FORK CREEK AT US 276 (I-385), 3.7 MI NNE OF CLINTON
B-072	P/BIO	FW	DUNCAN CREEK AT US 176, 1.5 MI SE OF WHITMIRE

03050108-050

B-071	BIO	FW	INDIAN CREEK AT US 176
B-054	P	FW	ENOREE RIVER AT S-36-45, 3.5 MI ABOVE CONFLUENCE WITH BROAD R.

03050107-010

B-317	P	FW	MUSH CREEK AT SC 253, BELOW TIGERVILLE
B-741	BIO	FW	SOUTH TYGER RIVER AT UNNUMBERED ROAD, S OF S-23-569
CL-100	W	FW	LAKE ROBINSON IN FOREBAY NEAR DAM
B-341	W	FW	LAKE CUNNINGHAM IN FOREBAY NEAR DAM

B-149	S	FW	South Tyger River at SC 14, 2.9 mi NNW of Greer
B-263	S	FW	South Tyger River at SC 290, 3.7 mi E of Greer
B-005A	BIO	FW	South Tyger River at S-42-242
B-005	S	FW	South Tyger River at S-42-63
B-332	W	FW	South Tyger River at S-42-86, 5 mi NE of Woodruff
03050107-020			
B-348	W	FW	Lake Cooley in forebay near dam
B-315	S	FW	Tributary to N.Tyger River at unnumbered road below Jackson #2 effluent
B-219	S	FW	North Tyger River at US 29, 7.2 mi W of Spartanburg
03050107-030			
B-017	BIO	FW	North Tyger River at SC 296
B-162	I	FW	North Tyger River at US 221, 7.6 mi NNE of Woodruff
B-018A	S	FW	North Tyger River at S-42-231, 11 mi S of Spartanburg
03050107-040			
B-148	P/BIO	FW	Middle Tyger River at SC 14, 2 mi SSW Gowansville
B-012	S	FW	Middle Tyger River at S-42-63
B-014	W/BIO	FW	Middle Tyger River at S-42-64
03050107-050			
B-008	P	FW	Tyger River at S-42-50, E of Woodruff
B-019	S	FW	Jimmies Creek at S-42-201, 2 mi E of Woodruff
B-733	BIO	FW	Dutchman Creek at S-42-511
B-051	P	FW	Tyger River at SC 72, 5.5 mi SW of Carlisle
03050107-060			
B-321	P	FW	Tributary to Fairforest Creek, 200 feet below S-42-65
B-020	S	FW	Fairforest Creek at US 221, S of Spartanburg
B-164	S	FW	Fairforest Creek at S-42-651, 3.5 mi SSE of Spartanburg
B-021	P/BIO	FW	Fairforest Creek at SC 56
B-235	S	FW	Kelsey Creek at S-42-321
CL-035	W	FW	Lake Johnson at spillway at S-42-359
CL-033	W	FW	Lake Craig 45 meters NW of dam
BF-007	S	FW	Fairforest Creek on county road 12, SW of Jonesville
B-199	S	FW	Mitchell Creek at county road 233, 2.3 mi SSW of Jonesville
B-067A	S	FW	Toschs Creek at US 176, 2 mi SW of Union
B-067B	S	FW	Toschs Creek at road to treatment plant off S-44-92, SW of Union
BF-008	S/BIO	FW	Fairforest Creek at S-44-16, SW of Union
B-286	S	FW	Tinker Creek at road to treatment plant, 1.3 mi SSE of Union
B-287	S	FW	Tinker Creek at unnumbered county road, 1.7 mi SSE of Union
B-336	W/BIO	FW	Tinker Creek at S-44-278, 9 mi SSE of Union

Water Quality Trends and Status by Station

Mean Seasonal Water Quality Values

BROAD BASIN WMU-0501

PARAMETER	STAT	SPRING (Mar-May)	SUMMER (Jun-Sep)	FALL (Oct-Nov)	WINTER (Dec-Feb)
TEMPERATURE (°C)	Mean	16.6	22.5	15.2	8.3
	Max	27.5	32.0	22.0	18.0
	Min	7.0	15.5	7.5	1.0
	Med	17.0	22.0	15.5	8.0
	95%	21.5	27.0	20.0	13.5
	N	338	832	267	202
DISSOLVED OXYGEN (mg/l)	Mean	8.6	7.6	8.8	10.5
	Max	10.8	11.0	11.2	14.1
	Min	4.0	1.5	4.7	4.8
	Med	8.6	7.6	8.8	10.4
	5%	6.8	5.9	7.3	8.7
	N	338	828	267	202
pH (SU)	Mean	6.7	6.8	6.8	6.7
	Max	9.1	9.6	8.1	8.9
	Min	5.1	5.0	5.8	5.1
	Med	6.7	6.7	6.8	6.7
	95%	7.4	7.4	7.4	7.4
	N	334	824	267	195
BOD_5 (mg/l)	Mean	1.7	1.2	1.3	1.5
	Max	29.0	7.4	7.8	11.0
	Min	0.1	0.1	0.1	0.0
	Med	1.2	1.0	1.0	1.1
	95%	4.2	2.8	3.3	4.0
	N	330	805	263	198
TURBIDITY (NTU)	Mean	26.5	22.5	30.4	31.9
	Max	310.0	400.0	600.0	320.0
	Min	1.0	0.5	0.7	1.0
	Med	17.0	14.0	10.0	18.0
	95%	76.0	66.0	150.0	100.0
	N	330	807	265	202
AMMONIA (mg/l)	Mean	0.19	0.17	0.26	0.18
	Max	0.83	1.13	1.30	0.85
	Min	0.05	0.05	0.05	0.05
	Med	0.13	0.08	0.10	0.11
	95%	0.49	0.74	1.30	0.44
	N	25	32	12	30

BROAD BASIN WMU-0501

PARAMETER	STAT	SPRING (Mar-May)	SUMMER (Jun-Sep)	FALL (Oct-Nov)	WINTER (Dec-Feb)
TKN (mg/l)	Mean	0.43	0.44	0.49	0.47
	Max	2.02	3.50	3.95	3.60
	Min	0.10	0.07	0.09	0.10
	Med	0.33	0.36	0.33	0.34
	95%	1.04	0.95	1.26	1.15
	N	171	248	127	190
NITRITE-NITRATE (mg/l)	Mean	0.79	0.91	0.88	0.78
	Max	10.00	9.40	9.80	6.10
	Min	0.02	0.02	0.02	0.07
	Med	0.55	0.55	0.49	0.57
	95%	2.70	3.20	3.00	3.00
	N	318	762	242	198
TOTAL PHOSPHORUS (mg/l)	Mean	0.16	0.18	0.26	0.13
	Max	4.80	1.72	6.80	0.92
	Min	0.02	0.02	0.02	0.02
	Med	0.07	0.08	0.10	0.08
	95%	0.55	0.75	0.90	0.46
	N	284	657	192	177
TOTAL ORGANIC CARBON (mg/l)	Mean	5.3	4.7	3.9	7.7
	Max	64.0	20.0	13.8	185.0
	Min	0.9	1.2	1.1	1.0
	Med	4.0	4.0	3.4	4.1
	95%	9.7	8.5	8.9	15.3
	N	71	83	62	73
FECAL COLIFORM BACTERIA (#/100ml)	Mean	309	550	326	184
	Max	160,000	4,000,000	100,000	8,000
	Min	2	1	2	2
	Med	290	460	310	220
	95%	4,000	8,700	3,500	2,000
	N	332	811	266	202

APPENDIX B. WMU-0502

Monitoring Station Descriptions

STATION TYPES (P=PRIMARY, S=SECONDARY, W=WATERSHED, BIO=BIOLOGICAL, I=INACTIVE)
CLASS (FW=FRESHWATER, ORW=OUTSTANDING RESOURCE WATERS)

03050105-090			
B-042	P	FW	BROAD RIVER AT SC 18, 4 MI NE GAFFNEY
B-088	S	FW	CANOE CREEK AT S-11-245, 1/2 MI W OF BLACKSBURG
B-211	S	FW	PEOPLES CREEK AT UNIMPROVED ROAD, 2.3 MI E OF GAFFNEY
B-100	S	FW	FURNACE CREEK AT S-11-50, 6 MI E OF GAFFNEY
B-323	S	FW	DOOLITTLE CREEK AT S-11-100, 1.25 MI SE OF BLACKSBURG
B-343	W	FW	LAKE CHEROKEE IN FOREBAY NEAR DAM
B-330	S	FW	GUYONMOORE CREEK AT S-46-233
B-044	P	FW	BROAD RIVER AT SC 211, 12 MI SE OF GAFFNEY
03050105-100			
B-740	BIO	FW	BUFFALO CREEK AT SC 198
B-119	S	FW	BUFFALO CREEK AT S-11-213, 2.2 MI NNW OF BLACKSBURG
B-057	S	FW	BUFFALO CREEK AT SC 5, 1 MI W OF BLACKSBURG
03050105-110			
B-056	S	FW	CHEROKEE CREEK AT US 29, 3 MI E OF GAFFNEY
03050105-120			
B-333	W/BIO	FW	KINGS CREEK AT S-11-209, 3 MI W OF SMYRNA
03050105-130			
B-342	W	FW	LAKE THICKETTY IN FOREBAY NEAR DAM
B-059	S	FW	IRENE CREEK AT S-11-307, 2.5 MI W OF GAFFNEY
B-095	S	FW	THICKETTY CREEK AT S-11-164
B-128	S	FW	LIMESTONE CREEK AT S-11-301
B-133	S/BIO	FW	THICKETTY CREEK AT SC 18, 8.3 MI S OF GAFFNEY
B-334	W/BIO	FW	GILKEY CREEK AT S-11-231, 9 MI SE OF GAFFNEY
B-062	S	FW	THICKETTY CREEK AT SC 211, 2 MI ABOVE JUNCTION WITH BROAD RIVER
03050105-140			
B-739	BIO	FW	BULLOCK CREEK AT S-46-40
B-325	S	FW	CLARK FORK INTO CRAWFORD LAKE ON UNNUMBERED ROAD NEAR SC 161 & 705
B-737	W	FW	LAKE YORK IN KINGS MOUNTAIN STATE PARK
B-326	S	FW	LONG BRANCH ON SC 216, BELOW KINGS MOUNTAIN PARK RECREATION AREA
B-157	BIO	FW	CLARK FORK AT S-46-63
B-159	S	FW	BULLOCK CREEK AT SC 97, 4.8 MI S OF HICKORY GROVE
03050105-150			
B-099-7	BIO	ORW	VAUGHN CREEK AT UNNUMBERED ROAD, 0.4 MI S OF S-23-319
B-099A	S	FW	LAKE LANIER ON # 1 INLET IN GREENVILLE COUNTY
B-099B	S	FW	LAKE LANIER AT DAM IN GREENVILLE COUNTY
B-719	BIO	FW	NORTH PACOLET RIVER AT S-42-128
B-301	S	FW	PAGE CREEK AT S-42-1258, 1.7 MI SE LANDRUM
B-026	P	FW	NORTH PACOLET RIVER AT S-42-956, 6.5 MI E LANDRUM
B-126	W	FW	NORTH PACOLET RIVER AT S-42-978, 1 MI SE OF FINGERVILLE

03050105-160

B-720	BIO	FW	SOUTH PACOLET RIVER AT S-42-183
B-103	S	FW	SPIVEY CREEK AT S-42-208, 2.5 MI SSE OF LANDRUM
B-302	S	FW	SOUTH PACOLET RIVER AT S-42-866, 1 MI SE CAMPOBELLO
B-340	W	FW	LAKE BOWEN NEAR HEADWATERS, 0.4 KM W OF S-42-37
B-339	W	FW	LAKE BOWEN IN FOREBAY NEAR DAM
B-113	S	FW	SPARTANBURG RESERVOIR #1 ON S-42-213 NE OF INMAN

03050105-170

B-028	S	FW	PACOLET RIVER AT S-42-55, BELOW CONFLUENCE OF NORTH & SOUTH PACOLET RIVERS
B-259	S	FW	LITTLE BUCK CREEK AT UNNUMBERED COUNTY ROAD, 2.3 MI SW OF CHESNEE
B-347	W	FW	LAKE BLALOCK IN FOREBAY NEAR DAM
B-163A	S	FW	PACOLET RIVER AT BRIDGE ON S-42-737, 2.9 MI NW OF COWPENS
B-191	S	FW	POTTER BRANCH ON ROAD 30, BELOW OUTFALL FROM HOUSING PROJECT, COWPENS
B-331	W	FW	PACOLET RIVER AT S-42-59, BEACON LIGHT ROAD IN CLIFTON

03050105-180

B-221	S/BIO	FW	LAWSONS FORK CREEK AT S-42-40, BELOW INMAN MILL EFFLUENT
B-277	S	FW	LAWSONS FORK CREEK AT S-42-218, 2.7 MI SSE OF INMAN
B-278	S	FW	LAWSONS FORK CREEK AT UNNUMBERED ROAD BELOW MILLIKEN CHEMICAL
BL-005	S	FW	LAWSONS FORK CREEK AT S-42-79 AT VALLEY FALLS
BL-001	P/BIO	FW	LAWSONS FORK CREEK AT S-42-108

03050105-190

BP-001	S	FW	PACOLET RIVER ABOVE DAM AT PACOLET MILLS
B-048	P	FW	PACOLET RIVER AT SC 105, 6 MI ABOVE CONFLUENCE WITH BROAD RIVER

03050106-010

B-344	W	FW	LAKE JOHN D. LONG IN FOREBAY NEAR DAM
B-046	P	FW	BROAD RIVER AT SC 72/215/121, 3 MI E OF CARLISLE

03050106-020

B-086	S	FW	ROSS BRANCH AT SC 49, SW OF YORK
B-136	W/BIO	FW	TURKEY CREEK AT SC 9, 14 MI NW OF CHESTER

03050106-030

B-064	S	FW	MENG CREEK AT SC 49, 2.5 MI E OF UNION
B-243	S	FW	TRIBUTARY TO MENG CREEK AT CULVERT ON S-44-384, 3 MI E OF UNION
B-155	W/BIO	FW	BROWNS CREEK AT S-44-86, 8 MI E OF UNION
B-335	W	FW	GREGORYS CREEK AT S-44-86, 8 MI E OF UNION

03050106-040

CL-023	W	FW	CHESTER STATE PARK LAKE, 100 M E OF SPILLWAY
B-074	S	FW	DRY FORK AT S-12-304, 2 MI SW OF CHESTER
B-075	S/BIO	FW	SANDY RIVER AT SC 215, 2.5 MI ABOVE CONFLUENCE WITH BROAD RIVER

03050106-050

B-143	BIO	FW	BEAVER CREEK AT S-20-99
B-047	S	FW	BROAD RIVER AT SC 34, 14 MI NE OF NEWBERRY
B-346	W	FW	PARR RESERVOIR 4.8 KM N OF DAM, UPSTREAM OF MONTICELLO RESERVOIR

B-751	BIO	FW	CANNONS CREEK AT US 176
B-328	P	FW	MONTICELLO RESERVOIR, UPPER IMPOUNDMENT AT BUOY IN MIDDLE OF LAKE
B-327	P	FW	MONTICELLO RESERVOIR, LOWER IMPOUNDMENT BETWEEN LARGE ISLANDS
B-345	W	FW	PARR RESERVOIR IN FOREBAY NEAR DAM

03050106-060

B-236	P	FW	BROAD RIVER AT SC 213, 2.5 MI SW OF JENKINSVILLE
B-110	S	FW	ELIZABETH LAKE AT SPILLWAY ON US 21
B-081	BIO	FW	CRANE CREEK AT US 321
B-316	P	FW	CRANE CREEK AT S-40-43 UNDER I-20, NORTH COLUMBIA
B-280	P/BIO	FW	SMITH BRANCH AT N MAIN ST (US 21) IN COLUMBIA
B-337	W	FW	BROAD RIVER AT US 176 (BROAD RIVER ROAD) IN COLUMBIA
B-080	P	FW	BROAD RIVER DIVERSION CANAL AT COLUMBIA WATER PLANT

03050106-070

B-145	S/BIO	FW	LITTLE RIVER AT S-20-60, 3.1 MI SW OF JENKINSVILLE

03050106-080

B-123	S	FW	WINNSBORO BRANCH AT US 321, ABOVE WINNSBORO MILLS OUTFALL
B-077	S	FW	WINNSBORO BRANCH BELOW PLANT OUTFALL
B-102	W/BIO	FW	JACKSON CREEK AT S-20-54, 5 MI W OF WINNSBORO
B-338	W	FW	MILL CREEK AT S-20-48, 10 MI SW OF WINNSBORO

03050106-090

B-320	W/BIO	FW	BIG CEDAR CREEK AT SC 215

Water Quality Trends and Status by Station

Mean Seasonal Water Quality Values

BROAD BASIN WMU-0502

PARAMETER	STAT	SPRING (Mar-May)	SUMMER (Jun-Sep)	FALL (Oct-Nov)	WINTER (Dec-Feb)
TEMPERATURE (°C)	Mean	17.2	23.0	15.4	8.6
	Max	29.5	33.0	24.0	18.0
	Min	7.5	6.9	7.0	1.0
	Med	18.0	23.0	15.0	9.0
	95%	23.0	29.0	21.0	13.0
	N	448	1077	350	260
DISSOLVED OXYGEN (mg/l)	Mean	8.7	7.5	8.7	10.5
	Max	12.0	17.0	11.6	14.6
	Min	2.3	1.4	1.7	2.8
	Med	8.6	7.5	8.8	10.5
	5%	6.8	6.0	6.8	8.3
	N	448	1079	350	258
pH (SU)	Mean	6.9	6.9	6.9	7.0
	Max	9.5	9.5	7.9	9.1
	Min	5.7	5.2	5.5	4.6
	Med	6.9	6.9	6.9	7.0
	95%	7.8	7.7	7.6	8.0
	N	445	1078	350	260
BOD_5 (mg/l)	Mean	1.6	1.5	1.5	1.4
	Max	8.9	11.0	15.0	7.9
	Min	0.3	0.1	0.1	0.1
	Med	1.3	1.1	1.1	1.1
	95%	3.7	4.0	4.0	3.5
	N	414	1021	335	244
TURBIDITY (NTU)	Mean	24.1	21.1	14.1	23.6
	Max	288.0	500.0	260.0	180.0
	Min	0.5	1.1	0.7	1.6
	Med	13.0	12.0	7.8	14.0
	95%	80.0	64.0	43.0	81.0
	N	430	1046	344	254
AMMONIA (mg/l)	Mean	0.13	0.33	0.37	0.17
	Max	0.52	6.70	2.64	1.20
	Min	0.05	0.05	0.05	0.05
	Med	0.10	0.07	0.18	0.08
	95%	0.35	1.12	2.64	0.50
	N	45	36	15	40

BROAD BASIN WMU-0502

PARAMETER	STAT	SPRING (Mar-May)	SUMMER (Jun-Sep)	FALL (Oct-Nov)	WINTER (Dec-Feb)
TKN (mg/l)	Mean	0.41	0.45	0.41	0.40
	Max	1.72	8.60	3.43	1.76
	Min	0.09	0.10	0.06	0.11
	Med	0.32	0.37	0.31	0.33
	95%	1.00	1.00	1.08	0.93
	N	241	372	177	244
NITRITE-NITRATE (mg/l)	Mean	0.66	0.85	0.76	0.49
	Max	13.30	14.00	10.80	2.90
	Min	0.02	0.02	0.02	0.02
	Med	0.38	0.41	0.33	0.37
	95%	1.85	3.30	2.50	1.56
	N	404	941	303	251
TOTAL PHOSPHORUS (mg/l)	Mean	0.14	0.20	0.18	0.08
	Max	3.30	3.00	1.65	0.84
	Min	0.02	0.02	0.02	0.02
	Med	0.07	0.07	0.08	0.06
	95%	0.47	0.94	0.81	0.19
	N	388	857	259	233
TOTAL ORGANIC CARBON (mg/l)	Mean	4.9	4.9	4.9	4.4
	Max	15.3	18.9	28.0	22.0
	Min	1.0	0.9	1.3	1.4
	Med	4.0	3.7	4.2	3.5
	95%	11.2	12.9	11.0	10.9
	N	118	170	70	112
FECAL COLIFORM BACTERIA (#/100ml)	Mean	224	357	219	119
	Max	90,000	200,000	420,000	170,000
	Min	1	1	1	1
	Med	280	420	250	170
	95%	5,100	6,600	4,000	2,500
	N	417	1032	340	246

Waterbody Index

Facility Index

Sec 2.3 Ref 25

Watershed Water Quality Assessment

Broad River Basin

Technical Report No. 001-01
June, 2001

Prepared By

South Carolina Department of Health and Environmental Control

Bureau of Water

2600 Bull Street

Columbia, S.C. 29201

(803) 898-4300

PREFACE

In 1993, the South Carolina Department of Health and Environmental Control (SCDHEC) published the first in a series of five watershed management documents. The fifth in that series, Watershed Water Quality Management Strategy: Broad Basin communicated SCDHEC's innovative watershed approach, summarizing water programs and water quality in the basins. The approach continues to evolve and improve.

The watershed documents facilitate broader participation in the water quality management process. Through these publications, SCDHEC shares water quality information with internal and external partners, providing a common foundation for water quality improvement efforts at the local watershed or large-scale, often interstate, river basin level.

Water quality data from the Broad River Basin was collected and assessed at the start of this second five-year watershed management cycle. The assessment incorporates data from many more sites than were included in the first round. This updated atlas provides summary information on a watershed basis, as well as geographical presentations of all permitted watershed activities. A waterbody index and a facility index allow the reader to locate information on specific waters and facilities of interest.

A brief summary of the water quality assessments included in the body of this document is provided following the Table of Contents. This summary lists all waters within the Broad River Basin that fully support recreational and aquatic life uses, followed by those waters not supporting uses. In addition, the summaries list changes in use support status; those that have improved or degraded over the last five years since the original strategy was written. More comprehensive information can be found in the individual watershed sections. The information provided is accurate to the best of our knowledge at the time of writing and will be updated in five years.

General information on Broad River Basin Watershed Protection and Restoration Strategies can be found under that section on page 23, and more detailed information is located within the individual watershed evaluations.

As SCDHEC continues basinwide and statewide water quality protection and improvement efforts, we are counting on the support and assistance of all stakeholders in the Broad River Basin to participate in bringing about water quality improvements. We look forward to working with you.

If you have questions or comments regarding this document, or if you are seeking further information on the water quality in the Broad River Basin, please contact:

Watershed Strategy Coordinator
SCDHEC Bureau of Water
2600 Bull St.
Columbia, SC 29201
(803) 898-4300
www.scdhec.net/water

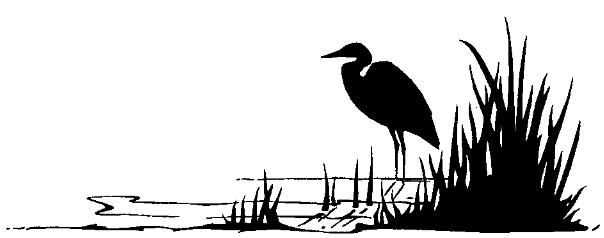


Table of Contents

Water Quality Assessment Summary

Broad River Basin

TERMS USED IN TABLES

AQUATIC LIFE USE SUPPORT (AL) - The degree to which aquatic life is protected is assessed by comparing important water quality characteristics and the concentrations of potentially toxic pollutants with standards. Aquatic life use support is based on the percentage of standards excursions at a sampling site.

For **dissolved oxygen** and **pH**:

> If the percentage of standard excursions is 10 percent or less, then uses are ***fully supported.***
>
> If the percentage of standard excursions is between 11-25 percent, then uses are ***partially supported.***
>
> If the percentage of standard excursions is greater than 25 percent, uses are ***not supported*** (see p.11 for further information).

For **toxins** (heavy metals, priority pollutants, chlorine, ammonia):

> If the acute aquatic life standard for any individual toxicant is not exceeded, uses are ***fully supported.***
>
> If the acute aquatic life standard is exceeded more than once, but is less than or equal to 10 percent of the samples, uses are ***partially supported.***
>
> If the acute aquatic life standard is exceeded in more than 10 percent of the samples, based on at least ten samples, aquatic life uses are ***not supported*** (see p.11 for further information).

RECREATIONAL USE SUPPORT (REC) - The degree to which the swimmable goal of the Clean Water Act is attained (recreational use support) is based on the frequency of fecal coliform bacteria excursions, defined as greater than 400/100 ml for all surface water classes.

> If 10 percent or less of the samples are greater than 400/100 ml, then recreational uses are said to be ***fully supported.***
>
> If the percentage of standards excursions is between 11-25%, then recreational uses are said to be ***partially supported.***
>
> If the percentage of standards excursions is greater than 25%, then recreational uses are said to be ***nonsupported*** (see p.12 for further information).

Excursion - The term excursion is used to describe a measurement that does not comply with the appropriate water quality standard.

Table 1. Fully Supported Sites in the Broad River Basin

* = Station not evaluated for Recreational Support

Watershed	Waterbody Name	Station #	Improving Trends	Other Trends
03050108-010	Durbin Creek	BE-022*		
03050108-020	Cedar Shoals Creek	B-785*		
03050108-030	Warrior Creek	B-742*		
03050108-050	Indian Creek	B-071*		
	Kings Creek	B-799*		
03050107-010	Lake Cunningham	B-341		
	Maple Creek	B-625*		
	Bens Creek	B-782*		
	Ferguson Creek	B-787*		
	South Tyger River	B-741*		
		B-149	Decreasing BOD_5, Turbidity	Decreasing Dissolved Oxygen, pH
03050107-030	North Tyger River	B-017*		
03050107-040	Middle Tyger River	B-794*		
03050107-050	Jimmies Creek	B-786*		
	Dutchman Creek	B-733*		
	Cane Creek	B-777*		
03050107-060	Mitchell Creek	B-781*		
	Sugar Creek	B-779*		
03050105-050	Suck Creek	B-296*		

Table 1. Fully Supported Sites in the Broad River Basin

* = Station not evaluated for Recreational Support

Watershed	Waterbody Name	Station #	Improving Trends	Other Trends
03050105-090	Ross Creek	B-789*		
	Bowen River	B-788*		
	Lake Cherokee	B-343		
03050105-100	Buffalo Creek	B-740*		
03050105-130	Lake Thicketty	B-342		
03050105-140	Lake York	B-737		
	Long Branch	B-326		Increasing Total Phosphorus
	Clark Fork	B-325		Decreasing pH
		B-157*		
	Bullock Creek	B-739*		
03050105-150	Vaughn Creek	B-099-7*		
	Lake Lanier	B-099B	Decreasing BOD_5	Decreasing pH
	North Pacolet River	B-719*		
	Obed Creek	B-791*		
03050105-160	Spivey Creek	B-104*		
	South Pacolet River	B-720*		
	Lake Bowen	B-340		
		B-339		
	Spartanburg Reservoir #1	B-113	Decreasing BOD_5	Increasing Fecal Coliform

Table 1. Fully Supported Sites in the Broad River Basin

* = Station not evaluated for Recreational Support

Watershed	Waterbody Name	Station #	Improving Trends	Other Trends
03050105-170	Buck Creek	B-783*		
	Lake Blalock	B-347		
	Pacolet River	B-163A	Decreasing BOD_5	Increasing Total Phosphorus; Decreasing pH
03050105-180	Meadow Creek	B-531*		
03050106-010	Neal Creek	B-778*		
03050106-040	Chester State Park Lake	CL-023		
03050106-050	Cannons Creek	B-751*		
	Lake Monticello	B-328	Decreasing BOD_5, Total Nitrogen, Turbidity	Decreasing Dissolved Oxygen, pH
		B-327	Decreasing Total Nitrogen	
	Parr Reservoir	B-346		
		B-345		
03050106-060	Broad River	B-236	Decreasing Total Nitrogen	Increasing Turbidity

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
03050108-010	Beaverdam Creek	BE-039	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Decreasing pH
		B-796*	AL	PS	Macroinvertebrates		
	Buckhorn Creek	B-795*	AL	PS	Macroinvertebrates		
	Mountain Creek	B-186	REC	NS	Fecal Coliform	Increasing Fecal Coliform	
		BE-008*	AL	PS	Macroinvertebrates		
	Princess Creek	B-192	AL	NS	Zinc		Increasing pH
			REC	NS	Fecal Coliform	Increasing Fecal Coliform	
	Brushy Creek	BE-035	AL	PS	Macroinvertebrates		
			REC	NS[T]	Fecal Coliform		
		BE-009	AL	PS	Macroinvertebrates		
			REC	NS[T]	Fecal Coliform	Increasing Fecal Coliform	
	Rocky Creek	BE-007	AL	PS	Macroinvertebrates		
			REC	NS	Fecal Coliform		
	Abner Creek	B-792*	AL	PS	Macroinvertebrates		
	Horsepen Creek	B-793*	AL	PS	Macroinvertebrates		
	Gilder Creek	BE-040	REC	NS	Fecal Coliform	Increasing Fecal Coliform	
		B-241	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Increasing pH
		BE-020	AL	PS	Macroinvertebrates		Increasing pH
			REC	NS	Fecal Coliform	Increasing Fecal Coliform	

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
03050108-010	Lick Creek	B-038	REC	NS	Fecal Coliform		
	Durbin Creek	B-035	REC	NS	Fecal Coliform		
		B-097	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Decreasing pH
	Enoree River	BE-001	AL	NS	Zinc		Decreasing pH
			REC	NS	Fecal Coliform	Increasing Fecal Coliform	
		B-797*	AL	PS	Macroinvertebrates		
		BE-015	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Increasing pH
		BE-017	AL	NS	Copper		Increasing pH
			REC	NS	Fecal Coliform		
		BE-018	AL	PS	Macroinvertebrates		
			REC	NS	Fecal Coliform		
		BE-019*	AL	PS	Macroinvertebrates		
		BE-037	REC	NS	Fecal Coliform		Decreasing pH
		BE-040	REC	PS	Fecal Coliform		
03050108-020	Enoree River	BE-041	AL	NS	Zinc		Decreasing pH
			REC	PS	Fecal Coliform		
		B-053	REC	NS	Fecal Coliform		
03050108-030	Beaverdam Creek	B-053	REC	NS	Fecal Coliform		
	Warrior Creek	B-150	REC	NS	Fecal Coliform		

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
03050108-040	Beards Fork Creek	B-231	AL	NS	Dissolved Oxygen		Decreasing pH
	Duncan Creek Reservoir	B-735	AL	PS	pH		
	Duncan Creek	B-072	REC	NS	Fecal Coliform		
03050108-050	Enoree River	B-054	AL	NS	Chromium		Decreasing Dissolved Oxygen; Increasing BOD_5, Turbidity
			REC	NS	Fecal Coliform		
03050107-010	Mush Creek	B-317	REC	NS	Fecal Coliform		
	Lake Robinson	CL-100	AL	PS	pH		
	South Tyger River	B-263	REC	PS	Fecal Coliform		Decreasing pH; Increasing Total Phosphorus, Turbidity
		B-005A*	AL	PS	Macroinvertebrates		
		B-005	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Decreasing pH; Increasing Total Phosphorus, Turbidity
		B-332	REC	PS	Fecal Coliform		
03050107-020	Lake Cooley	B-348	AL	PS	pH		
	North Tyger River Tributary	B-315	REC	NS	Fecal Coliform		Decreasing pH
	North Tyger River	B-219	AL	NS	Zinc		Decreasing Dissolved Oxygen pH; Increasing Turbidity
			REC	NS	Fecal Coliform		
03050107-030	North Tyger River	B-018A	REC	NS	Fecal Coliform		Decreasing Dissolved Oxygen; Increasing Total Phosphorus
03050107-040	Beaverdam Creek	B-784*	AL	PS	Macroinvertebrates		
03050107-040	Middle Tyger River	B-148	REC	NS[T]	Fecal Coliform	Increasing Fecal Coliform	Increasing Turbidity

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
		B-012	REC	NS	Fecal Coliform		Decreasing pH
		B-014	REC	NS	Fecal Coliform		
03050107-050	Tyger River	B-008	REC	NS	Fecal Coliform		Decreasing Dissolved Oxygen, pH; Increasing Turbidity
		B-051	REC	NS	Fecal Coliform		Decreasing pH; Increasing Total Phosphorus
	Jimmies Creek	B-072	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Decreasing pH; Increasing Total Phosphorus
03050107-060	Fairforest Creek	B-020	REC	NS	Fecal Coliform	Increasing Fecal Coliform	
		B-164	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Increasing Total Phosphorus
		B-021	AL	NS	Macroinvertebrates, Chromium, Zinc Copper		B-219
			REC	NS	Fecal Coliform	Increasing Fecal Coliform	
		BF-007	REC	NS	Fecal Coliform		
		BF-008	REC	NS	Fecal Coliform		Decreasing pH; Increasing Total Phosphorus
	Fairforest Creek Tributary	B-321	AL	NS	Chromium, Copper, Zinc		Decreasing pH
			REC	NS	Fecal Coliform	Increasing Fecal Coliform	
	Kelsey Creek	B-235	REC	NS	Fecal Coliform		Decreasing Dissolved Oxygen; pH
	Lake Johnson	CL-035	AL	NS	pH		
03050107-060	Lake Craig	CL-033	AL	PS	pH		
	Mitchell Creek	B-199	REC	NS	Fecal Coliform	Increasing Fecal Coliform	

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
	Toschs Creek	B-067A	REC	NS	Fecal Coliform		Decreasing pH
		B-067B	REC	NS	Fecal Coliform		Decreasing pH
	Tinkers Creek	B-286	REC	NS	Fecal Coliform		Decreasing pH; Increasing Total Phosphorus
		B-287	REC	NS	Fecal Coliform		
		B-336	REC	NS	Fecal Coliform		
03050105-090	Canoe Creek	B-088	AL	PS	Dissolved Oxygen		Decreasing pH
			REC	NS	Fecal Coliform		
	Peoples Creek	B-211	REC	NS	Fecal Coliform		Decreasing pH
	Furnace Creek	B-100	REC	NS	Fecal Coliform		
	Doolittle Creek	B-323	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Decreasing pH, Dissolved Oxygen
	Guyonmoore Creek	B-330	REC	PS	Fecal Coliform		
	Broad River	B-042	REC	PS	Fecal Coliform		Increasing Turbidity
	Broad River	B-044	REC	PS	Fecal Coliform		Increasing Turbidity
03050105-100	Buffalo Creek	B-119	REC	NS	Fecal Coliform	Increasing Fecal Coliform	
		B-057	AL	PS	Copper	Increasing Fecal Coliform	
			REC	NS	Fecal Coliform		
03050105-110	Cherokee Creek	B-056	REC	NS	Fecal Coliform		Decreasing pH
03050105-110	Cherokee Creek	B-679*	AL	PS	Macroinvertebrates		
03050105-120	Kings Creek	B-333	REC	PS	Fecal Coliform		

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
03050105-130	Irene Creek	B-059	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Decreasing pH
	Limestone Creek	B-128	REC	NS	Fecal Coliform		Decreasing pH
	Gilkey Creek	B-334	REC	NS	Fecal Coliform		
	Thicketty Creek	B-095	REC	NS	Fecal Coliform		Decreasing pH
		B-133	REC	NS	Fecal Coliform		Decreasing pH
		B-062	REC	NS	Fecal Coliform	Increasing Fecal Coliform	
03050105-140	Bullock Creek	B-159	REC	NS	Fecal Coliform	Increasing Fecal Coliform	
03050105-150	Lake Lanier	B-099A	REC	PS	Fecal Coliform		Decreasing Dissolved Oxygen; Increasing Turbidity
	Page Creek	B-301	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Decreasing pH
	North Pacolet River	B-026	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Decreasing Dissolved Oxygen, pH
		B-126	REC	NS	Fecal Coliform		
03050105-160	Spivey Creek	B-103	REC	PS	Fecal Coliform		Decreasing pH
	Motlow Creek	B-790*	AL	PS	Macroinvertebrates		
	South Pacolet River	B-302	REC	NS	Fecal Coliform		Decreasing pH
03050105-170	Little Buck Creek	B-259	REC	NS	Fecal Coliform		
	Potter Branch	B-191	REC	NS	Fecal Coliform		Decreasing pH
	Pacolet River	B-028	REC	NS	Fecal Coliform		
03050105-170	Pacolet River	B-331	REC	PS	Fecal Coliform		
03050105-180	Lawsons Fork Creek	B-221	AL	PS	Macroinvertebrates	Increasing Fecal Coliform	Increasing Total Phosphorus;

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
			REC	NS	Fecal Coliform		Decreasing pH
		B-277	REC	NS	Fecal Coliform		Increasing Total Phosphorus; Decreasing pH
		B-278	REC	NS	Fecal Coliform	Increasing Fecal Coliform	Increasing Total Phosphorus; Decreasing pH
		BL-005	REC	NS	Fecal Coliform		Increasing Total Phosphorus; Decreasing pH
		BL-001	AL	PS	Macroinvertebrates	Increasing Fecal Coliform	Increasing Total Nitrogen; Decreasing pH
			REC	NS	Fecal Coliform		
03050105-190	Mill Creek	B-780*	AL	PS	Macroinvertebrates		
	Pacolet River	BP-001	REC	NS	Fecal Coliform		Decreasing pH
		B-048	REC	NS	Fecal Coliform		
03050106-010	John D. Long Lake	B-344	AL	NS	pH		
	Broad River	B-046	REC	PS	Fecal Coliform		Decreasing pH
03050106-020	Ross Branch	B-086	REC	NS	Fecal Coliform		
	Turkey Creek	B-136	REC	PS	Fecal Coliform		
03050106-030	Meng Creek Tributary	B-243	REC	NS	Fecal Coliform		
	Meng Creek	B-064	REC	NS	Fecal Coliform		Decreasing pH
	Browns Creek	B-155	REC	PS	Fecal Coliform		
03050106-030	Gregorys Creek	B-335	REC	NS	Fecal Coliform		
03050106-040	Dry Fork	B-074	REC	NS	Fecal Coliform		Decreasing pH

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
	Sandy River	B-075	REC	NS	Fecal Coliform		Decreasing pH
03050106-050	Broad River	B-047	REC	PS	Fecal Coliform		
	Gregorys Creek	B-074	REC	PS	Fecal Coliform		Increasing Turbidity
	Heller Creek	B-151*	AL	PS	Macroinvertebrates		
03050106-060	Crims Creek	B-800*	AL	PS	Macroinvertebrates		
	Wateree Creek	B-801*	AL	PS	Macroinvertebrates		
	Elizabeth Lake	B-110*	REC	PS	Fecal Coliform	Increasing Fecal Coliform	Decreasing pH
	Cranes Creek	B-081*	AL	PS	Macroinvertebrates		
		B-316	AL	NS	Zinc		
			REC	PS	Fecal Coliform		
	Smith Branch	B-280	AL	NS	Macroinvertebrates, Zinc		Increasing Total Phosphorus
			REC	NS	Fecal Coliform		
	Broad River	B-337	REC	PS	Fecal Coliform		
		B-080	AL	NS	Copper		
			REC	PS	Fecal Coliform		
03050106-070	Little River	B-145	REC	NS	Fecal Coliform		
03050106-080	Winnsboro Branch	B-123	REC	NS	Fecal Coliform		
03050106-080	Winnsboro Branch	B-077	AL	NS	Copper, Zinc		Increasing Total Phosphorus
			REC	NS	Fecal Coliform		

Table 2. Impaired Sites in the Broad River Basin

REC=Recreational; AL=Aquatic Life; PS=Partially Supported Standards; NS=Nonsupported Standards; *=Station not evaluated for Recreational Support; T=TMDL Developed

Watershed	Waterbody Name	Station #	Use	Status	Water Quality Indicator	Undesirable Trends	Other Trends
	Jackson Creek	B-102	AL	PS	Macroinvertebrates		
			REC	PS	Fecal Coliform		
	Mill Creek	B-338	REC	NS	Fecal Coliform		
03050106-090	Big Cedar Creek	B-320	REC	PS^T	Fecal Coliform		

Table 3. Changes in Use Support Status

Broad River Basin Sites that Improved from 1995 to 1999

REC= Recreational; AL=Aquatic Life; FS=Fully Supported Standards; PS=Partially Supported Standards; NS=Nonsupported Standards

Watershed	Waterbody Name	Station #	Use	Status		Water Quality Indicator	
				1995	1999	1995	1999
03050108-020	Enoree River	B-041	REC	NS	PS	Fecal Coliform	Fecal Coliform
03050108-040	Beards Fork Creek	B-231	REC	PS	FS	Fecal Coliform	
03050107-010	South Tyger River	B-263	REC	NS	PS	Fecal Coliform	Fecal Coliform
03050107-050	Tyger River	B-051	AL	NS	FS	Zinc	
03050107-060	Fairforest Creek	BF-007	AL	PS	FS	Dissolved Oxygen	
03050105-090	Broad River	B-044	AL	NS	FS	Cadmium, Lead, Chromium, Zinc, Copper	
03050105-140	Long Branch	B-326	REC	PS	FS	Fecal Coliform	
	Clark Fork	B-325	REC	PS	FS	Fecal Coliform	
03050105-170	Pacolet River	B-163A	REC	PS	FS	Fecal Coliform	
		B-331	REC	NS	PS	Fecal Coliform	Fecal Coliform
03050106-060	Crane Creek	B-316	REC	NS	PS	Fecal Coliform	Fecal Coliform
	Broad River	B-236	REC	PS	FS	Fecal Coliform	
03050106-080	Jackson Creek	B-102	REC	NS	PS	Fecal Coliform	Fecal Coliform

Table 4. Changes in Use Support Status

Broad River Basin Sites that Degraded from 1995 to 1999

REC= Recreational; AL=Aquatic Life; FS=Fully Supported Standards; PS=Partially Supported Standards; NS=Nonsupported Standards

Watershed	Waterbody Name	Station #	Use	Status		Water Quality Indicator	
				1995	1999	1995	1999
03050108-010	Princess Creek	B-192	REC	PS	NS	Fecal Coliform	Fecal Coliform
	Brushy Creek	BE-009	AL	FS	PS		Macroinvertebrates
	Rocky Creek	BE-007	AL	FS	PS		Macroinvertebrates
	Gilder Creek	BE-020	AL	FS	PS		Macroinvertebrates
	Enoree River	BE-001	REC	PS	NS	Fecal Coliform	Fecal Coliform
		BE-017	AL	PS	NS	Copper	Copper
		B-037	REC	PS	NS	Fecal Coliform	Fecal Coliform
03050108-020	Enoree River	B-041	AL	FS	NS		Zinc
03050108-040	Beards Fork Creek	B-231	AL	PS	NS	Dissolved Oxygen	Dissolved Oxygen
	Duncan Creek Reservoir 6B	B-735	AL	FS	PS		pH
03050108-050	Enoree River	B-054	AL	FS	NS		Chromium
03050107-010	Mush Creek	B-317	REC	PS	NS	Fecal Coliform	Fecal Coliform
	South Tyger River	B-005	REC	PS	NS	Fecal Coliform	Fecal Coliform
		B-332	REC	FS	PS		Fecal Coliform
03050107-020	Lake Cooley	B-348	AL	FS	PS		pH
	North Tyger River	B-219	AL	PS	NS	Zinc	Zinc
03050107-060	Lake Johnson	CL-035	AL	FS	NS		pH
	Lake Craig	CL-033	AL	FS	NS		pH
	Fairforest Creek	BF-007	REC	PS	NS	Fecal Coliform	Fecal Coliform
		BF-008	REC	PS	NS	Fecal Coliform	Fecal Coliform
03050105-090	Broad River	B-044	REC	PS	NS	Fecal Coliform	Fecal Coliform
03050106-010	Lake John D. Long	B-344	AL	FS	NS		pH
03050106-020	Turkey Creek	B-136	REC	FS	PS		Fecal Coliform
03050106-030	Gregorys Creek	B-335	REC	FS	PS		Fecal Coliform
03050106-060	Elizabeth Lake	B-110	AL	FS	PS		pH
	Broad River	B-337	REC	FS	PS		Fecal Coliform
03050106-080	Winnsboro Branch	B-077	AL	FS	NS		Copper, Zinc

Introduction

The South Carolina Department of Health and Environmental Control (SCDHEC or the Department) initiated its first watershed planning activities as a result of a U.S. Environmental Protection Agency (USEPA) grant in June of 1972. These activities were soon extended by requirements for a Continuing Planning Process under • 303(e), "Federal Water Pollution Control Act Amendments of 1972", U.S. Public Law 92-500. In 1975, the SCDHEC published basin-planning reports for the four major basins in South Carolina. Watershed assessments are updated every five years for all river basins in the state. A related planning activity resulted from • 208 of the Federal Water Pollution Control Act, which required states to prepare planning documents on an areawide basis. Areawide plans were completed in the late 1970's for the five designated areas of the State and for the nondesignated remainder of the State. To date, these plans or their updated versions have served as information sources and guides for water quality management. The Continuing Planning Process, watershed assessments, and 208 plans are elements of South Carolina's overall water quality management plan.

The Bureau of Water emphasizes watershed planning to better coordinate river basin planning and water quality management. Watershed-based management allows the Department to address Congressional and Legislative mandates in a coordinated manner and to better utilize current resources. The watershed approach also improves communication between the Department, the regulated community, and the public on existing and future water quality issues.

Purpose of the Watershed Water Quality Assessment

A watershed is a geographic area into which the surrounding waters, sediments, and dissolved materials drain, and whose boundaries extend along surrounding topographic ridges. Watershed-based water quality management recognizes the interdependence of water quality related activities associated with a drainage basin including: monitoring, problem identification and prioritization, water quality modeling, planning, permitting, and other activities. The Bureau of Water's Watershed Water Quality Management Program integrates these activities by watershed, resulting in watershed management plans that appropriately focus water quality protection efforts. While an important aspect of the program is water quality problem identification and solution, the emphasis is on problem prevention.

The Department has divided the State into five regions (areas consisting of one or more river basins), along hydrologic lines, which contain approximately the same number of NPDES permitted dischargers. A Watershed Water Quality Assessment (WWQA) will be created for each river basin within the five regions and will be updated on a five-year rotational basis. This will allow for effective allocation and coordination of water quality activities and efficient use of available resources. The Broad River Basin is subdivided into 32 watersheds or hydrologic units within the State of South Carolina. Within the Department's Broad Basin are the Enoree River Basin, the Tyger River Basin, and the Broad River Basin. The hydrologic units used are the USDA Natural Resource Conservation Service 11-digit codes for South Carolina. All water quality related evaluations will be made at the watershed level. The stream names used are derived from USGS topographic maps. USEPA Reach data (RF3) were used for the digital hydrography and stream length estimates. Based on the blue line streams of the USGS topo maps, it is likely that portions of the stream network in terms of perennial, intermittent, and ephemeral streams are not represented.

The watershed-based assessments fulfill a number of USEPA reporting requirements including various activities under •303(d), •305(b), •314, and •319 of the Clean Water Act (CWA). Section 303(d) requires a listing of waters located within a watershed that do not meet applicable water quality standards. Section 305(b) requires that the State biennially submit a report that includes a water quality description and analysis of all navigable waters to estimate environmental impacts. Section 314 requires that the State submit a biennial report that identifies, classifies, describes, and assesses the status and trends in water quality of publicly owned lakes. The watershed plan is also a logical evaluation, prioritization, and implementation tool for nonpoint source (•319) requirements. Nonpoint source best management practices (BMPs) can be selected by identifying water quality impairments and necessary controls, while considering all the activities occurring in the drainage basin.

The assessment also allows for more efficient issuance of National Pollutant Discharge Elimination System (NPDES) and State wastewater discharge permits. Proposed permit issuances within a watershed may be consolidated and presented to the public in groups, rather than one at a time, allowing the Department to realize a resource savings, and the public to realize an information advantage.

The Watershed Water Quality Assessment (WWQA) is a geographically-based document that describes, at the watershed level, all water quality related activities that may potentially have a negative impact on water quality. The Watershed Implementation Staff investigates the impaired streams mentioned in the WWQA to determine, where possible, the source of the impairment and recommends solutions to correct the problems. As part of this effort, the watershed staff is forging partnerships with various federal and state agencies, local governments, and community groups. In particular, the Department's Watershed Program and the Natural Resource Conservation Service (NRCS) district offices are working together to address some of the nonpoint source (NPS) concerns in the basin. By combining NRCS's local knowledge of land use and the Department's knowledge of water quality, we are able to build upon NRCS's close relationships with landowners and determine where NPS projects are needed. These projects may include educational campaigns or special water quality studies.

Factors Assessed in Watershed Evaluations

Water Quality

The Water Program comprises activities within SCDHEC's Bureau of Water and Bureau of Environmental Services. The Program's objectives are to ensure that the water in South Carolina is safe for drinking and recreation, and that it is suitable to support and maintain aquatic flora and fauna. Functions include planning, permitting, compliance assurance, enforcement, and monitoring. This section provides an overview of water quality evaluation and protection activities.

Monitoring

In an effort to evaluate the State's water quality, the Department operates and collects data from a permanent statewide network of primary and secondary ambient monitoring stations and flexible, rotating watershed monitoring stations. The ambient monitoring network is directed toward determining long-term water quality trends, assessing attainment of water quality standards, identifying locations in need of additional attention, and providing background data for planning and evaluating stream classifications and standards.

Ambient monitoring data are also used in the process of formulating permit limits for wastewater discharges with the goal of maintaining State and Federal water quality standards and criteria in the receiving streams in accordance with the goals of the Clean Water Act. These standards and criteria define the instream chemical concentrations that provide for protection and reproduction of aquatic flora and fauna, help determine support of the classified uses of each waterbody, and serve as instream limits for the regulation of wastewater discharges or other activities. In addition, these data are used in the preparation of the biennial •305(b) report to Congress, which summarizes the State's water quality with respect to attainment of classified uses by comparing the ambient monitoring network data to the State Water Quality Standards.

SCDHEC•s ambient water quality monitoring network comprises four station types: primary (P), secondary (S), watershed (W), and biological (BIO) stations. These station types are listed in the site descriptions preceding the water quality information in each watershed and in the Appendices under Ambient Water Quality Monitoring Site Descriptions. Not all parameters are collected at every site. Primary stations are sampled on a monthly basis year round, and are located in high water-use areas or upstream of high water-use areas. The static primary station network is operated statewide, and receives the most extensive parameter coverage, thus making it best suited for detecting long-term trends.

Secondary stations are sampled monthly from May through October, a period critical to aquatic life, and is characterized by higher water temperatures and lower flows. Secondary stations are located in areas where specific monitoring is warranted due to point source discharges, or in areas with a history of water quality problems. Secondary station parameter coverage is less extensive and more flexible than primary or watershed station coverages. The number and locations of secondary stations have greater annual variability than do those in the primary station network, and during a basin's target year may have parameter coverage and sampling frequency duplicating that of primary or watershed stations.

Watershed stations are sampled on a monthly basis, year round, during a basin's target year. Additional watershed stations may be sampled monthly from May through October to augment the secondary station network. Watershed stations are located to provide more complete and representative coverage within the larger drainage basin, and to identify additional monitoring needs. Watershed stations have the same parameter coverage as primary stations.

Ambient trend monitoring, utilizing biological stations, is conducted to collect data to indicate general biological conditions of State waters that may be subject to a variety of point and nonpoint source impacts. In 1991, the Department began incorporating ambient macroinvertebrate data into the development of Watershed Water Quality Assessments. Ambient sampling is also used to establish regional reference or "least impacted" sites from which to make comparisons in future monitoring. Additionally, special macroinvertebrate studies, in which stream specific comparisons among stations located upstream and downstream from a known discharge or nonpoint source area, are used to assess impact.

Qualitative sampling of macroinvertebrate communities is the primary bioassessment technique used in ambient trend monitoring. A habitat assessment of general stream habitat availability and a substrate characterization is conducted at each site. Annual ambient monitoring is conducted during low flow "worst case" conditions in July - September. Some coastal plain streams that have no flow conditions in the summer months may be sampled in the winter (January-March). This technique may also be used in special studies for the purpose of determining if, and to what extent, a wastewater discharge or nonpoint source runoff is impacting the receiving stream. A minimum of two sample locations, one upstream and one downstream from a discharge or runoff area, is collected. At least one downstream recovery station is also established when appropriate. Sampling methodology follows procedures described in Standard Operating Procedures, Biological Monitoring. Only sites described as 'BIO' will collect information on the macroinvertebrate communities used in the ambient trend monitoring.

Many pollutants may be components of point source discharges, but may be discharged in a discontinuous manner, or at such low concentrations that water column sampling for them is impractical. Some pollutants are also common in nonpoint source runoff, reaching waterways only after a heavy rainfall; therefore, in these situations, the best media for the detection of these chemicals are sediment and fish tissue where they may accumulate over time. Their impact may also affect the macroinvertebrate community.

Aquatic sediments represent a historical record of chronic conditions existing in the water column. Pollutants bind to particulate organic matter in the water column and settle to the bottom where they become part of the sediment "record". Accumulated sediments not only reflect the impact of point source discharges, but also incorporate nonpoint source pollution washed into the stream during rain events. As a result, contaminant concentrations originating from irregular and highly variable sources are recorded in the sediment. The sediment concentrations at a particular location do not vary as rapidly with time as do the water column concentrations. Thus, the sediment record may be read at a later time, unrelated to the actual release time. Lakes act as settling basins for materials entering the lake system directly from a discharge or indirectly from the land surface washed into streams. Therefore, it is not unusual for lake sediment concentrations to be higher than sediment concentrations found in streams. This is especially true for chromium, copper, and zinc.

The ambient monitoring program has the capability of sampling a wide range of media and analyzing them for the presence or effects of contaminants. Ambient monitoring data from 25 primary (P) stations, 73 secondary (S) stations, 34 watershed (W) stations, and 68 biological (BIO) stations were reviewed for the Broad River Basin.

Classified Waters, Standards, and Natural Conditions

The waters of the State have been classified in regulation based on the desired uses of each waterbody. State standards for various parameters have been established to protect all uses within each classification. For a more detailed explanation of water classifications and standards, see South Carolina Regulation 61-68. The water-use classifications that apply to this basin are as follows.

Class ORW, or "outstanding resource waters", are freshwaters or saltwaters that constitute an outstanding recreational or ecological resource, or those freshwaters suitable as a source for drinking water supply purposes, with treatment levels specified by the Department.

Class A were freshwaters that were suitable for primary contact recreation. This class was also suitable for uses listed as Class B. As of April 1992, Class A and Class B waters were reclassified as Class FW, which protects for primary contact recreation.

Class B were freshwaters that were suitable for secondary contact recreation and as a source for drinking water supply, after conventional treatment, in accordance with the requirements of the Department. These waters were suitable for fishing, and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. This class was also suitable for industrial and agricultural uses. The main difference between the Class A and B freshwater was the fecal coliform standard. Class A waters were not to exceed a geometric mean of 200/100ml, based on 5 consecutive samples during any 30 day period; nor were more than 10% of the total samples during any 30 day period to exceed 400/100ml. Class B waters were not to exceed a geometric mean of 1000/100ml, based on 5 consecutive samples during any 30 day period; nor were more than 20% of the total samples during any 30 day period to exceed 2000/100ml. As of April 1992, Class A and Class B waters were reclassified as Class FW, which protects for primary contact recreation.

Class FW, or "freshwaters", are freshwaters that are suitable for primary and secondary contact recreation and as a source for drinking water supply, after conventional treatment, in accordance with the requirements of the Department. These waters are suitable for fishing, and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. This class is also suitable for industrial and agricultural uses.

Site specific numeric standards (*) for surface waters may be established by the Department to replace the numeric standards found in Regulation 61-68 or to add new standards not contained in R.61-68. Establishment of such standards shall be subject to public participation and administrative procedures for adopting regulations. In addition, such site specific numeric standards shall not apply to tributary or downstream waters unless specifically described in the water classification listing in R.61-69.

The standards are used as instream water quality goals to maintain and improve water quality and also serve as the foundation of the Bureau of Water's program. They are used to determine permit limits for treated wastewater dischargers and any other activities that may impact water quality. Using mathematical Wasteload Allocation Models, the impact of a wastewater discharge on a receiving stream is predicted. For free flowing streams, 7Q10 is defined as the critical low flow. For highly regulated streams and tidal streams, other more appropriate critical flows may be determined. These predictions are then used to set limits for different pollutants on the National Pollutant Discharge Elimination System (NPDES) permits issued by the Department. The NPDES permit limits are set so that, as long as a permittee (wastewater discharger) meets the established permit limits, the discharge should not cause a standards violation in the receiving stream. All discharges to the waters of the State are required to have an NPDES permit and must abide by those limits, under penalty of law.

Classifications are based on desired uses, not on natural or existing water quality, and are a legal means to obtain the necessary treatment of discharged wastewater to protect designated uses. Actual water quality may not have a bearing on a waterbody's classification. A waterbody may be reclassified if desired or existing public uses justify the reclassification and the water quality necessary to protect these uses is attainable. A classification change is an amendment to a State regulation and requires public participation, SCDHEC Board approval, and General Assembly approval.

Natural conditions may prevent a waterbody from meeting the water quality goals as set forth in the standards. The fact that a waterbody does not meet the specified numeric standards for a particular classification does not mean the waterbody is polluted or of poor quality. Certain types of waterbodies (ie. swamps, lakes, tidal creeks) may naturally have water quality lower than the numeric standards. A waterbody can have water quality conditions below standards due to natural causes and still meet its use classification. A site specific numeric standard may be established by the Department after being subjected to public participation and administrative procedures for adopting regulations. Site specific numeric standards apply only to the stream segment described in the water classification listing, not to tributaries or downstream unspecified waters.

Lake Trophic Status

Trophic status is a characterization of a lake's biological productivity based on the availability of plant nutrients, especially phosphorus. Commonly accepted systems for describing trophic status recognize a range of conditions, with "oligotrophic" indicating the least biologically productive lakes and "eutrophic" indicating significantly higher levels of productivity. A lake's trophic condition may shift over time. The trophic condition of South Carolina lakes is monitored through SCDHEC's network of routine sampling stations and through periodic sampling of additional lakes. All lakes of at least 40 acres in area that offer public access are monitored.

Most commonly, large external inputs of nutrients from point and/or nonpoint sources lead to advanced eutrophication. Advanced eutrophication is indicated by excessive algal growth, rapid sedimentation, and seasonal or daily dissolved oxygen deficiencies. Advanced eutrophication can cause undesirable shifts in the composition of aquatic life, or even fish kills. Restoring a lake to a more desirable trophic condition requires reductions in nutrient inputs, usually phosphorus.

Water Quality Indicators

Water quality data are used to describe the condition of a waterbody, to help understand why that condition exists, and to provide some clues as to how it may be improved. Water quality indicators include physical, chemical, and biological measurements. Copies of the Standard Operating Procedures used for these measurements are available from the Department's Bureau of Water and the Bureau of Environmental Services. The current State of S.C. Monitoring Strategy is available on our website at www.scdhec.net/eqc/admin/html/eqcpubs.html#wqreports and describes what parameters are sampled, where they are sampled, and how frequently.

MACROINVERTEBRATE COMMUNITY

Macroinvertebrates are aquatic insects and other aquatic invertebrates associated with the substrates of waterbodies (including, but not limited to, streams, rivers, tidal creeks, and estuaries). Macroinvertebrates can be useful indicators of water quality because these communities respond to integrated stresses over time that reflect fluctuating environmental conditions. Community responses to various pollutants (e.g. organic, toxic, and sediment) may be assessed through interpretation of diversity, known organism tolerances, and in some cases, relative abundances and feeding types.

FISH TISSUE

Many pollutants occur in such low concentrations in the water column that they are usually below analytical detection limits. Over time many of these chemicals may accumulate in fish tissue to levels that are easily measured. By analyzing fish tissue it is possible to see what pollutants may be present in waterbodies at very low levels. This information can also be used to determine if consumption of the fish poses any undue human health concerns and to calculate consumption rates that are safe.

DISSOLVED OXYGEN

Oxygen is essential for the survival and propagation of aquatic organisms. If the amount of oxygen dissolved in water falls below the minimum requirements for survival, aquatic organisms or their eggs and larvae may die. A severe example is a fish kill. Dissolved oxygen (DO) varies greatly due to natural phenomena, resulting in daily and seasonal cycles. Different forms of pollution also can cause declines in DO.

Changes in DO levels can result from temperature changes or the activity of plants and other organisms present in a waterbody. The natural diurnal (daily) cycle of DO concentration is well documented. Dissolved oxygen concentrations are generally lowest in the morning, climbing throughout the day due to photosynthesis and peaking near dusk, then steadily declining during the hours of darkness.

There is also a seasonal DO cycle in which concentrations are greater in the colder, winter months and lower in the warmer, summer months. Streamflow (in freshwater) is generally lower during the summer and fall, and greatly affects flushing, reaeration, and the extent of saltwater intrusion, all of which affect dissolved oxygen values.

BIOCHEMICAL OXYGEN DEMAND

Five-day biochemical oxygen demand (BOD_5) is a measure of the amount of dissolved oxygen consumed by the decomposition of carbonaceous and nitrogenous matter in water over a five-day period. The BOD_5 test indicates the amount of biologically oxidizable carbon and nitrogen that is present in wastewater or in natural water. Matter containing carbon or nitrogen uses dissolved oxygen from the water as it decomposes, which can result in a dissolved oxygen decline. The quantity of BOD_5 discharged by point sources is limited through the National Pollutant Discharge Elimination System (NPDES) permits issued by the Department. The discharge of BOD_5 from a point source is restricted by the permits so as to maintain the applicable dissolved oxygen standard.

pH

pH is a measure of the hydrogen ion concentration of water, and is used to indicate degree of acidity. The pH scale ranges from 0 to 14 standard units (SU). A pH of 7 is considered neutral, with values less than 7 being acidic, and values greater than 7 being basic.

Low pH values are found in natural waters rich in dissolved organic matter, especially in Coastal Plain swamps and black water rivers. The tannic acid released from the decomposition of vegetation causes the tea coloration of the water and low pH.

High pH values in lakes during warmer months are associated with high phytoplankton (algae) densities. The relationship between phytoplankton and daily pH cycles is well established. Photosynthesis by phytoplankton consumes carbon dioxide during the day, which results in a rise in pH. In the dark, phytoplankton respiration releases carbon dioxide. In productive lakes, carbon dioxide decreases to very low levels, causing the pH to rise to 9-10 SU. Continuous flushing in streams prevents the development of significant phytoplankton populations and the resultant chemical changes in water quality.

Fecal Coliform Bacteria

Coliform bacteria are present in the digestive tract and feces of all warm-blooded animals, including humans, poultry, livestock, and wild animal species. Fecal coliform bacteria are themselves generally not harmful, but their presence indicates that surface waters may contain pathogenic microbes. Diseases that can be transmitted to humans through water contaminated by improperly treated human or animal waste are the primary concern. At present, it is difficult to distinguish between waters contaminated by animal waste and those contaminated by human waste.

Public health studies have established correlations between fecal coliform numbers in recreational and drinking waters and the risk of adverse health effects. Based on these relationships, the USEPA and SCDHEC have developed enforceable standards for surface waters to protect against adverse health effects from various recreational or drinking water uses. Proper waste disposal or sewage treatment prior to discharge to surface waters minimizes this type of pollution.

Nutrients

Oxygen demanding materials and plant nutrients are common substances discharged to the environment by man's activities, through wastewater facilities and by agricultural, residential, and stormwater runoff. The most important plant nutrients, in terms of water quality, are phosphorus and nitrogen. In general, increasing nutrient concentrations are undesirable due to the potential for accelerated growth of aquatic plants, including algae. Nuisance plant growth can create imbalances in the aquatic community, as well as aesthetic and access issues. High densities of phytoplankton (algae) can cause wide fluctuations in pH and dissolved oxygen.

The forms of nitrogen routinely analyzed at SCDHEC stations are ammonia and ammonium nitrogen (NH_3/NH_4), total Kjeldahl nitrogen (TKN), and nitrite and nitrate nitrogen (NO_2/NO_3). Ammonia and ammonium are readily used by plants. TKN is a measure of organic nitrogen and ammonia in a sample. Nitrate is the product of aerobic transformation of ammonia, and is the most common form used by aquatic plants. Nitrite is usually not present in significant amounts.

Total phosphorus (TP) is commonly measured to determine phosphorus concentrations in surface waters. TP includes all of the various forms of phosphorus (organic, inorganic, dissolved, and particulate) present in a sample.

TURBIDITY

Turbidity is an expression of the scattering and absorption of light through water. The presence of clay, silt, fine organic and inorganic matter, soluble colored organic compounds, and plankton and other microscopic organisms increases turbidity. Increasing turbidity can be an indication of increased runoff from land. It is an important consideration for drinking water as finished water has turbidity limits.

TOTAL SUSPENDED SOLIDS

Total Suspended Solids (TSS) are the suspended organic and inorganic particulate matter in water. Although increasing TSS can also be an indication of increased runoff from land, TSS differs from turbidity in that it is a measure of the mass of material in, rather than light transmittance through, a water sample. High TSS can adversely impact fish and fish food populations and damage invertebrate populations. There are no explicit State standards for TSS.

HEAVY METALS

Concentrations of cadmium, chromium, copper, lead, mercury, and nickel in water are routinely measured by the Department to compare to State standards intended to protect aquatic life and human health. These metals occur naturally in the environment, and many are essential trace elements for plants and animals. Human activities, such as land use changes and industrial and agricultural processes have resulted in an increased flux of metals from land to water. Atmospheric inputs are recognized as important sources of metals to aquatic systems. Metals are released to the atmosphere from the burning of fossil fuels (coal, oil, gasoline), wastes (medical, industrial, municipal), and organic materials. The metals are then deposited on land and in waterways from the atmosphere via rainfall and attached to particulates (dry deposition).

Assessment Methodology

The Watershed Water Quality Assessment is a geographically-based document that describes, at the watershed level, water quality as well as conditions and activities related to water quality. Significant revisions to South Carolina's Water Quality Standards were effective on June 22, 2001. USEPA approved these standards for use in implementing the Clean Water Act on November 28, 2001. The data assessments for this document were based on previous Water Quality Standards. This section provides an explanation of the information assessment methodology used to generate the watershed-level summaries. Water quality data summaries used in this assessment are presented in Appendices A-C.

USE SUPPORT DETERMINATION

At the majority of SCDHEC's surface water monitoring stations, samples for analysis are collected as surface grabs once per month, quarter, or year, depending on the parameter. Grab samples collected at a depth of 0.3 meters are considered surface measurements, and are used to establish representative physical conditions and chemical concentrations in the waterbodies sampled. At most stations sampled by boat, dissolved oxygen and temperature are sampled as a water column profile, with measurements being made at a depth of 0.3 meters below the water surface and at one-meter intervals to the bottom. At stations sampled from bridges, these parameters are measured only at a depth of 0.3 meters. All water and sediment samples are collected and analyzed according to standard procedures. Macroinvertebrate community structure is analyzed routinely at selected stations as a means of detecting adverse biological impacts on the aquatic fauna due to water quality conditions which may not be readily detectable in the water column chemistry.

For the purpose of assessment, only results from surface samples are used in water quality standards comparisons and trend assessments. This information is considered to represent "average" conditions, as opposed to extremes, because of the inability to target individual high or low flow events on a statewide basis. Results from water quality samples can be compared to State standards and USEPA criteria, with some restrictions due to time of collection and sampling frequency. The monthly sampling frequency employed in the ambient monitoring network may be insufficient for strict interpretation of certain standards. The USEPA does not define the sampling method or frequency other than indicating that it should be "representative." A grab sample is considered to be representative for indicating excursions relative to standards: a single grab sample is more representative of a one-hour average than a four-day average, more representative of a one-day average than a one-month average, and so on (see also Screening & Additional Considerations for Water Column Metals below). When the sampling method or frequency does not agree with the intent of the particular standard, conclusions about water quality should be considered as only an indication of conditions.

The time period used to assess standards compliance is the most recent complete five years of data, which for the Broad River Basin is 1995 through 1999.

AQUATIC LIFE USE SUPPORT

One important goal of the Clean Water Act and State standards is to maintain the quality of surface waters in order to provide for the survival and propagation of a balanced indigenous aquatic community of fauna and flora. The degree to which aquatic life is protected (aquatic life use support) is assessed by comparing important water quality characteristics and the concentrations of potentially toxic pollutants with standards. Aquatic life use support is based on the percentage of standards excursions at a sampling site, and where data are available, the composition and functional integrity of the biological community. For lakes, support of aquatic life uses is also evaluated using a measure of trophic state. A number of waterbodies have been given specific standards for pH and dissolved oxygen, which reflect natural conditions.

For assessment purposes, a dissolved oxygen (DO) standard of not less than 4 mg/l is used for Class SB, a standard of not less than 6 mg/l is used for TN and TPGT, and a daily average not less than 5 mg/l with a low of 4 mg/l is used for all other Classes. The term excursion is used to describe a DO concentration measurement of less than the stated standard. Dissolved oxygen and pH may vary from the ranges specified in the standards due to a variety of natural causes.

For pH, there are several acceptable ranges applied depending on the Class of water: 6-8 SU for TPGT; 6-8.5 SU for FW; 5-8.5 SU for FW*; and 6.5-8.5 for SFH, SA, and SB. For DO and pH, if 10 percent or less of the samples contravene the appropriate standard, then aquatic life uses are said to be fully supported. A percentage of standards excursions between 11-25 is considered partial support, and a percentage greater than 25 is considered to represent nonsupport, unless excursions are due to natural conditions.

When comparing sampling data to DO standards, it is necessary to consider sampling bias due to season or tide stage. Samples are collected as a single instantaneous grab sample, which is not truly representative of the daily average used as the criterion for most classifications. Secondary stations are sampled only during summer months and generally experience a higher percentage of DO excursions as a result. It is essential to examine the data to ascertain such patterns of excursions before summarily concluding that the indicated violations constitute poor water quality.

For any individual toxicant (heavy metals, priority pollutants, chlorine, ammonia), if the acute aquatic life standard is exceeded in more than 10 percent of the samples, based on at least ten samples, aquatic life uses are not supported. If the acute aquatic life standard is exceeded more than once, but in less than or equal to 10 percent of the samples, uses are partially supported. If fewer than ten samples were collected, discretion must be used and other factors considered, such as the magnitude of the excursions or number of toxicants with excursions. In such a circumstance, the site is prioritized for the collection of biological data, or additional monitoring and investigation, to verify the true situation. Biological data are the ultimate deciding factor for determining support of aquatic life uses, regardless of chemical conditions.

MACROINVERTEBRATE DATA INTERPRETATION

Macroinvertebrate community assessments are used, where available, to supplement or verify Aquatic Life Use Support determinations and to evaluate potential impacts from the presence of sediment contaminants. Aquatic and semi-aquatic macroinvertebrates are identified to the lowest practical taxonomic level depending on the condition and maturity of specimens collected. The EPT Index and the North Carolina Biotic Index are the main indices used in analyzing macroinvertebrate data. To a lesser extent, taxa richness and total abundance may be used to help interpret data.

The EPT Index or the Ephemeroptera (mayflies) - Plecoptera (stoneflies) - Trichoptera (caddisflies) Index is the total taxa richness of these three generally pollution-sensitive orders. EPT values are compared with least impacted regional sites. The Biotic Index for a sample is the average pollution tolerance of all organisms collected, based on assigned taxonomic tolerance values. A database is currently being developed to establish significant EPT index levels to be used in conjunction with the Biotic Index to address aquatic life use support.

Taxa richness is the number of distinct taxa collected and is the simplest measure of diversity. High taxa richness is generally associated with high water quality. Increasing levels of pollution progressively eliminate the more sensitive taxa, resulting in lower taxa richness. Total abundance is the enumeration of all macroinvertebrates collected at a sampling location. This is generally not regarded as a qualitative metric. However, when gross differences in abundance occur between stations this metric may be considered as a potential indicator.

RECREATIONAL USE SUPPORT

The degree to which the swimmable goal of the Clean Water Act is attained (recreational use support) is based on the frequency of fecal coliform bacteria excursions, defined as greater than 400/100 ml for all surface water classes. Comparisons to the bacteria geometric mean standard are not considered appropriate based on sampling frequency and the intent of the standard. If 10 percent or less of the samples are greater than 400/100 ml then recreational uses are said to be fully supported. A percentage of standards excursions between 11-25 percent is considered partial support of recreational uses, and greater than 25 percent is considered to represent nonsupport of recreational uses.

FISH CONSUMPTION USE SUPPORT

The Department uses a risk-based approach to evaluate fish tissue data and to issue consumption advisories in affected waterbodies. This approach contrasts the average daily exposure dose to the reference dose (RfD). Using these relationships, fish tissue data are interpreted by determining the consumption rates that would not be likely to pose a health threat to adult males and nonpregnant adult females. Because an acceptable RfD for developmental neurotoxicity has not been developed, pregnant women, infants, and children are advised to avoid consumption of fish from any waterbody where a mercury advisory was issued.

Fish consumption use support is determined by the occurrence of advisories or bans on consumption for a waterbody. For the support of fish consumption uses, a fish consumption advisory indicates partial use support, a consumption ban indicates nonsupport of uses.

HUMAN HEALTH STANDARDS

State standards for human health are also evaluated in the preparation of the Watershed Water Quality Assessments. For contaminants with human health standards (e.g. heavy metals, pesticides), a potential human health threat is indicated if the median concentration exceeds the standard.

Additional Screening and Prioritization Tools

Evaluation of water quality data and other supplemental information facilitates watershed planning. Information from the following sources is used to develop watershed-based protection and prevention strategies.

LONG-TERM TREND ASSESSMENT

As part of the Watershed Water Quality Assessments, surface data from each station are analyzed for statistically significant long-term trends using a modification of Kendall's tau, which is a nonparametric test removing seasonal effects. Flows are not available for most stations, and the parametric concentrations are not flow-corrected. Seasonal Kendall's tau analysis is used to test for the presence of a statistically significant trend of a parameter, either increasing or decreasing, over a fifteen-year period. It indicates whether the concentration of a given parameter is exhibiting consistent change in one direction over the specified time period. A two sided test at p=0.1 is used to determine statistically significant trends, and the direction of trend. An estimate of the magnitude of any statistically significant trend is calculated.

A rigorous evaluation for trends in time-series data usually includes a test for autocorrelation. The data are not tested for autocorrelation prior to the trend analysis. It is felt that autocorrelation would not seriously compromise a general characterization of water quality trends based on such a long series of deseasonalized monthly samples.

One of the advantages of the seasonal Kendall test is that values reported as being below detection limits (DL) are valid data points in this nonparametric procedure, since they are all considered to be tied at the DL value. When the DL changed during the period of interest, all values are considered to be tied at the highest DL occurring during that period. Since it is possible to measure concentrations equal to the value of the DL, values less than DL are reduced by subtraction of a constant so that they remain tied with each other, but are less than the values equal to the DL. Since fecal coliform bacteria detection limits vary with sample dilution, there is no set DL; therefore, for values reported as less than some number, the value of the number is used.

For the purposes of this assessment, long-term trends in selected parameters were examined using data collected from 1984 through 1999. In 1992 a phosphate detergent ban was instituted in South Carolina, so for total phosphorus a second trend assessment is included for the period 1992 through 1999. For total phosphorus it is this second time period that is reported in the text.

SEDIMENT SCREENING

There are no sediment standards; therefore, in order to identify sediments with elevated metals concentrations, percentiles are constructed using five years of statewide sediment data. Only values greater than the detection limit were used for chromium, copper, nickel, lead, and zinc. Because so few concentrations of cadmium and mercury are measured above the detection limit, all samples were pooled for these metals. A sediment metal concentration is considered to be high if it is in the top 10% of the pooled results, and very high if it is in the top 5%. Any analytical result above detection limits is flagged for pesticides, PCBs, and other priority pollutants. Sites with noted high metals concentrations or the occurrence of other contaminants above detection limits are prioritized for the collection of biological data, or additional monitoring and investigation, to verify the true situation.

For saltwater sediments, national studies have been conducted by the National Oceanic and Atmospheric Administration (NOAA) and the State of Florida that have developed Sediment Quality

Guidelines (SQGs) for the United States and the southeastern region. These SQGs summarize all published toxicology and biomonitoring studies for a given contaminant and ranked them from lowest to highest concentration where an adverse effect was observed. The tenth percentile of the ranked data, from all published studies that reported an adverse effect, is termed the Effects Range Low (ERL) or Threshold Effects Level (TEL) and represents the threshold concentration for toxicity to occur. The median concentration where adverse effects in benthos are observed (the fiftieth percentile) is termed the Effects Range Median (ERM) or Probable Effects Levels (PEL). Measured sediment contaminant levels may be compared with ERLs/ERMs or TELs/PELs to predict potential probability for sediment bound contaminants to cause toxicity in benthic faunal communities. Saltwater sediment contaminant levels were compared with existing sediment quality guidelines by both individual compound. Sites with sediments which had individual chemical contaminant concentrations which exceeded ERL/TEL and ERM/PEL guideline levels are identified to indicate that trace metal, pesticide, PAH or PCB concentrations exceeded levels potentially toxic to estuarine organisms.

WATER COLUMN METALS ANALYSES

The USEPA criteria for heavy metals to protect aquatic life are specified as a four-day average and a one-hour average, and have been adopted as State standards. Because of the quarterly sampling frequency for heavy metals, comparisons to chronic toxicity standards (four-day average concentration) are not considered appropriate; therefore, only the acute standard (one-hour average) for the protection of aquatic life is used in the water quality assessment (Table 1).

Table 1. Metal Standards in Water (µg/l)

Metal	Present Detection Level	Freshwater 1Hr. Acute Ave.	Saltwater 1Hr. Acute Ave.	Human Health
*Cadmium	10.0	1.79	43.0	5.00
Chromium (VI)	10.0	16.00	1100.0	100.00
*Copper	10.0	9.22	2.9	
*Lead	50.0	33.78	140.0	
Mercury	0.2	2.40	2.1	0.15
*Nickel	20.0	789.00	75.0	100.00
*Zinc	10.0	65.00	95.0	5000.00

* Freshwater standards based on a hardness of 50 mg/l as $CaCO_3$.

Zinc and copper are elevated in surface waters statewide and concentrations are frequently measured in excess of the calculated acute aquatic life standards. To identify areas where zinc, copper, and other metals are elevated in the water column above normal background concentrations, concentrations greater than the detection limit from all SCDHEC monitoring sites statewide for a five-year period are pooled and the 90th and 95th percentiles are computed. This is done separately for each metal for both fresh and saltwaters. The individual measurements from each monitoring station are then compared to these percentiles, as well as to State standards. As in sediments, a metal concentration is referred to as "high" if it is in the top 10% of the pooled results, and "very high" if it is in the top 5%. All water column values referred to as "high" or "very high" are also in excess of the acute aquatic life standard listed in Table 1. For chromium, because so few concentrations are above the detection limit, all samples collected are used to generate the percentiles. Sites with high metals concentrations are prioritized for the collection of biological data, or additional monitoring and investigation, to verify the true situation.

The analytical procedures used by the Department yield total metal concentration, which is a relatively conservative measure, since the total metal concentration is always greater than the acid-soluble or dissolved fraction. Most heavy metal criteria for freshwater are calculated from formulas using water hardness. The formulas used to calculate criteria values are constructed to apply to the entire United States, including Alaska and Hawaii. As with all the USEPA criteria, there is also a large margin of safety built into the calculations. The applicability of the hardness-based criteria derived from the USEPA formulas to South Carolina waters has been a subject of much discussion. Hardness values vary greatly nationwide (from zero into the hundreds), with South Carolina representing the lower end of the range (statewide average value is approximately 20 mg/l). Representatives of the USEPA Region IV standards group have stated that no toxicity data for hardness values less than 50 mg/l were used in the development of the formulas. They have expressed reservations about the validity of the formulas when applied to hardness values below 50 mg/l. Based on this opinion, South Carolina's State standards for metals are based on a hardness of 50 mg/l for waters where hardness is 50 mg/l or less, resulting in several criteria values below the Department's current analytical detection limits. Therefore, any detectable concentration of cadmium, copper, or lead is an excursion beyond recommended criteria.

The SCDHEC monitoring data have historically indicated that zinc and copper levels in South Carolina waters are elevated relative to USEPA criteria, apparently a statewide phenomenon in both fresh and salt waters, and possibly resulting from natural conditions, nonpoint sources, or airborne deposition. These levels do not appear to adversely affect state fisheries or macroinvertebrate communities, which suggests that the levels are the result of long-term local conditions to which the fauna have adapted, as opposed to point source pollution events. It is difficult to assess the significance of heavy metal excursions due to the questionable applicability of the formulas at low hardness values and calculated criteria below present detection limits.

NPDES Program

The Water Facilities Permitting Division and the Industrial, Agricultural, and Stormwater Permitting Division are responsible for drafting and issuing National Pollutant Discharge Elimination System (NPDES) permits. Facilities are defined as either "major" or "minor". For municipal permits, a facility is considered a "major" if it has a permitted flow of 1 MGD or more and is not a private facility. The determination for industrial facilities is based on facility and stream characteristics, including toxicity, amount of flow, load of oxygen, proximity of drinking water source, potential to exceed stream standards, and potential effect on coastal waters.

Permitting Process

A completed draft permit is sent to the permittee, the SCDHEC District office, and if it is a major permit, to the USEPA for review. A public notice is issued when the permit draft is finalized. Comments from the public are considered and, if justified, a public hearing is arranged. Both oral and written comments are collected at the hearing, and after considering all information, the Department staff makes the decision whether to issue the permit as drafted, issue a modified permit, or to deny the permit. Everyone who participated in the process receives a notice of the final decision. A copy of the final permit will be sent to anyone who requests it. Staff decisions may be appealed according to the procedures in R.61-72 and the rule of the Administrative Law Judge Division of South Carolina.

The permitting Divisions use general permits with statewide coverage for certain categories of discharges. Discharges covered under general permits include utility water, potable surface water treatment plants, potable groundwater treatment plants with iron removal, petroleum contaminated groundwater, mine dewatering activities, aquaculture facilities, bulk oil and gas terminals, hydrostatic test waters (oil & gas lines), and vehicle wash waters. Additional activities proposed for general permits include ready-mix concrete/concrete products and concentrated animal feeding operations. State Land application systems for land disposal and lagoons are also permitted.

Wasteload Allocation Process

A wasteload allocation (WLA) is the portion of a stream's assimilative capacity for a particular pollutant that is allocated to an existing or proposed point source discharge. Existing WLAs are updated during the basin review process and included in permits during the normal permit expiration and reissuance process. New WLAs are developed for proposed projects seeking a discharge permit or for existing discharges proposing to increase their effluent loading at the time of application. Wasteload allocations for oxygen demanding parameters and nutrients are developed by the Water Quality Modeling Section, and WLAs for toxic pollutants and metals are developed by the appropriate permitting division.

The ability of a stream to assimilate a particular pollutant is directly related to its physical and chemical characteristics. Various techniques are used to estimate this capacity. Simple mass balance/dilution calculations may be used for a particular conservative (nondecaying) pollutant while complex models may be used to determine the fate of nonconservative pollutants that degrade in the environment. Waste characteristics, available dilution, and the number of discharges in an area may, along with existing water quality, dictate the use of a simple or complex method of analysis. Projects that generally do not require complex modeling include: groundwater remediation, noncontact cooling water, mine dewatering, air washers, and filter backwash.

Streams are designated either effluent limited or water quality limited based on the level of treatment required of the dischargers to that particular portion of the stream. In cases where the USEPA published effluent guidelines and the minimum treatment levels required by law are sufficient to maintain instream water quality standards, the stream is said to be effluent limited. Streams lacking the assimilative capacity for a discharge at minimum treatment levels are said to be water quality limited. In cases where better than technology limits are required, water quality, not minimum requirements, controls the permit limits. The Department's Water Quality Modeling Section recommends limits for numerous parameters including ammonia nitrogen (NH3-N), dissolved oxygen (DO), total residual chlorine (TRC), and five-day biochemical oxygen demand (BOD5). Limits for other parameters, including metals, toxics, and nutrients are developed by the Water Facilities Permitting Division or the Industrial, Agricultural, and Stormwater Permitting Division in conjunction with support groups within the Department.

Nonpoint Source (NPS) Management Program

NPS water pollution, sometimes called •runoff pollution••or •polluted runoff••does not result from a discharge at a specific, single location (or point), but generally comes from diffuse, numerous sources. Runoff occurring after a rain event may transport sediment from plowed fields, construction sites, or logging operations, pesticides and fertilizers from farms and lawns, motor oil and grease deposited on roads and parking lots, or bacteria containing waste from agricultural animal facilities or malfunctioning septic systems. The rain moves the pollutants across the land to the nearest waterbody or storm drain where they may impact the water quality in creeks, rivers, lakes, estuaries, and wetlands. NPS pollution may also impact groundwater when it is allowed to seep or percolate into aquifers. Adverse effects of NPS pollution include physical destruction of aquatic habitat, fish kills, interference with or elimination of recreational uses of a waterbody (particularly lakes), closure of shellfish beds, reduced water supply or taste and odor problems in drinking water, and increased potential for flooding because waterbodies become choked with sediment.

Congress recognized the growing problem of nonpoint source pollution in the late 1980s, and added NPS provisions to the federal law. Section 319 of the 1987 Amendments to the Clean Water Act required states to assess the nonpoint source water pollution associated with surface and groundwater within their borders and then develop and implement a management strategy to control and abate the pollution. The first Assessment of Nonpoint Source Pollution in South Carolina accomplished this purpose. The Department•s Bureau of Water manages the ongoing State NPS Management Program, which develops strategies and targets waterbodies for priority implementation of management projects. Section 319 funds various voluntary efforts, including watershed projects, which address many aspects of the pollution prevention management measure and provide education, outreach and technical assistance to various groups and agencies. Most of the projects are implemented by cooperating agencies.

Many land activities can individually or cumulatively contribute to NPS pollution. Eight categories of NPS pollution sources have been identified as contributing to water quality degradation in South Carolina: agriculture, forestry, urban areas, marinas and recreational boating, mining, hydrologic modification, wetlands and riparian areas disturbance, land disposal, and groundwater contamination. There are programs, both regulatory and voluntary, in-place that address all eight categories.

Agriculture

In South Carolina, pesticides, fertilizers, animal waste, and sediment are potential sources of agricultural NPS pollution. Agricultural activities also have the potential to directly impact the habitat of aquatic species through physical disturbances caused by livestock or equipment, and through the management of water. The State has laws and regulations that prevent NPS pollution from several agricultural sources including pesticides and animal waste. Funding programs including those under section 319 grants from EPA, cost share funds from USDA under EQIP and CRP are used to implement best management practices that are not covered under regulations. Agriculture land acreage is quantified in the basin-wide and individual watershed evaluations.

Silviculture

Forests comprise a major portion of South Carolina's land base. Sixty-six percent, or 12.6 million acres, of the State's total land area is in timberland. Silvicultural practices associated with road access, harvest, and regeneration of timber present the most significant potential for NPS pollution. Silvicultural activities have the potential to degrade the State's waters through the addition of sediment, nutrients, organics, elevated temperature, and pesticides. Erosion and subsequent sedimentation are the most significant and widespread NPS problems associated with forestry practices. Sudden removal of large quantities of vegetation through harvesting or silvicultural practices can also increase leaching of nutrients from the soil system into surface waters and groundwaters. Programs to abate or control NPS pollution from forestry activities are primarily the responsibility of the S.C. Forestry Commission (SCFC) and the United States Department of Agriculture's Forest Service (USFS), with other agencies having supplementary programs. S.C. Forestry Commission provides monthly courtesy exams to SCDHEC's Division of Water Quality and to forest industries. If water quality was impacted by a forestry operation, SCDHEC may institute enforcement action under the South Carolina Pollution Control Act. The United States Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) also provides technical assistance to government, landowners, and land users. Forest land acreage is quantified in the basin-wide and individual watershed evaluations.

Urban Areas

Urbanization has been linked to the degradation of urban waterways. The major pollutants found in runoff from urban areas include sediment, nutrients, oxygen-demanding substances, heavy metals, petroleum hydrocarbons, pathogenic bacteria, and viruses. Suspended sediments constitute the largest mass of pollutant loadings to receiving waters from urban areas. Construction sites are a major source of sediment erosion. Nutrient and bacterial sources of contamination include fertilizer usage, pet wastes, leaves, grass clippings, and faulty septic tanks. Petroleum hydrocarbons result mostly from automobile sources. In the 1980's, the average statewide population growth was 11.7 percent, while the coastal counties had an increase of 22 percent, nearly double the State rate during the same time period. This continuing development and population growth has the potential to make urban runoff the most significant source of pollution in waters of the State in the future. Urban land acreage is quantified in the basin-wide and individual watershed evaluations.

SCDHEC has a number of statewide programs that address components of urban NPS pollution. The Bureau of Water (BOW) administers four permitting programs that control runoff from new and existing urban sources. These include the Stormwater and Sediment Reduction program, Municipal

Separate Storm Sewer System (MS4), Industrial NPDES Stormwater Permits, and the Section 401 water quality certification program (see p.24). Additional controls for urban runoff in the coastal zone are implemented by SCDHEC's Oceans and Coastal Resources Management (OCRM) through the State Coastal Zone Management Plan.

The Bureau of Environmental Health's Division of Onsite Wastewater Management administers the Onsite Sewage Disposal System program for the entire State, and oversees the permitting for the installation and management of septic systems. Although not associated with urban land use, this Division permits the septic systems of camping facilities if the facility is not on public sewer. The types of camping facilities that fall into this category through R.61-39 are Resident Camps and Family Camps. Resident camps are organized camps where one or more buildings are provided for sleeping quarters. These camps are typically operated for educational, recreational, religious, or health purposes. Family camps are organized camps where campsites are provided for use by the general public or certain groups. The camp sewage is discharged into a public collection, treatment and disposal system if available, or an onsite wastewater treatment and disposal system (septic tank) is used. Camp locations are identified in the appropriate watershed evaluations.

Marinas and Recreational Boating

Potential adverse environmental impacts associated with marinas include dissolved oxygen deficiencies and high concentrations of toxic metals in aquatic organisms. In addition, marina construction activities can lead to the physical destruction of sensitive ecosystems and bottom-dwelling aquatic communities. Presently, there are more than 100 marinas in South Carolina, with 68 of them in the coastal zone. The U.S. Army Corps of Engineers and the SCDHEC are responsible for permitting marinas in South Carolina. Within SCDHEC, the two offices that have marina permitting authority are the Office of Ocean and Coastal Resource Management (SCDHEC OCRM) and the Office of Environmental Quality Control (SCDHEC Bureau of Water). SCDHEC OCRM issues critical area permits for marinas within the critical area of the coastal zone. SCDHEC Bureau of Water issues permits for marinas at all other locations within the State and issues Section 401 Water Quality Certifications (see p.24) for marinas statewide. The U.S. Coast Guard and the S.C. Department of Natural Resources are responsible for managing recreational boating activity.

Mining

South Carolina's mineral production consists of non-fuel minerals that provide raw materials for construction products and a precious metal industry. Portland cement clays (kaolin and brick), sand and gravel, and crushed stone represent the majority of the total mineral value. At the end of FY 1997-1998, there were 495 mining operations in South Carolina affecting more than 19,000 acres. Surface mining has the potential to generate NPS pollution during mineral exploration, mine development extraction, transportation, mining and processing, product storage, waste disposal, or reclamation. Potential nonpoint source impacts related to mining activities generally include hydrologic modification, erosion and sedimentation, water quality deterioration, fish and wildlife disturbances, and public nuisances.

The Department's Bureau of Land and Waste Management has primary regulatory responsibility for mining activities. Within the Bureau, the Division of Mining and Solid Waste Permitting is responsible for administering and implementing the S.C. Mining Act and its associated regulations. The Mining Act serves as part of an overall management plan for NPS pollution from active mines. Mining activities and locations are identified in the appropriate watershed evaluations.

Hydromodification

Hydrologic modification (or hydromodification) is defined as stream channelization, channel modification, and dam construction. These activities can negatively impact water quality, destroy or modify in-stream habitat and increase streambank and shoreline erosion. Two State permits, implemented by the SCDHEC, are involved in the implementation of management measures for hydromodification. A critical area permit is required for coastal waters, saltwater wetlands, and beaches defined as critical areas. A navigable waters permit is required for the remainder of the State. Implementation of State policy for dam construction is similar to control of other hydromodification projects in South Carolina, requiring the same State permits and certifications. In addition, dams require a State dam safety permit or a State stormwater management and sediment reduction permit. The Department must also issue Water Quality Certifications pursuant to Section 401 of the Federal Clean Water Act for dam construction and hydropower operations licensed by the Federal Energy Regulatory Commission.

Wetlands

Twenty-three percent of South Carolina is covered by 4.5 million acres of wetlands. The U.S. Army Corps of Engineers implements the federal program for regulating development in wetlands with guidelines established by EPA. The Corps delineates wetlands and determines which wetlands fall under regulatory jurisdiction and require a federal permit for development. The Wetlands Reserve Program, administered by the NRCS, is designed to restore and protect wetlands. At the state level, the primary focus of wetland regulation is the •401 Water Quality Certification. In the •401 certification process, applications for wetland alterations may be denied or modified due to the special nature of a wetland or the functions that a wetland provides. Wetland impacts must be compensated through restoration, enhancement, preservation, or creation and protected in perpetuity. Future development would be prohibited in these mitigated and legally protected areas. Knowledge of areas that are restricted from development due to mitigation or special water classification is useful in planning future development in a watershed. Wetland acreage is quantified in the basin-wide and individual watershed evaluations.

Land Disposal

Although modern solid waste disposal sites are considered point sources of pollution and regulated, leachate from sanitary landfills and dumps have the potential to pollute large portions of adjacent groundwater aquifers. Toxic compounds are commonly a part of the overall composition of landfill leachate, especially when the landfill has been used for the disposal of toxic chemicals. There are currently 140 permitted landfills in South Carolina. This total represents 35 municipal solid waste landfills (MSWLF), 62 industrial waste landfills, 41 construction and demolition (C&D) landfills, one sludge monofill, and one ash monofill. Regulatory authority over solid waste disposal activities resides with SCDHEC's Bureau of Land and Waste Management. All active and closed industrial and municipal solid waste landfills are identified in the appropriate watershed evaluations.

Land application is a form of recycling because it allows recovery of elements needed for crop production. Land application of biosolids may be beneficial and environmentally sound when applied at the correct agronomic rate. Land applying biosolids can benefit farmers by offsetting the costs of fertilizer and lime while reducing the pressure on existing landfills. SCDHEC's Bureau of Water, Division of Water Monitoring, Assessment and Protection, Groundwater Quality Section conducts a program to prevent, monitor, and correct groundwater contamination from nonpoint source pollution from land application of wastewater biosolids, solids, animal manures, biosolids, and sewage sludge. Land application, which is not a discharge, requires a "no discharge" permit (ND). All active industrial and municipal land applications are identified in the appropriate watershed evaluations.

Groundwater Contamination

All aquifers in the State are potential Underground Sources of Drinking Water and are protected under the S.C. Water Classifications and Standards. Groundwaters are thus protected in a manner consistent with the SCDHEC groundwater protection strategy. Staff hydrogeologists implement a screening program for nonpoint source impacts from pits, ponds, and lagoons associated with the permitted storage, treatment, and disposal of industrial and municipal wastewaters. In cases where a groundwater impact has been identified in violation of S.C. Water Classifications and Standards, appropriate actions will be coordinated with the facility owner to ensure regulatory compliance. The hydrogeologist coordinates with the facility owner to implement source identification, contaminant extent assessments, initiation of contaminant remediation systems, and performance evaluations of corrective actions. In addition to releases from wastewater treatment systems, the staff evaluates releases from other nonpoint sources such as above ground tanks, nonregulated fuel oil tanks, spills and/or leaks. Sites with confirmed groundwater impact will be placed under a Consent Agreement or an Order. SCDHEC's South Carolina Groundwater Contamination Inventory quantifies the status of groundwater quality in South Carolina. The sites in the inventory are known groundwater contamination cases in the State, and are referenced by name and county, and updated annually.

Water Supply

Water treatment facilities are permitted by the Department for municipal and industrial potable water production. As per the 1983 Water Use Reporting and Coordination Act (Act 282), all water uses over 100,000 gallons per day must report their usage. This includes industrial, agricultural, mining, golf courses, public supply, commercial, recreational, hydropower, thermo power, and nuclear power activities. Intake location and the volume removed from a stream are identified in the watershed evaluations for municipal (potable) uses.

Consumer Confidence Reports

The Consumer Confidence Report (CCR) is an annual water quality report required of all Community water systems. The rationale behind the CCR is that consumers have a right to know what is in their drinking water and where it comes from. These reports are to educate consumers and help them make informed choices that affect the health of themselves and their families. It is believed that educated consumers are more likely to protect their drinking water sources. All CCRs are to include the following basic components:

- the water source, its location, and the availability of source water assessment plan;
- information about the water system (name and telephone number of a contact person, opportunities for public participation, and information for non-English speaking populations if applicable);
- definitions of terms and abbreviations used in the report;
- table of detected contaminants including the known or likely source of the contaminants;
- the health effects language for Maximum Contaminant Level violations and an explanation of the violation;
- information on cryptosporidium, radon, and other contaminants if applicable; and
- educational information that includes an explanation of contaminants and their presence in drinking water, an advisory for immuno-compromised people, the Safe Drinking Water Hotline telephone number, and other statements about lead, arsenic, and nitrate if applicable.

Growth Potential and Planning

Land use and management can define the impacts to water quality in relation to point and nonpoint sources. Assessing the potential for an area to expand and grow allows for water quality planning to occur and, if appropriate, increased monitoring for potential impairment of water quality. Indicators used to predict growth potential include water and sewer service, road and highway accessibility, and population trends. These indicators and others were used as tools to determine areas within the Broad River Basin having the greatest potential for impacts to water quality as a result of development.

SCDHEC's Strategic Plan for 2000-2005 (www.scdhec.net/news/releases/pdf files/Stratpln.pdf) acknowledges that growth issues are best handled at the local government level. SCDHEC's role is to work with local governments and communities to help them understand the importance of planning for smart growth: buffers, greenspaces, mass transit, subdivision and roadway planning, bike paths and bike lanes, and park and ride lots. SCDHEC can also provide assistance in helping local entities access information and provide consultation on technical issues such as the establishment of buffers and watershed stormwater planning. Many counties in the Broad River Basin lack county wide zoning ordinances; therefore, there is little local regulatory power to influence the direction or magnitude of regional growth. The majority of municipalities have zoning ordinances in place; however, much of the growth takes place just outside the municipal boundaries, where infrastructure is inadequate. Section 208 of the Clean Water Act serves to encourage and facilitate the development and implementation of areawide waste treatment management plans. The 208 Areawide Water Quality Management Plans were completed in great detail during the 1970's and have recently been updated. Information from the updated reports is used in the individual watershed evaluations. South Carolina's water quality management plans support consolidation of wastewater treatment facilities into larger regional systems.

Watershed boundaries extend along topographic ridges and drain surrounding surface waters. Roads are commonly built along ridge tops with the best drainage conditions. Cities often develop in proximity to ridges as a result of their plateau terrain. It is not uncommon, then, to find cities or road corridors located along watershed boundaries, and thus influencing or impacting several watersheds.

Watershed Protection and Restoration Strategies

SCDHEC's Bureau of Water is responsible for ensuring that South Carolina's water is safe for drinking and recreation, and suitable to support aquatic life. This section provides an overview of other important Bureau programs and strategies applied statewide to protect and restore water quality. The point and nonpoint source controls described previously assist with achieving these goals.

Under section 303(d) of the Federal Clean Water Act, each state is required to provide a comprehensive inventory of impaired waters for which existing required pollution controls are not stringent enough to achieve State water quality standards or Federal Clean Water Act goals. This biennial list, commonly referred to as the "303(d) list", is the basis for targeting waterbodies for watershed-based solutions. A copy of the current 303(d) list can be obtained by contacting the Bureau of Water. Several Bureau programs address these impaired streams in an effort to restore them.

Total Maximum Daily Load

A Total Maximum Daily Load (TMDL) is the calculated maximum allowable pollutant loading to a waterbody at which water quality standards are maintained. A TMDL is made up of two main components, a load allocation and a wasteload allocation. A load allocation is the portion of the receiving water's loading capacity attributed to existing or future nonpoint sources or to natural background sources. The waste load allocation is the portion of a receiving water's loading capacity allocated to an existing or future point source.

A TMDL is a means for recommending controls needed to meet water quality standards in a particular water or watershed. Historically, the typical TMDL has been developed as a wasteload allocation, considering a particular waterbody segment, for a particular point source, to support setting effluent limitations. In order to address the combined cumulative impacts of all sources, broad watershed-based TMDLs are now being developed.

The TMDL process is linked to all other State water quality activities. Water quality impairments are identified through monitoring and assessment. Watershed-based investigations result in source identification and TMDL development. TMDLs form links between water quality standards and point and nonpoint source controls. Where TMDLs are established, they constitute the basis for NPDES permits and for strategies to reduce nonpoint source pollution. The effectiveness and adequacy of applied controls are evaluated through continued monitoring and assessment.

Funding for TMDL implementation is currently available with USEPA's Section 319 of the Clean Water Act grants. For more information, see the Bureau of Water web page www.scdhec.net/water or call the Watershed Program at (803) 898-4300.

Antidegradation Implementation

The State's Antidegradation Policy as part of S.C. Regulation 61-68 is represented by a three-tiered approach to maintaining and protecting various levels of water quality and uses; streams included on the 303(d) list are addressed under Tier 1. Tier 1 antidegradation policies apply to all waters of the

State and require that existing uses and the minimum level of water quality for those uses be maintained and protected. Tier 2 policies apply to high quality water where the water quality exceeds the mandatory minimum levels to support the Clean Water Act's goals of propagation of fish, shellfish, wildlife, and recreation in and on the water. The Department considers all the waters of the State as high quality waters. Tier 3 policies apply to the maintenance of water quality in waters that constitute an Outstanding National Resource Water and do not allow for any permanent permitted dischargers. Outstanding Resource Waters of the State are provided a higher level of protection than Tier 2, but do not meet the requirements of Tier 3.

Tier 1 protection will be implemented when applying numeric standards included in Regulation 61-68 for human health, aquatic life, and organoleptic protection as follows: if a waterbody has been affected by a parameter of concern causing it to be on the 303(d) list, then the Department will not allow a permitted net increase of loading for the parameter of concern unless the concentration will not contribute to a violation of water quality standards. This no net increase will be achieved by reallocation of existing total load(s) or by meeting applicable water quality standard(s) at the end-of-pipe. No discharge will be allowed to cause or contribute to further degradation of a 303(d) listed waterbody.

The Antidegradation Rules apply to both nonpoint source pollution and for point sources into impaired waters. Many activities contributing to nonpoint source pollution are controlled with voluntary measures. The Department implements permitting or certification programs for some of these activities and has the opportunity to ensure compliance with the Antidegradation Rules. The activities of primary concern are land development projects which are immediately adjacent to and discharge runoff or stormwater into impaired waters.

401 Water Quality Certification Program

If a Federal permit for a discharge into waters of the State, including wetlands, is required, the Department must issue Water Quality Certification pursuant to Section 401 of the Federal Clean Water Act. Certification is required for permits issued by the U.S. Army Corps of Engineers for construction in navigable waters and for deposition of dredged or fill material.

Regulation 61-101 presents administrative and technical guidance for the water quality certification program and requires SCDHEC to consider whether or not a project is water dependent; whether or not there are feasible alternatives which will have less adverse consequences on water quality and classified uses; the intended purpose of the project; and all potential water quality impacts of the project, both direct and indirect, over the life of the project. Any project with the potential to affect waters of the State must be conducted in such a manner to maintain the specified standards and classified and existing water uses.

As a routine part of the 401 Water Quality Certification review process, the waterbody in question is identified as impaired or not impaired according to the 303(d) list. If it is impaired, the parameter of concern is noted, along with any steps required to prevent further degradation of the water quality of that waterbody. In an effort to facilitate watershed restoration where appropriate, mitigation for unavoidable wetland impacts is encouraged in areas that improve 303(d) listed waters.

Stormwater Program

Stormwater discharges result from precipitation during rain events. Runoff washes pollutants associated with industrial activities (including construction activity), agricultural operations, and commercial and household sites directly into streams, or indirectly into drainage systems that eventually drain into streams. The SCDHEC Stormwater Permitting Program focuses on pollution prevention to reduce or eliminate stormwater pollution. The Department has general permitting authority for stormwater discharges associated with industrial activity, including construction. General permits SCR000000 and SCR100000 for industrial and construction activities, respectively, require permittees to develop and implement stormwater pollution prevention plans that establish best management practices to effectively reduce or eliminate the discharge of pollutants via stormwater runoff. The Stormwater and Agricultural Permitting Section is responsible for issuing NPDES stormwater permits to prevent degradation of water quality as well as for issuing sediment and erosion control permits for construction sites. Currently, NPDES permits are required for construction sites greater than five acres. SCDHEC's Office of Ocean and Coastal Resource Management manages the State sediment and erosion control in the coastal area.

Regulation 61-9 requires a compilation of all existing State water quality data with STORET data being used as a baseline. If analysis indicates a decrease in water quality then corrective measures must be taken. The permittee will identify all impaired water bodies in a Stormwater Management Plan (SWMP). In addition, existing pollution discharge control methods will be identified and incorporated into the SWMP. Procedures, processes, and methods to control the discharge of pollutants from the municipal separate storm sewer system (MS4) into impaired waterbodies and publicly owned lakes included on the 303(d) list will be described in the SWMP. The effectiveness of these controls will be assessed and necessary corrective measures, if any, shall be developed and implemented.

Permits for municipal systems allow communities to design stormwater management programs that are suited for controlling pollutants in their jurisdiction. There are two population-based categories of municipal separate storms sewers: large municipal (population greater than 250,000) and medium municipal (population between 100,000 and 250,000). In the Broad River Basin, Greenville and Richland Counties and the City of Columbia must obtain a comprehensive municipal permit that addresses stormwater within their jurisdiction. These municipalities are defined as medium municipalities.

South Carolina Animal Feeding Operations Strategy

Among the general categories of pollution sources, agriculture ranks as the number one cause of stream and lake impairment nationwide. Many diseases can potentially be contracted from drinking water or coming into contact with waters contaminated with animal wastes. The Department uses S.C. Regulation 61-43: *Standards for the Permitting of Agricultural Animal Facilities* to address the permitting of animal feeding operations (AFOs). Implementing these regulations and their corresponding compliance efforts are a priority for the Department in order to reduce public health and environmental impacts from AFOs. There are currently no federally defined concentrated animal feeding operations (CAFOs) in operation in South Carolina, and approximately 2,000 AFOs. Using the Watershed Program cycle and the division of the State into five regions, AFOs will be monitored and inspected by region. The 303(d) list will be used to prioritize the inspections. After all the inspections have been made in a region, the Department will move to the river basins in the next region in the watershed cycle. The Department is continuing to work in cooperation and coordination with the U.S. Department of Agriculture, the Natural Resources Conservation Service, the S.C. Department of Agriculture, the S.C. Soil and Water Conservation Districts, and the Clemson Extension Service.

Sanitary Sewer Overflow Strategy

Sanitary sewers are designed to collect municipal and industrial wastewater, with the allowance for some acceptable level of infiltration and inflow, and transport these flows to a treatment facility. When the sewer system is unable to carry these flows, the system becomes surcharged and an overflow will occur. Sanitary sewer overflows (SSOs) have existed since the introduction of separate sanitary sewers, and most are caused by inadequate operation, maintenance, and management of the collection system.

The Department encourages utilities to embrace the principals of EPA's capacity Management, Operations, and Maintenance (cMOM) program. Through this program utilities can ensure adequate funding and capacity as well as a proactive approach to operations and maintenance. Those that have implemented cMOM programs have been able to significantly reduce or eliminate overflows from their collection systems.

The Department's approach has been to shift resources historically applied to treatment plant inspections to include evaluations of pump stations and collection systems where problems are suspected. To assist evaluators in identifying water quality violations related to SSOs, staff have utilized the 303(d) list of impaired waters to identify waters impacted by fecal coliform or other appropriate pollutants and correlate those with collection systems with incidences of SSOs. The Department's Enforcement Referral Procedures Document is be used to determine when a collection system should be referred to enforcement for SSOs. The enforcement process allows for the Department to consider actions taken by the collection system such as: timely and proper notification, containment and mitigation of discharge, voluntarily conducting self evaluations, and requests for compliance assistance. The Department will take immediate action where it has been determined that SSOs have occurred and the collection system has not made timely and proper notification.

Referral Strategy for Effluent Violations

The Department has developed referral effluent violation guidelines to specifically address discharges into impaired waters. The goal of the referral guidelines is to reduce pollutant discharges into impaired waters in order to ultimately restore them to their full potential usage. To achieve this goal, enforcement actions are initiated earlier in an effort to improve the quality of waters that do not meet standards. If a stream is impaired by a pollutant and the permit limit for that pollutant is exceeded more than once in a running annual reporting period, formal enforcement action will be initiated against the discharger.

SCDHEC's Watershed Stewardship Programs

Public participation is an important component of the Department's Watershed Water Quality Management Program. Benefits to this interaction on the local level include improved public awareness about SCDHEC water programs, and increased local interest and participation in water quality improvement. Described below are some of the Department's water programs that encourage public interest and involvement in water quality. These programs and their contacts are listed on the Department's website at www.scdhec.net/water.

Source Water Assessment Program

A safe, adequate source of drinking water is key to development of communities and the health of citizens. The Safe Drinking Water Act (SDWA) provides authority to protect sources of drinking water. As a result of the 1996 amendments to the SDWA, source water protection has become a national priority. States are required to develop a plan for assessment of source waters for all federally defined public groundwater and surface water systems.

The Source Water Assessment Program (SWAP) involves determining the boundaries of the areas that are the source of waters for public water systems. For groundwater systems, these areas are defined using groundwater flow models. For surface water systems, the 14-digit Hydrologic Unit Code watershed is the designated protection area (although certain areas within the basin will be segmented as being of greater vulnerability to contamination from overland flow, groundwater contributions to surface water, and direct spills into the surface water). Known and potential sources of contamination in the delineated area must be identified, and the inventoried sources evaluated to determine the susceptibility of public water systems to such contaminants. Assessments must be made available to the public.

Local involvement will be a critical factor in the success of the SWAP, and local government, citizen groups, environmental groups, water suppliers, and the Department must all work together to increase the general public's awareness of where drinking water comes from and how to better protect sources of drinking water. Implementation of source water protection activities will occur at the local level, and local authorities may wish to base zoning and land-use planning on the source water assessments. The SWAP will be a key part of the Department's watershed management approach. To avoid duplication, information gathered from existing regulatory programs and/or watershed protection efforts will be utilized (e.g., ambient monitoring programs, TMDLs, etc.).

Nonpoint Source Education

The goal of the Nonpoint Source Outreach Program is to educate the citizens of South Carolina about the sources of polluted runoff and techniques that can be used to reduce this runoff. The Program provides presentations on runoff pollution to community, church, civic, or professional groups; a variety of technical and nontechnical publications on runoff pollution and reduction techniques; *Turning the Tide*, a free, quarterly Nonpoint Source newsletter; and teacher training that includes the *Action for a Cleaner Tomorrow* curriculum and information on reducing polluted runoff. To arrange a presentation, order publications, or ask questions, contact the Nonpoint Source Education coordinator at 803-898-4300 or visit our website.

South Carolina Water Watch

South Carolina Water Watch is a unique effort to involve the public and local communities in water quality protection. The Water Watch program was developed to encourage South Carolina's citizens to become stewards of the State's lakes, rivers, streams, estuaries, and wetlands. Volunteers select a water resource on which to focus and perform activities aimed at protecting water quality, such as shoreline surveys, public education, and litter cleanups. The Water Watch coordinator assists participants with materials and training to help make projects successful. SCDHEC invites individuals, school groups, civic organizations, businesses, and local governments to learn about and protect the quality of our waterways by contacting the Water Watch coordinator at 803-898-4300 or visit our website.

Champions of the Environment

Champions of the Environment is a student recognition program that raises awareness of environmental issues. Nationally recognized for its innovative approach to environmental education, the program promotes hands-on learning by recognizing students working on exemplary environmental projects beyond the realm of the classroom. With scholarships and media coverage, Champions of the Environment encourages student initiative and self-esteem. The program promotes environmental awareness, leadership, conservation, creativity, and self-confidence through activities such as group projects, public speaking, and environmental research. Champions of the Environment is jointly sponsored by Dupont, International Paper, WIS-TV, and SCDHEC. For more information contact the Champions of the Environment coordinator at 803-898-4300 or visit our website.

Clean Water State Revolving Fund

Congress created the Clean Water State Revolving Fund (SRF) in 1987, to replace the 201 Construction Grants program. In doing so, 'state banks' were created to lend money for virtually any type of water pollution control infrastructure project. Project types include construction of wastewater treatment systems and nonpoint source pollution control. The interest rate on the loans is always below the current market rate. As repayments are made on the loans, funds are recycled to fund additional water protection projects. The vast majority of the SRF funds have been used for the construction of traditional municipal wastewater treatment systems. Because of its inherent flexibility, the SRF program is well suited to accommodate the watershed approach.

SRF loans are available to units of state, local, and regional government, and special purpose districts. South Carolina law prevents loans from being made directly to private organizations and individuals. Local governments such as cities and counties and other units of government such as Soil and Water Conservation Districts, Councils of Government, and Water and Sewer Districts are encouraged to apply for SRF loans for nonpoint source projects. Nonpoint source projects may include construction and maintenance of stormwater management facilities, establishment of a stormwater utility, purchase of land for wetlands and riparian zones, and implementation of source water protection assessments. For more information, contact the State Revolving Fund coordinator at 803-898-4300 or visit our website.

Citizen-Based Watershed Stewardship Programs

Throughout the Broad River Basin, water quality is a common interest among citizen groups. The issues and membership of these groups vary widely. Some of the citizen groups interested in water quality in the Broad River Basin are described below.

Friends of Lawsons Fork Creek

The Friends of Lawsons Fork Creek is a citizen advocacy group, founded in 2001, working on behalf of the creek. The group does regular water sampling, sponsors river clean-ups, and hosts events to bring attention to Lawsons Fork Creek. The Friends, which operates under the auspices of the Spartanburg Conservation Endowment SPACE, meets monthly to discuss issues relating to the creek. In 2000, the creek was the subject of a book, The Lawson's Fork: Headwaters to Confluence.

The Scenic Broad River Advisory Council

The 15.3 mile stretch of the Broad River, from 99 Islands Dam to its confluence with the Pacolet River, was designated a Scenic River on May 31, 1991. An advisory council was formed consisting of landowners and representatives from industry and state and local governments. This group published a management plan in August 1993. The advisory council is currently updating the plan that provides recommendations for the management of the Scenic Broad River.

Lake Bowen Home Owners and Boaters Association

The Lake Bowen Home Owners and Boaters Association is a non-profit organization dedicated to promoting a safe and enjoyable environment on and around Lake Bowen by educating the public about safe boating and swimming practices and good environmental practices.

Gilder Creek Watershed Association

The Gilder Creek Watershed Association was organized in 1998 and consists of interested citizens in the watershed. The primary goal of the association is the promotion of more stringent county-level regulation of storm water runoff, chiefly for flood control.

Lovers of the Enoree

Originally founded as a Water Watch group, the Lovers of the Enoree group tries to bring attention to water quality issues concerning the Enoree River. A main focus area for the group is promoting the appropriate use of Best Management Practices (BMPs) on construction sites to help reduce sediment runoff.

Sec 2.3 Ref 26

Source Water Protection

What is a Source Water Assessment?
What do I do with the Assessments?
Source Water Protection Plan Development Guide
Outreach Resources For Source Water Protection
View a Video About Source Water Protection
What are the Benefits of Source Water Protection?

Contact Source Water Assessment Program Area

The 1996 Amendments to the Exit DHEC Safe Drinking Water Act (SDWA) provide for a greater focus on pollution prevention as an approach to protecting surface water and groundwater supplies from pollution. The amendments require SCDHEC to provide Sourc Water Assessments to federally defined public water supply systems .

The US EPA approved South Carolina's Source Water Assessment and Protection Program Plan on November 6, 1999. In May 2003, the SDHEC provided an assessment report to all federally defined public water supply systems (those systems which have at least 15 service connections or provide water to at least 25 people for 60 or more days out of the year). This assessment contains important information about the drinking water source and how susceptible it may be to contamination.

Source Water Assessment Reports

Click on the above link for information about web-availability of final reports.

View a Video About Source Water Proteciton
(Apple Quicktime Player Required)
A SC DHEC 10-minute video that covers concepts such as the water cycle, surface water, groundwater, p pollution, nonpoint source pollution (runoff), and the fundamental elements of source water protection.
Connection Speed: ISDN(5MB), T1(8MB)

What is a Source Water Assessment?

The Source Water Assessment is a report that provides basic information to the public water suppliers ar public about drinking water sources. The Assessments include the following:

Source Water Protection Area(s) - This includes a description of the drinking water source such as a grou surface water intake and the land area that contributes water to that source (Source Water Protection Area Maps showing the location of the SWPA are included.

Potential Contaminant Source Inventory - This is a listing of the land uses and activities within the SWP. potentially release contaminants to the source water. Maps showing the locations of the potential contam within the SWPA are included.

Susceptibility Analysis - This is an evaluation of the contaminant inventory to determine how likely it is t contaminant source will affect a nearby drinking water source. Susceptibility is the combination of natur of the water source to an impact and the physical and chemical properties of the potential contaminants.

What do I do with the Assessments?

The Assessment contains important information that can be used to manage potential sources of contami well or intake. You can use this information to develop a community based plan to prevent pollution of t lakes, rivers and streams that serve as sources of drinking water to your community. These efforts shoul

Formation of a local team - A team of individuals assembled to guide the process in a cohesive, efficient team's primary objective should be the protection of drinking water sources. However, they must also rec constraints from ongoing activities in the watershed.

Management Measures - Management of contaminant sources that have been identified and inventoried t water assessment program. The basic goal of management strategies is to reduce or eliminate the potenti drinking water supplies. This may be accomplished either through federal, state, or local regulatory contr non-regulatory measures centering around an involved public.

Contingency Planning - The development and implementation of both long and short-term drinking wate replacement strategies for supplying safe drinking water to the consumer in the event of contamination o disruption.

What are the Benefits of Source Water Protection?

- A more secure and safe drinking water supply for the community and for its future generations.
- Possible reduction in the costs associated with treating and distributing drinking water. This cost m through items such as reduced monitoring initiatives.
- A general cost reduction through contamination prevention measures versus the expense of cleanu contamination has occurred.

Resources

General Information

- South Carolina's Source Water Assessment and Protection Program Plan
- Community Involvement in Drinking Water Source Assessments (US EPA) *(PDF-176KB)* Exit DHEC
- Groundwater Fact Sheet *(PDF-156KB)*
- Citizens' Guide to Clean Water November 1999 *(PDF-309KB)*
- Non Point Source Education
- Water Watch Program
- General Information on Source Water (US EPA) Exit DHEC
- The Groundwater Foundation - Groundwater Guardian Program Exit DHEC

Organizations Exit DHEC

- International City/County Management Association (ICMA)'s Local Government Environmental A Network (LGEAN)
- LGEAN Drinking Water Page
- LGEAN Source Water Awareness Media Tool Kit
- National Safety Council's Environmental Health Center Drinking Water Bulletins
- National Association of Towns and Township's National Center for Small Communities - Main Pa

- National Association of Towns and Townships' National Center for Small Communities - Source V

Management Tools Exit DHEC

- Source Water Protection at the Local Level (US EPA)
- Model Ordinances to Protect Local Resources-Source Water Protection (US EPA)
- Contingency Planning Tools (US EPA)
- Public Availability (US EPA)
- Local Source Water Protection (US EPA)
- Networking Resources (US EPA)
- For Water Systems (US EPA)

Funding Tools Exit DHEC

- Financial Assistance Tools (US EPA)
- Local Government Resources (US EPA)

Source Water Assessment Reports Web-Availability
Web-availability of the final Source Water Assessment Reports are limited to the text portions of the rep system specific tables, maps, and appendices are not web available security reasons. To view the web-ve reports click here.

For Complete Source Water Assessment Reports - You can view the complete report (including syste tables, maps and appendices) by contacting your public water supply system (PWS) directly.

Should the PWS not allow access to the report, you may contact SCDHEC's Freedom of Information (FC Please note that the public water supply system will be notified that a request is being made to view the c Complete copies of the reports can only be viewed in the SCDHEC FOI office by appointment; copies of not be removed from the FOI office.

To view a complete Source Water Assessment report via the SCDHEC FOI process, the following steps completed:

1. Submit a completed FOI request form to SCDHEC FOI in order to schedule an appointment to view th report. Requests should include justification for the request.

2. Once an appointment to view the report has been scheduled by SCDHEC FOI; requestor must bring a the appointment and will be required to sign a log-book before viewing the report.

3. No copies of the complete reports may be removed from the SCDHEC FOI office.

To get a copy of the SCDHEC FOI request form go to www.scdhec.net/foi/. For further information abo process please contact Jody Hamm, Director of the Freedom of Information Center at (803) 898-3882 or hammjm@dhec.sc.gov.

Assessment reports for public water supply systems are listed by county. To access the report for your s the county you live in and then click on the system name. This will take you to an Adobe Acrobat version you do not have Adobe Acrobat Reader, click here to download the free software Acrobat PDF Reader.

Systems that use both groundwater and surface water as sources for drinking water will have two report *the groundwater source and one for the surface water source. For security reasons, portions of the repo available on the web. These include Table 1, Figure 2, Appendices A and B for the groundwater reports Appendices B and C for the surface water reports.*

ABBEVILLE

Abbeville, City Of , System No. 0110001
Cold Springs School, System No. 0170104
Colony East II, System No. 0150013
Diamond Hill School, System No. 0170105
Forresters Restaurant, System No. 0172001
High Meadows CC, System No. 0170875
Lake Russell Bait and Tackle, System No. 0170902
Maxium MFG, System No. 0130004
Mohawk Industries, System No. 0130003
Nance Water System II, System No. 0150006
Pinehurst SD, System No. 0150003
SCPRT Jim Rampy Rec, System No. 0170901
USFS Fell Hunt Camp, System No. 0170651
USFS Parsons Mountain, System No. 0170650
US Utilities Purdy Shores, System No. 0150014
Woodlawn MHP, System No. 0160003
Yoders Restaurant, System No. 0170200

Top of Page Back to County List

AIKEN

Aiken, City of, System No. 0210001 (Groundwater Source)
Aiken, City Of, System No. 0210001 (Surface Water Source)
Aiken Gymnastics, System No. 0270104
American Hearth Inn, System No. 0270408
Ashley Motor Motel, System No. 0270402
Avondale Mills, Inc., System No. 0240002
Bath W/D, System No. 0220003
Beech Island W/D, System No. 0220004
Ben Feagin, System No. 0270901

Bishop Gravatt Center, System No. 0270677
Bobbys BBQ, System No. 0270206
Breezy Hill W/D, System No. 0220006
Burnettown W/D, System No. 0220007
C&H MHP, System No. 0260037
Cameron MHP, System No. 0260038
Camp Long Leadership Center, System No. 0270678
Carolina Springs Park, System No. 0260014
College Acres, System No. 0220002
CWS-Hunter Glen S/D, System No. 0250005
Deluxe Inn, System No. 0270409
Dixie Clay Co., System No. 0230003
Dukes Bar-B-Que, System No. 0272002
Gentry's MHP, System No. 0260002
Graniteville Co., System No. 0240002
Holmes Labor Camp #2, System No. 0271003
Holmes Labor Camp #3, System No. 0271004
Hwy 19 Blimpie and Shell Station, System No. 0270924
Town of Jackson, System No. 0210002
Jessamine MHP, System No. 0260029
Kent's Corner #18, System No. 0272003
Kent's Corner/Hwy 19 & I-20, System No. 0270911
Kent's Corner #16, System No. 0270918
Langley W/D, System No. 0220001
Mobile Home Estate, System No. 0260001
Monetta, Town of, System No. 0210008
Montmorenci W/D, System No. 0220008
Nazarene Campground, System No. 0270800
New Ellenton, System No. 0210007
New Holland, System No. 0220010
North Augusta, City Of, System No. 0210003
Oakhill Subdivision, System No. 0250004
Oakwood School, System No. 0270103
Olsons Restaurant, System No. 0272005
Ora, System No. 0270908
Perry, Town of, System No. 0210006
Ramada Inn, System No. 0270401
Salley, Town of, System No. 0210005
Sand Hill Rentals, System No. 0270906
SCPRT/Aiken Campground, System No. 0270600
SCPRT/Aiken Campground, System No. 0270601
SREL Conference Center, System No. 0270909
State Park Grocery, System No. 0270905
Talatha W/D, System No. 0220005
Vale Service Co., System No. 0250009
Valley PSA, System No. 0220012
Wagner, Town of, System No. 0210004
Weyerhauser, System No. 0240004

Top of Page Back to County List

ALLENDALE
301 Club, System No. 0372000
Allendale Country Club, System No. 0370801
Allendale Industrial, System No. 0320002
Allendale, Town of, System No. 0310001
Allendale Welcome Center, System No. 0370625
Clariant, System No. 0330001
Fairfax, Town of, System No. 0310004
Silk, System No. 0370901
Ulmer, Town of, System No. 0310002

Wingate Motel, System No. 0370401

Top of Page Back to County List

ANDERSON
Belton-Honea Path Water Authority, System No. 0410011
Belle Meade Acres, System No. 0450016
Big Water Marina, System No. 0470850
Anderson Regional Water System No. 0420011
Hollywood MHP, System No. 0460024
Sherwood Forest, System No. 0450029
Sunrise Manor, System No. 0460014
Town Creek, System No. 0450003
UPST Heater Bridgewater, System No. 0450033
UPST Heater Clearview, System No. 0450026
UPST Heater Fieldcrest, System No. 0450032
UPST Heater Haynie, System No. 0450063
UPST Heater Hidden Lake, System No. 0450072
UPST Heater Lakewood, System No. 0450065
UPST Heater Nevitt, System No. 0450007

Top of Page Back to County List

BAMBERG
Andrew Jackson Academy, System No. 0570100
Bamberg Public Works, System No. 0510001
Denmark, Town of, System No. 0510002
Ehrhardt, Town of, System No. 0510003
Govan, Town of, System No. 0510005
International Reinforced Plastics, System No. 0570900
Kearse Mfg Co., System No. 0530004
Olar, Town of, System No. 0510004
O-W Disco Club, System No. 0570905
Phoenix Specialty, System No. 0530001
Phoenix Specialty, System No. 0530002
Rivers Bridge SP, System No. 0570600

Top of Page Back to County List

BARNWELL
Town of Barnwell, System No. 0610001
Blacks Restaurant, System No. 0670202
Blackville, Town of, System No. 0610003
Chappels Labor Camp, System No. 0671000
Chem Nuclear Systems, LLL, System No. 0630004
Edisto Experimental Station, System No. 0670900
Elko, Town of, System No. 0610005
Hilda, Town of, System No. 0610004
Jackson MHP, System No. 0660002
Rogers MHP, System No. 0660003
SCPRT/Barnwell, System No. 0670600
Sheltons Food Store, System No. 0670912
Starmet CMI, System No. 0630006
Sweetwater C.C., System No. 0670800
Williston, Town of, System No. 0610002
Two Moon Junction, System No. 0672001
Williams Entertainment, System No. 0670911

Top of Page Back to County List

BEAUFORT

Barony House, System No. 0770233
Beaufort Jasper W&SA, System No. 0720003 (Groundwater Source)
Beaufort Jasper W&SA, System No. 0720003 (Surface Water Source)
Beaufort MHP, System No. 0760016
Briarwood MHP, System No. 0760076
Broad Creek MHP, System No. 0760053
Broad Creek PSD, System No. 0720009
Budget Inn, System No. 0770401
Chaplins Laundry, System No. 070234
Crestwood MHP, System No. 0760005
Deerfield, System No. 0760079
Dixie MHP, System No. 0760003
Freeport Marina, System No. 0770236
Garden Corner, System No. 0770406
Green Acres MHP, System No. 0760033
Green Pond, System No. 0750003
Haig Point, System No. 0750036
Harveys Grocery, System No. 0770918
Hilton Head PSD, System No. 0720006
Hilton Head Utility, System No. 0750028
Honeybee Island, System No. 0770050
Island West, System No. 0770875
James J Davis Elementary, System No. 0770101
Lakeview MHP, System No. 0760001
Lobeco, System No. 0770110
Lobeco Products, System No. 0730002
Low Country, System No. 0770675
May River, System No. 0750005
Melrose SD, System No. 0750038
Oak Ridge, System No. 0760060
Okatee River, System No. 0750023
Otterbern Park, System No. 0760002
Palmetto Bluff Village, System No. 0770925
Pritchardville, System No. 0750027
Rivers Grocery, System No. 0770928
Sheldon Convenience Store, System No. 0770927
Sheldon Health, System No. 0770901
South Island PSD, System No. 0720001
Spoken Word, System No. 0770914
Stoney Crest, System No. 0760081
Taylor MHP, System No. 0760015
Wells East S/D, System No. 0750026
Whale Branch, System No. 0760071

Top of Page Back to County List

BERKELEY
A Place In The Woods, System No. 0872010
AD Hare Waterworks Inc, System No. 0820006
AJ's MHP, System No. 0860023
Als Seafood Place, System No. 0872022
Angel Cafe, System No. 0870215
Angels TP, System No. 0870805
Arrowhead Motel, System No. 0870408
Atkins Landing, System No. 0870852
Baucom, System No. 0870960
BCWSA/Lake Moultrie Estate, System No. 0820004
BCWSA/Land O Pine SD, System No. 0820003
BCWSA/Sangaree W/R, System No. 0820002
Beccas Deli, System No. 0872018
Berkeley C.C., System No. 0870875

Berkeley Restaurant and Motel, System No. 0870279
Berkeley Systems, System No. 0870129
Big Oak Landing, System No. 0870802
Blacks Landing, System No. 0870216
Bonneau Ferry Conference Center, System No. 0870680
C&C BBQ, System No. 0870277
Cainhoy Park ASG, System No. 0870944
Cainhoy School, System No. 0870112
Cainhoy TP, System No. 0860070
Canal Lakes Resort, System No. 0872011
Canal One Stop, System No. 0870930
Cherry Grove Campground, System No. 0870811
CR Bard Inc, System No. 0830012
Crawford Landing, System No. 0870856
Cross Elementary School, System No. 0870122
Cross High School, System No. 0870121
Daniel Marina, System No. 0870858
Davis Bar and Loung, System No. 0872002
Duck Pond, System No. 0872033
Eaze On Inn, System No. 0870270
Gates Rubber Company, System No. 0830009
Georgia Pacific Corporation, System No. 0830004
Grandmas Kitchen, System No. 0872026
Handi Mart, System No. 0872006
Harrys Fish Campground, System No. 0870850
HE Bonner Elementary School, System No. 0870127
Helen Diner, System No. 0872012
Hess Mart, System No. 0870911
Hills Landing, System No. 0870851
Horseshoe Concession, System No. 0870268
Huger Tackle Shop, System No. 0870964
Jamestown, Town of, System No. 0810003
J&W's Convenience Store & Grill, System No. 0872025
JK Gourdin School, System No. 0870120
KC MHP #3, System No. 0860077
Kellys BBQ #2, System No. 0872029
Libbys Kitchen 2, System No. 0872030
Lions Beach Pavilion, System No. 0870237
Locklairs Landing, System No. 0870853
Luckys African Club, System No. 0870280
M&B Community Mart, System No. 0872031
MacDougall Youth Correctional Center, System No. 0870050
Macedonia Middle School, System No. 0870114
Macs Landing, System No. 0870855
Miracle Academy Nursing Center, System No. 0870139
Moncks Corner, City of, System No. 0810001
Moncks Corner Youth, System No. 0870931
New Hope Center for Children, System No. 0870004
Nucor Steel Construction Trailer, System No. 0830029
Nucor Steel-Berkeley Plant, System No. 0830032
O Haynes System, System No. 0850014
O Moooo Community Care Home, System No. 0870003
Oakley Vocational Center, System No. 0870124
P&C Grocery, System No. 0870271
Paradise Lounge, System No. 0870275
Petes Quick Stop, System No. 0870284
Pine Lake MHP, System No. 0870807
Pioneer Christian Academy, System No. 0870135
Pringletown Quick Stop, System No. 0872034
Quattlebaum MHP, System No. 0860067
Randys Bait and Tackle, System No. 0870934

Rews Run In, System No. 0872019
Roper-Davis Grocery, System No. 0872032
Russels Store, System No. 0870244
S&S Campground, System No. 0870217
Sandy Run MHP, System No. 0860037
Santee Cooper - Cross Plant, System No. 0830019
Santee Cooper - Wampee, System No. 0870918
Santee Cooper - Jefferies, System No. 0830016
Santee Cooper Regional Water, System No. 0820008
Short Stay Recreational Area, System No. 0870803
Spires Landing, System No. 0870857
St Stephens, Town of, System No. 0810002
St Thomas Point SD, System No. 0850015
Tall Pines Campground, System No. 0870809
Tall Pines Campground #2, System No. 0870810
The Dock Restaurant, System No. 0870204
Timberland HS, System No. 0870137
Trinity Christian Academy, System No. 0870136
USFS Witherbee Work Center, System No. 0870656
VFW Post Restaurant, System No. 0870282
Wando Grocery, System No. 0870906
Wassamassaw Rec, System No. 0870945
Wrights Grocery, System No. 0870922
Wrights Mini Mart, System No. 0870929
Youngs Food Store #45, System No. 0872014

Top of Page Back to County List

CALHOUN

Brakefield Restuarant, System No. 0970203
Calhoun Country Club, System No. 0970875
Camp Harry Daniels, System No. 0970677
Citgo/Travel, System No. 0970907
Dieter Bryce Inc, System No. 0930007
Hickory Spring, System No. 0973001
I-26 Rest Area - West, System No. 0970625
I-26 Rest Area - East, System No. 0970626
Poplar Creek, System No. 0960001
St. Matthews, Town of, System No. 0910001
Standard Corp, System No. 0930005
Stumphole Landing, System No. 0970201
Sweet Water Lake, System No. 0970800
Sweet Water Shell, System No. 0970903
Teepak, System No. 0930003
Tri-Co Electric Coop, System No. 0970901
Upper Calhoun Bellville, System No. 0920001
Upper Calhoun Sandy Run, System No. 0920002

Top of Page Back to County List

CHARLESTON

Adams Run Civic Center, System No. 1070148
Archibald Rutledge School, System No. 1070140
BG's, System No. 1072007
Buckshot Carryout, System No. 1072008
Camp Ho Non Wah, System No. 1070675
Cape Romain National Wildlife Refuge, System No. 1070678
Charleston CPW, System No. 1010001
Dewees Island, System No. 1050011
Deytens Shipyard, System No. 1030005
East Cooper Airport, System No. 1070910

Edisto Island Community Center, System No. 1070921
Edisto Presbyterian Day Care, System No. 1070127
Edith Frierson Elementary, System No. 1070115
Exxon, System No. 1070915
Hathaway Restaurant, System No. 1070234
Isle of Palms, System No. 1010004
Jane Edwards Elementary, System No. 1070122
Jerico Trailer Park, System No. 1060061
Kellys BBQ, System No. 1070232
Kiawah Island Utility, System No. 1010008
Lake Aire Park, System No. 1070804
McClellanville Lincoln, System No. 1070103
Minie Hughes Elementary, System No. 1070124
Mt. Pleasant W&S, System No. 1010002
Oak Plantation Campground, System No. 1070802
Old Post Office Restaurant, System No. 1070247
Parker Labor Camp, System No. 1070959
Porchers School, System No. 1070105
R A Davis Labor Camp, System No. 1071003
Rachel's Deli, System No. 1072006
SCPRT - Hampton Plantation, System No. 1070600
Seabrook Island, System No. 1010009
Seawee Coastal Retreat, System No. 1070677
See Wee Restaurant, System No. 1072001
St James Santee FHC Inc, System No. 1070006
St James School, System No. 1070143
Sullivans Island, System No. 1010003
Sunny Point Farms, System No. 1071001
T G Davis Labor Camp, System No. 1071011
T W Graham Co, System No. 1072002
The Crab Pot, System No. 1070236
The Pantry #878, System No. 1070913
USFS Wambaw Work Center, System No. 1070654
W A Burbage MHP I, System No. 1060014
W A Burbage TP #3, System No. 1060063
Wadmalaw Island Community Center, System No. 1070958
Watts MHP, System No. 1060064
Winwood Farm Home, System No. 1070963

Top of Page Back to County List

CHEROKEE
Boren Brick Blacksburg, System No. 1130003
Broad River Truck Stop, System No. 1170202
Coggins MHP, System No. 1160006
Gaffney BPW, System No. 1110001
Grassy Pond WD, System No. 1120002
Industrial Minerals, System No. 1130009
Mr Waffle 104, System No. 1170210
Pinecone Campground, System No. 1170800

Top of Page Back to County List

CHESTER
Best Stop 39, System No. 1270213
Broad River Mart, System No. 1270901
Campbells Grill, System No. 1270212
Catawba Fish Camp, System No. 1270205
Chester Metro, System No. 1220002
Clariant Corporation, System No. 1230006
Edgemore Community Center, System No. 1270103

Lowrys One-Stop, System No. 1270906
Mogs Restaurant, System No. 1272000
N Chester Head Start, System No. 1270108
SCPRT Chester, System No. 1270600
Stockyard Grill, System No. 1272001
The Afterdeck, System No. 1270207
UPST Heater Lakewood SD, System No. 1250004
UPST Heater Leeds Hunt Camp, System No. 1270651
UPST Heater Woods Ferry Camp, System No. 1270650
Wilsons BBQ, System No. 1272002

Top of Page Back to County List

CHESTERFIELD
Alligator Rural, System No. 1320004
Camp Beaver Lake, System No. 1370677
Cash Rural Water Company, System No. 1320002
CCA Patrick Camp, System No. 1370678
Cheraw, Town Of, System No. 1310001
Chesterfield, City Of, System No. 1310002
Country Homes MHP, System No. 1360011
Country Village TP, System No. 1360008
Janice Circle, System No. 1360001
Jefferson, Town Of, System No. 1310005
Mama Clark Day Care, System No. 1370100
McLeod Farms, System No. 1371000
Moores Drive Inn, System No. 1370207
Pageland, City Of, System No. 1310003
Patrick, Town of, System No. 1310006
Walnut Ridge MHP, System No. 1360019
Westside Estates, System No. 1370300
White Plains CC, System No. 1370875

Top of Page Back to County List

CLARENDON
Alcolu Water System, System No. 1410001
Alpha Inn, System No. 1470412
Barnhill Store, System No. 1470906
Barrineau WS, System No. 1420002
Billops Landing, System No. 1470857
Camp Bob Cooper, System No. 1470675
Camp Robinson, System No. 1470678
Chadmoss Village, System No. 1450004
Charlies Landing, System No. 1470856
Coker Camp, System No. 1471008
Coopers MHP, System No. 1460002
Cypress Point Condos, System No. 1470304
Eagle Point SD, System No. 1450003
Economy Inn, System No. 1470406
Elliots Landing, System No. 1470859
Gin Pond Shores, System No. 1450005
Goat Island W&S, System No. 1470852
Haley New Camp, System No. 1471024
Haley Witherspoon Camp, System No. 1471004
Harry Durant I, System No. 1471009
Jacks Creek Marina, System No. 1470862
Lake Marion MHP, System No. 1460010
Lake Marion Shores - E&R, System No. 1450002
Light Point Campground, System No. 1470868
Manning, Town of, System No. 1410002

Micheaus Restaurant, System No. 1470865
Paxville Head Start, System No. 1470108
Pollys Landing, System No. 1470863
Quail Ridge SD, System No. 1450007
Randolphs Landing Motel, System No. 1470410
Randolphs MHP, System No. 1460003
Remini Marine Institute, System No. 1470904
Rikki Ds, System No. 1470910
Salem Mini Mart, System No. 1470908
Santee Lakes Campground, System No. 1470800
Santee Resort, System No. 1470405
SC Water Fowl Association, System No. 1470909
Scarborough Landing, System No. 1470854
Scott Jackson Camp, System No. 1471005
Sigfield Water Company Inc, System No. 1450006
St Paul Elementary, System No. 1470100
Summerton, Town of, System No. 1410003
Taw Caw Campground, System No. 1470853
Turbeville, Town of, System No. 1410004
Travelers Inn, System No. 1470411
Viars Tri Mart, System No. 1470907
Walker Gamble Elementary 1, System No. 1470104
Willowglen Academy, System No. 1470109
Windsor Manor Inc, System No. 1470001
Wyboo Bait & Grill, System No. 1472001
Wyboo Plantation Ltd, System No. 1450010

Top of Page Back to County List

COLLETON
Bell Elementary, System No. 1570106
Bennets TP, System No. 1560001
Bewers-Meister X-treme CC, System No. 1570875
Bobops Amoco Canadys, System No. 1570917
Circle C Auto Stop, System No. 1570205
Cottageville Elementary/Junior High S, System No. 1570100
Creel, Town of, System No. 1520003
Crosby MHP, System No. 1560006
Edisto Beach, System No. 1510006
Fishing Creek POA, System No. 1550002
HP Penny Pincher, System No. 1570905
I-95 Rest Area, System No. 1570903
Jacksonboro Citgo Angler, System No. 1570920
Jonesville Elementary, System No. 1570102
LCCS Head Start, System No. 1570115
Lodge, Town of, System No. 1510001
Main Street Diner, System No. 1570210
N And W Grocery, System No. 1570921
Norda Convenience Store, System No. 1570212
Polks BBQ, System No. 1570204
Ruffin, Town of, System No. 1510005
SCE&G-Canadys, System No. 1530002
Smoaks, Town of, System No. 1510002
SCPRT Colleton Wayside, System No. 1570600
Tomers Restaurant, System No. 1570211
Williams, Town of, System No. 1510003
Walterboro, System No. 1510004
Walterboro Veneer, System No. 1530003
Woods Campground, System No. 1560003
Youmans Shop No II, System No. 1570915

Top of Page Back to County List

DARLINGTON

Camp Sexton-United Methodist, System No. 1670800
City Mobile Court, System No. 1660046
Darlington, City of, System No. 1610001
Darlington County W&SA, System No. 1620001
Hartsville, City of, System No. 1610003
Hartsville Golf Club, System No. 1670875
Lakeview Club, System No. 1670676
Lamar, Town of, System No. 1610004
Palmetto Auto Auction, System No. 1670908
Weinbergs Plant, System No. 1630802

Top of Page Back to County List

DILLON

City of Dillon, System No. 1710001
Latta, System No. 1710002
Manor House, System No. 1770002
South of the Border, System No. 1770208
Trico Water Company, System No. 1720001

Top of Page Back to County List

DORCHESTER

Blue Circle Cement, System No. 1830005
Brax N Riggs, System No. 1872001
Brosnan Forest #1, System No. 1870675
Brosnan Forest #2, System No. 1870676
Carters Quick Stop, System No. 1870212
Chip Shots, System No. 1870916
CWS/Teal on Ashley, System No. 1850007
DCPW BLDG, System No. 1870903
DCPW Edisto Tribal Council, System No. 1850010
DCPW I-95, System No. 1870914
DCPW Woodlands HS, System No. 1870119
DCWA Conoflow, System No. 1820007
DCWA Knightsville, System No. 1820001
DCWA Tranquil Acres, System No. 1820003
Dixie Boy Travel Center, System No. 1870205
Dorchester County Career Center, System No. 1870109
Dorchester Shrine Club, System No. 1870906
Francis Beidler Forest, System No. 1870901
Francis Lieber, System No. 1870050
Giant Cement Holding Co, System No. 1830001
Givhans Community School, System No. 1870100
Harleyville, Town of, System No. 1810002
Harleyville Elementary, System No. 1870101
Middleton Place, System No. 1870902
Ralph Infingers Grocery, System No. 1870917
Reeseville, Town of, System No. 1820002
Ridgeville, Town of, System No. 1810004
Ronnies BP Station, System No. 1870200
SCPRT/GIvhans Park, System No. 1870600
Showa Denka Inc, System No. 1830007
St George, Town of, System No. 1810001
St George CC, System No. 1870875
Summerville, Town of, System No. 1810003
Summit SD, System No. 1850013

Wagners Daycare, System No. 1870117

Top of Page Back to County List

EDGEFIELD

Edgefield Co W&SA, System No. 1920001
Glover MHP and Day Care, System No. 1960002
JW Yonce 303, System No. 1971001
JW Yonce 606, System No. 1971004
Pine Ridge Club - Pond, System No. 1970875
Titan Farms Camp 5, System No. 1971009
Titan Farms Camp 9, System No. 1971010
USFS Lick Fork Lake Rec, System No. 1970650

Top of Page Back to County List

FAIRFIELD

Blackstock Fish Camp, System No. 2070909
Blackstock Shell, System No. 2070910
Dutchman Creek Marina, System No. 2070850
Fairfield Boat Club, System No. 2070903
Fairfield Home, System No. 2070002
Heater/Royal Hill, System No. 2050002
Jenkinsville Water District #2, System No. 2020001
Longtown Corner Store, System No. 2070904
Midcounty Water District #1, System No. 2020002
Ridgeway, Town of, System No. 2010002
SCE&G 99 Boat Ramp, System No. 2070913
SCE&G Monticello Rec, System No. 2070676
SCE&G Monticello Rec, System No. 2070677
SCPRT/Wateree State Park, System No. 2070600
VC Summer Nuclear Station, System No. 2030004
White Oak Conference Center, System No. 2070900
Winnsboro, Town Of, System No. 2010001

Top of Page Back to County List

FLORENCE

Allisons Food Mart, System No. 2170237
Ashley MHP, System No. 2160059
Barn House Restaurant, System No. 2172002
Camellia Motel, System No. 2170407
Camerontown Industries, System No. 2130022
Florence, City of, System No. 2110001
Cokers Grocery, System No. 2170915
Country Apts, System No. 2170307
Coward, Town of, System No. 2110012
Delta Mkt Pamplico, System No. 2130004
Dootles Kitchen, System No. 2172001
Ervins BBQ, System No. 2170250
FCW/Effingham, System No. 2120002
Florence Flea Market, System No. 2170235
Forest Lake MHP, System No. 2160004
Hannas Res Manor, System No. 2170006
Jackson Motel, System No. 2170401
JI Daves Lounge, System No. 2170221
Johnsonville, System No. 2110011
Lake City, System No. 2110007
Libby's Country Kitchen, System No. 2172003
Lindas Restaurant, System No. 2170251
Little Fishers Country Store, System No. 2170252

N Prospect FWB, System No. 2170123
Olanta, Town of, System No. 2110006
Pamplico, System No. 2110010
Poston Labor Camp, System No. 2171000
Quail Arbor I, System No. 2160062
School House Restaurant, System No. 2170253
SCPRT Lynches River, System No. 2170600
SCPRT Lynches River, System No. 2170911
Scranton, Town of, System No. 2110009
Stone Container Corp, System No. 2130003
Thomlinson & Mcwhite Din, System No. 2172000
Timmonsville, Town of, System No. 2110005
Todds MHP, System No. 2160108
Village East, System No. 2160008

Top of Page Back to County List

GEORGETOWN
Andrews, Town of, System No. 2210003
Brown's Ferry WS, System No. 2220003
Deep Creek Elementary, System No. 2270106
GCWSD - Debordieu, System No. 2250004
GCWSD - Garden City Point, System No. 2220011
GCWSD - Kilsock Water, System No. 2220002
GCWSD - North Santee, System No. 2220012
GCWSD - Plantersville, System No. 2220004
GCWSD - Red Hill, System No. 2220007
GCWSD - Waccamaw Neck, System No. 2220010 (Groundwater Source)
GCWSD - Waccamaw Neck, System No. 2220010 (Surface Water Source)
GCWSD - Yauhannah, System No. 2220013
Georgetown, City of, System No. 2210001 (Groundwater Source)
Georgetown, City Of, System No. 2210001 (Surface Water Source)
Georgetown Mar Belle, System No. 2270906
Georgetown Rural, System No. 2220001
Highway 521 Mini Mart, System No. 2270917
International Paper - Sampit, System No. 2230002
Pleasant Hill High School, System No. 2270111
Pleasnat Hill Middle School, System No. 2270103
Rose Hill, System No. 2220008
Wagon Wheel Farm, System No. 2230801
Waterford Heights SD, System No. 2250006

Top of Page Back to County List

GREENVILLE
Asbury Hills Camp, System No. 2370678
Beech Springs Campground, System No. 2370802
Ceasras Head Water Co, System No. 2350002
Camp Awanita Valley, System No. 2370684
Camp Greenville, System No. 2370677
Camp Old Indian, System No. 2370676
Camp Spearhead, System No. 2370682
Camp Waback, System No. 2370680
Charles Aiken Academy, System No. 2370116
Cliff Ridge Colony, System No. 2350021
Cliffs at Glassy, System No. 2350023
CWS/Woodmont Estates, System No. 2350013
CWS/Kingswood, System No. 2350011
CWS/Trollingwood SD, System No. 2350010
Edgewater Acres SD, System No. 2350024
F Mart Store, System No. 2370909

Foxrun Country Club, System No. 2370875
Generation Alternative, System No. 2370500
Generations Group Home, System No. 2370914
Greenville Water System, System No. 2310001
Greer CPW, System No. 2310005
Knoll Creek SD, System No. 2350022
Look Up Lodge, System No. 2370805
Marieta Baptist Camp, System No. 2370681
McCuen MHP, System No. 2360009
Mountain Lake Colony, System No. 2370803
Orchard View Mt, System No. 2330803
Palmetto Bible Camp, System No. 2370679
Paris Mountain State Park, System No. 2370603
River Oaks Retreat Center, System No. 2370881
SCPRT Jones Gap State Park, System No. 2370688
Scuffletown USA Country Music, System No. 2370912
Standing Springs Baptist Church, System No. 2370118

Top of Page Back to County List

GREENWOOD
Augusta Fields SD, System No.2450014
Country Acres SD, System No.2450057
Emerald MHP, System No.2460004
Epworth Camp, System No.2470676
Fairforest SD, System No.2450026
Gilbert WS, System No.2450060
Greenwood CPW, System No. 2410001
Greenwood Shores I, System No.2450030
Greenwood Shores II, System No.2450020
Harless Seymore WS, System No.2450016
Harris Landing, System No.2470851
Hyde Park SD, System No.2450001
Irvings Landing, System No.2470850
Lakeland Village, System No.2450036
Lakeview Dr, System No.2450029
Mathews Heights, System No.2450021
Mitchell MHP, System No.2460001
Murrells Grocery, System No.2470908
One Stop Marina, System No.2470853
Parkland Golf Club, System No.2470876
Pier 96, System No.2470852
SCPRT Greenwood SP, System No.2470601
SCPRT Greenwood SP, System No.2470600
Star Fort Country, System No.2470875
Sunrise Circle MHP, System No.2450042
Village Store, System No.2450053

Top of Page Back to County List

HAMPTON
Brunson, System No.2510004
Cummings Oil, System No.2540001
Ellie's Place, System No.2572000
Estill, Town of, System No.2510002
Furman, System No.2510007
Gifford, Town of, System No.2510009
Hampton, System No.2510001
Hampton Co. Industrial, System No.2570908
Housey Grocery & TP, System No.2560008
Lesters BBQ, System No.2570205

Luray, System No.2510003
Mary's Palace, System No.2570910
Patrick Henry Academy, System No.2570102
Scotia, System No.2510008
SCPRT/Lake Warren State Park, System No.2570600
Shuman's Stop and Shop, System No.2570907
Simmons Truck Stop, System No.2570203
Varnville, System No.2510005
Webb Wildlife Center, System No.2570677
Yemassee, Town of, System No.2510006

Top of Page Back to County List

HORRY
Aynor, Town of, System No.2610009
Bell Pontiac, System No.2670931
Bucksport Water Co, System No.2620003
Budget Inn, System No.2670407
Christian Fellowship Academy, System No.2670146
Conway, City of, System No.2610008
Conway Rural, System No.2620001
Daisy Elementary, System No.2670102
EJ Country Kitchen, System No.2672006
FFA Camp, System No.2670676
Finklea Career Center, System No.2670103
Four Seasons Ice Company, System No.2630001
Frys MHP, System No.2660052
Grace Christian School, System No.2670145
Grand Strand WSA, System No.2620004 (Groundwater Source)
Grand Strand WSA, System No.2620004 (Surface Water Source)
Green Sea Floyd High School, System No.2670104
Hardee Williams Mfg Co, System No.2630008
Horry Co Public Safety, System No.2670936
Horry County Admin Bldg, System No.2670918
Lakewood Campground, System No.2660049
Lay Fisher Chevy Olds, System No.2670929
Little River W&SA, System No.2620002
Longwood Golf Corp, System No.2670880
Loris, City of, System No.2610010
Man of War Golf Course, System No.2670921
Martins Grocery, System No.2670926
Midlands Elementary, System No.2670111
Midlands Grocery, System No.2670925
Mike Williamson MHP, System No.2660036
Myrtle Beach, City of, System No.2610001 (Groundwater Source)
Myrtle Beach, City of, System No.2610001 (Surface Water Source)
Myrtle West, System No.2670878
City of North Myrtle Beach, System No.2610011
Ocean Drive Lions Club, System No.2670914
Ocean Lakes Ltd, System No.2660048
Pee Dee Farms Store, System No.2670916
Pepsi Bottling, System No.2630002
Playcard Environmental, System No.2670906
Pleasant View Trading Post, System No.2670946
Powells Tire & Axle, System No.2670941
Radd Dew BBQ, System No.2672005
Razzle Dazzle Club, System No.2670927
Sandhills Links Inc, System No.2670879
Sugar Bears, System No.2670909
The Wizard Golf Course, System No.2670933
Thompkins MHP, System No.2660045

WACC EOC Greensea Head, System No.2670138
Waccatee Zoo, System No.2670915
Walker Variety and Auto, System No.2670924

Top of Page Back to County List

JASPER
Bobop's #10, System No. 2770909
Cooler's Grocery, System No. 2770913
Coosawhatchie, System No. 2770900
Dixie Boy Truck, System No. 2770212
Eddie's Shop & Wash, System No. 2770910
Flamingo Casino, System No. 2770906
Garbades General Store, System No. 2770914
Glitter's Casino, System No. 2770911
Handy Dans #2, System No. 2770904
Handy Dan's I, Tillman, System No. 2770915
Hardeeville, Town of, System No. 2710002
Levy Limehouse, System No. 2750029
Murray Grocery, System No. 2770917
Nezie's Drive In, System No. 2770206
Plantation Motel, System No. 2770205
Point South, System No. 2750028
Ridgeland, Town of, System No. 2710001
Sgt Jasper Park, System No. 2770600
Showboat Casino, System No. 2770912
Shuman's Grocery, System No. 2770916
State Line Casino, System No. 2770908
Store & Grill, System No. 2772002
Stuckey's #502 Po Boys, System No. 2770215
Stuckeys Restaurant, System No. 2770201
The Old House Smoke House, System No. 2772001
Thomas Heyward Academy, System No. 2770103
Tikton Hall, System No. 2760003
Travel World, System No. 2770907

Top of Page Back to County List

KERSHAW
Bethune, Town of, System No. 2810002
Bethune Rural I, System No. 2820006
Bethune Rural II, System No. 2820009
Builders Transport, System No. 2830009
Camden, City of, System No. 2810001
Cassat Water Co, System No. 2820005
Dupont-May, System No. 2830001
Elgin, Town of, System No. 2810004
Green Hills Golf, System No. 2870876
Lugoff-Elgin WA, System No. 2820001 (Groundwater Source)
Lugoff-Elgin WA, System No. 2820001 (Surface Water Source)
Mill Pond Rest, System No. 2870901
New South, System No. 2830010
Nonwoven, System No. 2830003
Nosoca Pines Ranch, System No. 2870675
Sharpe Shop, System No. 2870209

Top of Page Back to County List

LANCASTER
Belltown Bait & Tackle, System No. 2972001
Boral Bricks, System No. 2930005

Catawba River WTP, System No. 2920002
Faith Christian School, System No. 2970102
Kershaw, Town Of, System No. 2910003
Meltons MHP, System No. 2960001
Mr Gs Flat Creek, System No. 2970903
Springs-Grace Bleachery, System No. 2940001
UPST Heater Pleasant, System No. 2950006

Top of Page Back to County List

LAURENS
Camp Fellowship, System No. 3070679
Camp Fellowship, System No. 3070678
Clinton, City of, System No. 3010002
Cross Hill Country Store, System No. 3072000
Dillards MHP, System No. 3060005
Dockside Landing, System No. 3070852
Floydsville Community System 1, System No. 3050006
Hickory Tavern Recreational Center, System No. 3070675
Hunter and Blakely, System No. 3050003
Joanna KOA Campground, System No. 3070801
Johnsons BP, System No. 3070902
Lakeforest Drive, System No. 3050012
Lakeview Motel, System No. 3070402
Laurens Baptist Assembly, System No. 3070677
Laurens CPW, System No. 3010001
Laurens Proving Ground, System No. 3030005
Moon Landing, System No. 3070802
Ranch Road Water, System No. 3050008
Reeders Fishing Village, System No. 3060003
Skippers Landing, System No. 3070853
Sunset Point MHP, System No. 3050013
Time Out II, System No. 3070210

Top of Page Back to County List

LEE
A&T Quik Stop, Inc., System No. 3170900
Bishopville, Town of, System No. 3110001
L&W Citgo, System No. 3170207
SCPRT/Lee State Park Campground, System No. 3170601
SCPRT/Lee State Park Picnic Area, System No. 3170600

Top of Page Back to County List

LEXINGTON
AAA-Hilton Sound, System No. 3250024
AAA-Huntington Park, System No. 3250074
AAA-Ironstone S/D, System No. 3250096
AAA-Lakeside Forest 2, System No. 3250030
AAA-Mallard Bay, System No. 3250059
AAA-Mill Pond, System No. 3250075
AAA-Murray Hill Estate, System No. 3250014
Amicks Ferry, System No. 3250077
B&M Grocery, System No. 3270961
Basin Rock MHP, System No. 3260164
Batesburg-Leesville, Town Of, System No. 3210002
Boardwalk Villa, System No. 3270304
Boral Brick Lexington Plant, System No. 3230014
Bright Ideas, System No. 3270110
Bumgarner's MHP, System No. 3260033

Calks Ferry MHP, System No. 3260202
Camp Kinard, System No. 3270680
Caughman Meat, System No. 3230803
Cedar Acres, System No. 3270010
Cedar Grove Store, System No. 3270927
Chappel MHP, System No. 3260132
Cheap-O's Inc, System No. 3270949
Ciera MHP, System No. 3260171
Coldstream Country Club, System No. 3270877
Congaree Dairy Bar, System No. 3270207
Congaree Girl Scout #1, System No. 3270677
Congaree Girl Scout #2, System No. 3270685
Congaree Girl Scout #3, System No. 3270686
Cooper Creek Co, System No. 3270878
Country Cafe, System No. 3270231
Country Park, System No. 3260187
Creekside MHP, System No. 3260025
Cresthaven MHP, System No. 3260081
Crossroads Cafe, System No. 3272004
Crystal Pines, System No. 3250065
CWS Cedarwood, System No. 3250047
CWS Creekwood, System No. 3250042
CWS Falcon Ranches, System No. 3250016
CWS Glenn Village II, System No. 3250058
CWS Harborplace, System No. 3250081
CWS Harborside Condos, System No. 3270302
CWS Heatherwood Blue Ridge, System No. 3250015
CWS Hidden Valley, System No. 3250073
CWS I-20, System No. 3250012
CWS Idlewood, System No. 3250017
CWS Indian Fork, System No. 3250066
CWS Indian Pines, System No. 3250051
CWS Lands End Condos, System No. 3270300
CWS Mallard, System No. 3250076
CWS Peachtree Acres, System No. 3250045
CWS Smallwood, System No. 3250064
CWS The Landing, System No. 3250063
CWS Peachtree Acres, System No. 3250045
CWS Westside Terrace, System No. 3250002
CWS Windward Point, System No. 3250079
Depot Building Supply, System No. 3270962
Depot Food Stores, System No. 3270976
Dutchman Acres, System No. 3250028
Edmund Flea Market, System No. 3270958
Emerald Shores, System No. 3250088
Fisherman's Wharf, System No. 3270200
Four Oaks Farms, System No. 3230806
Gaston Copper, System No. 3230012
Gaston MHP Community, System No. 3260175
Gaston Rural, System No. 3220002
Gilbert-Summit W/D, System No. 3220001
Glendale Estates, System No. 3260103
Greenwood MHP, System No. 3260067
Halter Acres MHP, System No. 3260090
Halter MHP, System No. 3260042
Hard Knox MHP, System No. 3260183
Hardee's Quick Stop, System No. 3270930
Hermitage MHP, System No. 3260189
Hickory Hill MHP, System No. 3260115
Hidden Acres MHP, System No. 3260207
Hidden Oaks MHP, System No. 3260140

Hidden Valley, System No. 3260030
Hidden Valley CC, System No. 3270875
Hideaway MHP, System No. 3260127
Hillview MHP, System No. 3260104
Hwy #3 MHP, System No. 3260191
I-20 Speedway, System No. 3270980
Isle of Pines, System No. 3250062
Jackson MHP, System No. 3260005
Jake's Landing, System No. 3260048
Just Wright Grill, System No. 3272000
Key Foods, System No. 3230805
L&J's MHP, System No. 3260138
Lake Lodge Apartments, System No. 3270301
Laurel Meadows, System No. 3260185
Lazy Pines MHP, System No. 3260055
Lexington County Recreational, System No. 3270906
Lexington County Service Commission, System No. 3270907
Lucas's Store, System No. 3270227
McGregory Downs, System No. 3260059
Midland Hills MHP, System No. 3260182
Midstate Auto Auction, System No. 3270206
Mills MHP 1&2, System No. 3260050
Mineral Spring MHP, System No. 3260002
Miracle Wells Inc., System No. 3280000
Mr. B's III, System No. 3270925
Oak Grove School, System No. 3270102
Ole Timey Meat Market, System No. 3230807
Padgetts Grocery, System No. 3270956
Pine Island Club, System No. 3270681
Pine Ridge MHP, System No. 3260157
Pleasant Ridge MHP, System No. 3260147
Ponderosa MHHP, System No. 3260131
Putnams Landing, System No. 3270850
Rapha Residential Care, System No. 3270011
Red Oak MHP, System No. 3260064
Regency Square 2, System No. 3260170
Rolling Meadows, System No. 3260027
SCE&G South Recreational Area, System No. 3270679
SCWS Arrowhead Shores, System No. 3250036
SCWS Bellmeade S/D, System No. 3250031
SCWS Charwood, System No. 3250035
SCWS Emma Terrace, System No. 3250022
SCWS Fox Trail, System No. 3250038
SCWS Glenn Village, System No. 3250026
SCWS Hilton Place, System No. 3250072
SCWS Indian Cove S/D, System No. 3250020
SCWS Lake Village, System No. 3250054
SCWS Lakewood Estates, System No. 3250005
SCWS Lexington Estates, System No. 3250050
SCWS Lexington Farms, System No. 3250069
SCWS Milmont Shores, System No. 3250025
SCWS Murray Lodge, System No. 3250013
SCWS Murray Park Estates, System No. 3250019
SCWS Parkwood, System No. 3250029
SCWS Sangaree MHP, System No. 3260012
SCWS South Congaree, System No. 3250008
SCWS Tanya Terrace, System No. 3250023
SCWS The Estates @ Hilton, System No. 3250103
SCWS Varnsdale S/D, System No. 3250027
SCWS Windy Hill, System No. 3250057
Shady Acres, System No. 3250060

Shops of Horse Creek, System No. 3270936
Siesta Cove RV Park & Marina, System No. 3270802
Silver Lake MHP, System No. 3260022
Sizzlin Pig, System No. 3270985
South Oak MHP, System No. 3260165
South Oak MHP #2, System No. 3260204
Stephenson's Lake, System No. 3250018
Swansea Park, System No. 3270941
Swansea, Town of, System No. 3210006
Taners Mill S/D, System No. 3250095
Tiger Express #6, System No. 3270920
Triple Acres, System No. 3260049
Triple Acres MHP #2, System No. 3260029
US 1 Metro Flea Market, System No. 3270960
US Silica, System No. 3230005
USF Holland, System No. 3270959
Van Lott, System No. 3230013
West Columbia, City Of, System No. 3210004
Wild Meadows S/D, System No. 3250097
Wingard's MHP #2, System No. 3260174
Wintergreen Woods, System No. 3270932
YMCA Camp, System No. 3270678

Top of Page Back to County List

MARION
BJ Kitchen, System No. 3370210
Brittons Neck Elementary School, System No. 3370103
Brittons Neck High School, System No. 3370104
Hot Spot #2021, System No. 3372002
Little Pee Dee, System No. 3370205
Lou's Mart and Grill, System No. 3370211
Marco Rural Water Co, System No. 3320001
Marion, City of, System No. 3310001
Mullins, City of, System No. 3310002
Nichols, Town of, System No. 3310003
Wayside TP, System No. 3360005

Top of Page Back to County List

MARLBORO
Bennettsville, City of, System No. 3410001 (Groundwater Source)
Bennettsville, City Of, System No. 3410001 (Surface Water Source)
Blenheim Bottle, System No. 3430006
Camp Pee Dee, System No. 3470800
Clio, Town of, System No. 3410002
Girl Scout Camp, System No. 3470675
Marlboro Academy, System No. 3470107
Marlboro Water Co, System No. 3420001
McColl, Town of, System No. 3410003
Odom Apartments, System No. 3470301
Powell Mfg, System No. 3430005
Revells BBQ, System No. 3430801
Rogers MHP, System No. 3460008
Southern Oaks Restaurant, System No. 3470203
Stantons BBQ, System No. 3470200
Wallace Water Co, System No. 3420002

Top of Page Back to County List

MCCORMICK

B and B Grocery, System No. 3570210
Chigger Ridge, System No. 3570800
Hawe Creek, System No. 3570654
McCormick CPW, System No. 3510001 (Groundwater Source)
McCormick CPW, System No. 3510001 (Surface Water Source)
SCPRT Hamilton Branch, System No. 3570603

Top of Page Back to County List

NEWBERRY
Beckys Flea Mrt & Grill, System No. 3672000
Bo's Place, System No. 3672003
Boys Farm Inc., System No. 3670108
H.J. Smith Properties, System No. 3670903
Lakeview Country Store, System No. 3670902
Lesters Carryout, System No. 3672001
Newberry, City of, System No. 3610001
Newberry Co WS, System No. 3620002
Newberry Park Estates, System No. 3660003
Town of Prosperity, System No. 3610005
Saluda River Resort, System No. 3670800
Shealy MHP, System No. 3660001
The Que Stick, System No. 3670211
Three B Corner, System No. 3670904
USFS Indian Creek WC, System No. 3670652
Whitmire, Town of, System No. 3610004
Whites MHP, System No. 3660014
Top of Page Back to County List

OCONEE
Bay Ridge SD, System No. 3750027
Bucket T Cafe, System No. 3772000
Construction Yard, System No. 3730010
Craig Water and Sewer, System No. 3750008
Dixie Aluminum Prod, System No. 3730018
Fall Creek Village Campground, System No. 3770806
Fountain Head Water I, System No. 3780001
Jocassee RV Camp, System No. 3770803
Keowee Bay SD, System No. 3750026
Oconee Station, System No. 3770659
ONS Softball FL, System No. 3730015
Port Bass I, System No. 3750002
Port Bass II, System No. 3750012
Salem, Town of, System No. 3710001
SCPRT Devils Fork, System No. 3770608
SCPRT Oconee State Park, System No. 3770600
SCPRT Oconee State Park, System No. 3770606
Seneca, City of, System No. 3710002
Tamassee DAR, System No. 3770105
Timberlake I, System No. 3750006
Timberlake II, System No. 3750007
Tagaloo Environmental Research, System No. 3770916
Traders Junction, System No. 3770914
USFS Pickens RS, System No. 3770650
Walhalla, City of, System No. 3710004
Westminster CPW, System No. 3710003
Wild Water Ltd, System No. 3770909

Top of Page Back to County List

ORANGEBURG

A M Blount Cottages, System No. 3870419
Bells Marina, System No. 3870418
Bowman, Town of, System No. 3810004
Bowman Texaco, System No. 3870903
Branchville, System No. 3810005
Bull Swamp, System No. 3820001
Country Junction, System No. 3872000
Cypress Shores Marina, System No. 3870220
Elloree, Town of, System No. 3810003
Eutawville, Town of, System No. 3810006
Georgia Pacific, System No. 3830021
Georgia Pacific, System No. 3830001
Georgia Pacific Office, System No. 3830024
Holly Hill, Town of, System No. 3810002
Holnam Cement, System No. 3830002
I-95 Truck Stop, System No. 3870200
Lake Holly Hill Academy, System No. 3870111
Lake Marion Resort and Marina, System No. 3870852
Miller Landing, System No. 3860001
Mountaineer Motel and Campground, System No. 3870403
North, Town of, System No. 3810010
Old Pro Cover Co, System No. 3873001
Orangeburg DPU, System No. 3810001
Orangeburg Drag Strip, System No. 3870916
Prezzys MHP, System No. 3860018
Quick C Mart, System No. 3870905
R C Grocery, System No. 3870924
R T Blount MHP, System No. 3860007
Rocks Pond Campground, System No. 3870801
Santee, Town of, System No. 3810011
Santee Cabins, System No. 3870600
Santee Campground, System No. 3870601
Santee Campground #2, System No. 3870606
Santee Sports Club, System No. 3870907
Santee Swim Area, System No. 3870602
SCE&G-Cope Power Plant, System No. 3830003
Silver Springs, System No. 3820002
Slumberland Motel, System No. 3870401
Speedway Super Stop #8446, System No. 3870902
Springfield, Town of, System No. 3810009
Stricks One Stop, System No. 3870911
The Oaks Apartment, System No. 3870300
Vance Elementary School, System No. 3870102

Top of Page Back to County List

PICKENS
Aldersgate SD, System No. 3950002
Aunt Sues Country Store, System No. 3970204
Camp Ellenburg, System No. 3970680
Easley Central Water District, System No. 3920001
Easley Combined Utility, System No. 3910002
Gap Hill Landing No II, System No. 3970802
Gauley Falls WS, System No. 3950004
Keowee Camp, System No. 3970803
Laurel Lodge, System No. 3970201
McCall RA Camp, System No. 3970675
Mircle Hill Girls, System No. 3970111
Oolenay Visitors Center, System No. 3970910
Pickens, City of, System No. 3910001
River Bluff SD, System No. 3950005

Rocky Bottom Camp Blind, System No. 3970677
SCPRT-Keowee Toxaway, System No. 3970604
Table Rock Resort, System No. 3970300
Table Rock State Park, System No. 3970607
Twin Lakes Campground, System No. 3970651
Victorious Valley Home, System No. 3970909
Wesleyan Camp, System No. 3970800

Top of Page Back to County List

RICHLAND
AAA/Fairlawn SD, System No. 4050009
Albene Park SD, System No. 4050007
All Gods Children Daycare, System No. 4070131
American Avenue Property, System No. 4050032
Any Day Inn, System No. 4070400
Ashley Acres N. (Taki MH Ranch), System No. 4060038
Ashley Oaks, System No. 4050030
Ballentine Park, System No. 4070679
Bays BBQ, System No. 4072004
Bel-Aire MHP, System No. 4060009
Bettys Daycare, System No. 4070119
Big T's Bar-B-Q, System No. 4070226
Blythewood Middle School, System No. 4070129
Capital Heights-Bay Berry, System No. 4050031
Cedar Creek MHP, System No. 4060035
Center Express, System No. 4070925
Charleswood SD, System No. 4050008
Columbia, City of, System No. 4010001
Congaree Convenience Store, System No. 4070949
Congaree Swamp national Monument, System No. 4070600
Cresthaven MHP, System No. 4060001
Crossroad Community Care, System No. 4070112
Drawdes MHP, System No. 4060052
Eastover, System No. 4010002
Farrow Wood Estates, System No. 4050012
Franklin Park, System No. 4050016
Freeway MHP, System No. 4060005
Gadsen Elementary, System No. 4070100
Harmon Hill, System No. 4050011
Heater/Springfield Acres, System No. 4050006
High Chapparall, System No. 4060006
Hopkins Elementary, System No. 4070102
Hopkins Jr High, System No. 4070101
Hopkins Park, System No. 4070675
Horrell Hill MHP, System No. 4060014
Huron Tech Corp, System No. 4030013
Kountry Kitchen, System No. 4070233
Lake Murray Marina, System No. 4070204
Lake Wood MHP, System No. 4060032
Lands Point SD, System No. 4050004
Lower Richland MHP, System No. 4060012
Manchester Farms, System No. 4030801
McDonalds MHP, System No. 4060010
Metal Fabricators, System No. 4030004
Myers Day Care, System No. 4070113
New Light Day Care, System No. 4070125
Northgate MHP, System No. 4060055
Percival Estates, System No. 4060021
Pinewood Community Care, System No. 4070910
Polo Road Park, System No. 4070677

Powells II MHP, System No. 4060020
Progressive Church, System No. 4070941
Ralphs MHP, System No. 4060058
Richtex Brick, System No. 4030007
S&S Corner Mart, System No. 4070935
Sandy Hill MHP - Lot #39, System No. 4060064
Scallon Productions, System No. 4030008
SCE&G Wateree Station, System No. 4030001
SCWS - Oakridge Hunt Club, System No. 4050019
SCWS - Raintree Acres, System No. 4050015
Sedgewood Country Club, System No. 4070876
Sharp's Shoppe #2, System No. 4072000
Sikes Bar-B-Q, System No. 4070203
SMI Joist Lower Richland, System No. 4030003
Spivey's 66, System No. 4070914
Spring Valley MHP, System No. 4060019
Stonegate, System No. 4050014
Stop and Munch, System No. 4070940
Tabias Inc., System No. 4070927
The Last Stop, System No. 4072002
Union Camp, System No. 4030005
Videomania, System No. 4070231
Washington Heights, System No. 4050013
Whales Tail, System No. 4070217
Wildwood Forest MHP, System No. 4060024
Winsor Valley MHP, System No. 4060008
Woodsmoke Campground, System No. 4070680

Top of Page Back to County List

SALUDA
AAA/Perry WS, System No. 4150007
Amicks Poultry, System No. 4130803
Barn Campground, System No. 4170802
Blacksgate East, System No. 4150005
Blacksgate West, System No. 4150004
Gentry Poultry, System No. 4130803
Hornes Grocery, System No. 4170901
International Paper Johnson Plant, System No. 4130002
J Forrest R Spring Camp, System No. 4171000
Jimmy Forrest Labor Camp, System No. 4171011
L & B Resident Care, System No. 4170001
Little River Marina, System No. 4170803
Longs Residential Care, System No. 4170002
MPP Frick Camp 16, System No. 4171005
MPP Hare Camp, System No. 4171007
MPP Possum Hollow Camp, System No. 4171008
Saluda Waters SD, System No. 4150010
Top of Page Back to County List

SPARTANBURG
Brannons Restaurant, System No. 4270234
Inman Mills WD, System No. 4220001
Inman Mills WD, System No. 4220002
City of Landrum, System No. 4210003
Oakridge Country Club, System No. 4270875
Pioneer Fish Camp, System No. 4270206
Rainbow Park MHP, System No. 4260039
Riverdale Mills WD, System No. 4220008
SCPRT Crofts State Park, System No. 4270603
Spartanburg Boys Home, System No. 4270108

Spartanburg Water System, System No. 4210001
Stinley, Jackson, Wellford, Duncan Water District, System No. 4220006

Top of Page Back to County List

SUMTER
American MHP, System No. 4360012
Borrowed Money, System No. 4370919
Buckhorn Ranch, System No. 4370211
Camp Burnt Gin, System No. 4370675
Camp Mac Boykin, System No. 4370677
Cedar Hills MHP, System No. 4360010
Country Fixins Bar-B-Que, System No. 4372000
Cresent MHP, System No. 4360011
CWS Pocalla Development, System No. 4350007
Dalzell, Town of, System No. 4320001
Don Mar RV Sales, System No. 4370921
Eagle Inn Motel, System No. 4370408
Ebenezer Daycare, System No. 4370127
Ebenezer Middle School, System No. 4370103
Goodwill Headstart, System No. 4370119
Granada SD, System No. 4350008
Griffin MHP, System No. 4360067
Headquarters Store, System No. 4370917
High Hills, System No. 4320003
Ideal TP, System No. 4360031
Jack's Superette, Inc., System No. 4370918
Laidlaw Environmental Services of SC, System No. 4330010
Lees TP, System No. 4360046
Mayesville, Town of, System No. 4310003
Mayewood Middle School, System No. 4370110
Oaklawn MHP, System No. 4360008
Palmetto Pigeon Processing Plant, System No. 4330805
Paxville Superette, System No. 4370922
Pineview Golf Club, System No. 4370909
Pinewood, Town of, System No. 4310002
Pocalla Country Club, System No. 4370875
Quail Hollow SD, System No. 4350014
Rafting Creek School, System No. 4370106
RE Davis Elementary, System No. 4370109
Rembert, Town of, System No. 4310004
Roy Hudgins Academy, System No. 4370112
SCPRT/Poinsett State Park, System No. 4370601
SCWS Oakland Plantation SD, System No. 4350006
Shaw Oaks MHP, System No. 4360069
Shop and Go Grill, System No. 4370230
St Johns Daycare, System No. 4370124
St Johns Elementary, System No. 4370111
Sumter, City of, System No. 4310001
Sumter Wessex SD, System No. 4350016
Super 8 Motel, System No. 4370411
Thistle Cove, System No. 4320004
Wateree Correctional Institution, System No. 4370050
Wedgefield Statesburg, System No. 4320002
Whispering Pines MHP, System No. 4360021
Woods Bay State Park, System No. 4370604
Top of Page Back to County List

UNION
Carlisle Cone Mills, System No. 4430003
City of Union, System No. 4410001

Top of Page Back to County List

WILLIAMSBURG

Battery Park School, System No. 4570100
Cades Hebron Elementary, System No. 4570103
Coopers Country Store, System No. 4570922
D P Cooper Elementary, System No. 4570101
Fermpro, System No. 4530001
Greeleyville, Town of, System No. 4510001
H & S Mingo Shop, System No. 4570924
Hemingway, Town of, System No. 4510004
House of Raeford, System No. 4530004
Kennys BBQ, System No. 4572009
Kingstree, Town of, System No. 4510002
Lane, Town of, System No. 4510005
M & M Country Store, System No. 4570907
Morees BBQ, System No. 4570203
Nesmith Community Day Care, System No. 4570115
Nesmith Covenience Store, System No. 4570911
Oceda Grocery, System No. 4570917
Rock Bluff SD, System No. 4550001
Santee Grocery, System No. 4570931
Scotts BBQ, System No. 4572004
St Mark School, System No. 4570107
Stucky, Town of, System No. 4510003
Trio Mini Mart, System No. 4570909
Watfords Grocery, System No. 4570932

Top of Page Back to County List

YORK

Across the Border, System No. 4670937
Adnah Hills MHP, System No. 4660115
Associated Telecom Inc, System No. 4630046
Beaver Creek MHP, System No. 4660033
Bethany School, System No. 4670101
Bethel Day Care, System No. 4670110
Bethelwood Center, System No. 4670900
Bethesda Pres Child Development, System No. 4670120
Blessed Hope School, System No. 4670106
Camp Catawba Girl Scout, System No. 46708032
Carolina Downs, System No. 4670964
Carroll MHP I, System No. 4660087
Carroll MHP II, System No. 4660088
Catawba Baptist Child Development Center, System No. 4670118
Catawba Community Care, System No. 4670001
Cedar Valley MHP, System No. 4660009
Celanese Acetate LLC, System No. 4630007
Chucks MHP, System No. 4660077
Clover, Town of, System No. 4610006
Commercial Fleet, System No. 4630026
Country Oaks SD, System No. 4650020
Country Store, System No. 4670236
Crenco, System No. 4670963
Cross Roads Amoco, System No. 4670967
Crystal Springs Golf Club, System No. 4670877
Culp Circle SD, System No. 4650003
CWS - Tega Cay, System No. 4650005
CWS River Hills SD, System No. 4650006
D N P Cash and Carry, System No. 4672000

Dulins Well, System No. 4650013
Duncan MHP, System No. 4660093
EFP Products, System No. 4630052
Farm Pond UST, System No. 4650056
Farmers Meat Ct, System No. 4630801
Fast Bucks, System No. 4670943
Fern Forest, System No. 4660001
Forest Estates, System No. 4660112
Forest Lake Estates, System No. 4650045
Fort Mill Academy, System No. 4670111
Gemstone Village, System No. 4670930
Gnatos Acres, System No. 4650010
Goods MHP, System No. 4660098
Grannys Kitchen, System No. 4670240
Handle's Bar & Grill, System No. 4672002
Henson MHP, System No. 4660111
Hickory Grove, System No. 4610004
Jamestown, System No. 4650055
Kimbrells MHP, System No. 4660055
Kings Court SD, System No. 4650011
Kings Mountain National Military Park, System No. 4670650
Lake Wylie MHP, System No. 4660081
Lakeview MHP, System No. 4660023
Lambert MHP, System No. 4660108
Little Country Chevron, System No. 4670225
Lost Colony, System No. 4650019
Macks Grill, System No. 4670220
McAfees MHP, System No. 4660008
McCon Mart, System No. 4670255
McConnells Corner Mart, System No. 4670958
Middle Stream SD, System No. 4650052
Mountainview MHP, System No. 4660064
Mt Holly Fish Camp, System No. 4670218
Nivans Handy Mart, System No. 4670247
Oak Pond Manor, System No. 4670114
Pack and Snack, System No. 4670251
Passmore Grill, System No. 4670206
Petro Peddlers, System No. 4670981
Pharr Yarns, System No. 4630005
Pinecrest MHP, System No. 4670802
Portors Motel, System No. 4670400
Quail Meadows Park, System No. 4660063
Rainbow Day Care, System No. 4670119
River Pines SD, System No. 4650002
Fort Mill Ford, System No. 4670946
River Rat Restaurant, System No. 4670254
Riverstop Inc, System No. 4670850
Rock Hill, City of, System No. 4610002
Rock Hill Motel & MHP, System No. 4660003
Rons BBQ, System No. 4672004
SC DOR-DMV, System No. 4670901
Scotland Yard MHP, System No. 4660105
SCPRT Kings Mountain Camp C, System No. 4670881
SCPRT Kings Mountain Camp Y, System No. 4670880
SCPRT Kings Mountain Crawford, System No. 4670603
Screen Printing, System No. 4630008
Serenity Club, System No. 4670878
Sharon, Town of, System No. 4610005
Shaws Food Store, System No. 4670913
Shell Inn, System No. 4670223
Shield of Faith, System No. 4670957

Smith Circle, System No. 4650039
Stone Hill MHP, System No. 4660067
Tara Plantation, System No. 4650050
TC Shaved Ice, System No. 4670977
The Boys Home, System No. 4670500
Tracy Trigg Inc, System No. 4670801
Twin Lakes MHP, System No. 4660007
UPST Heater - Brown Borough, System No. 4650061
UPST Heater - Brown Neal, System No. 4650047
UPST Heater - Cameron Acre, System No. 4650059
UPST Heater - Carowood, System No. 4650035
UPST Heater - Foxwood, System No. 4650008
UPST Heater - Hidden Lake, System No. 4650040
UPST Heater - Mallard Lake, System No. 4650057
UPST Heater - Pepperidge, System No. 4660101
UPST Heater - Pinetuck, System No. 4650015
UPST Heater - Pollys Circle, System No. 4660073
UPST Heater - Ridgewood, System No. 4650031
UPST Heater - Southbend Estate , System No. 4660100
UPST Heater - Springlake, System No. 4650012
UPST Heater - Windwood, System No. 4650034
UPST Heater - Windy Run, System No. 4650048
UPST Heater - Winterwood, System No. 4650017
UPST Heater - Woodbridge, System No. 4650028
USSC - Shiloh Quarters, System No. 4660092
UST Heater - Barney Rhett, System No. 4650018
UST Heater - Hickory Hills, System No. 4650025
UST Heater - Kims Acres, System No. 4650041
UST Heater - Lesslie Woods, System No. 4650051
UST Heater - Lessliedale, System No. 4660095
UST Heater - Old Farm, System No. 4650042
UST Heater - Olympic Acres, System No. 4650053
UST Heater - Riverbend Estate, System No. 4660103
UST Heater - Shandon , System No. 4650009
UST Heater - Valleymere, System No. 4650046
Versatile Knits, System No. 4630047
Village Market, System No. 4670975
Water Lynn Downs, System No. 4660045
Wesleywood UST, System No. 4650016
Whitmore MHP, System No. 4660036
Willwood SD, System No. 4650004
Worthington Steel, System No. 4630003
Worthy Boys Camp, System No. 4670976
York, City of, System No. 4610001 (Groundwater Source)
York, City of, System No. 4610001 (Surface Water Source)
York Electric Coop Inc, System No. 4630016

Top of Page Back to County List

Contacts for Source Water Assessment Program

For more SWAP information,
contact: David Baiz
4272 or e-mail at *baizedg@dhec.sc.gov*
Rob Devlin at (803) 898-3798 or e-mail at *devlinrj@dhec.sc.gov*
Chris Wargo at (803) 898-3799 or e-mail at *wargoca@dhec.sc.gov*

Top of Page

See 2.3 Ref 27
SCDHEC 2004

Section 2.3.3 Ref.

A draft 2006 303(d) list is available below for review and comment. Please submit written comments to the attention of Richelle Tolton, Bureau of Water, SCDHEC, 2600 Bull Street, Columbia, South Carolina 29201. To be considered, written comments on the draft list must be received by 5:00 PM on March 6, 2006.

- **2006 303(d) Draft List** - State of South Carolina Integrated Report Part I: Listing of Impaired Waters (PDF-435KB)
  2006 305(b) Report - State of South Carolina Integrated Report Part II: Assessment and Reporting
- **2004 303(d) List** - State of South Carolina Integrated Report Part I: Listing of Impaired Waters (PDF-341 KB) **2004 305(b) Report** - State of South Carolina Integrated Report Part II: Assessment and Reporting
- **2002 303(d) List** (PDF-463 KB)
- **2000 303(d) List** (PDF-235 KB)
  - *Supplement to the 2000 303(d) List* - January 2001 (PDF-128KB)
  - *Supplement concerning Enoree River (BE-017)* - October 2001 (PDF-59K)
  - *Supplement to the 2000 303(d) List* - January 2002 (PDF-280KB)
- **1998 303(d) List**

Links

Exit DHEC Links to non-DHEC organizations found at this site are provided solely as a service to our users. The links do not constitute an endorsement of these organizations or their programs. DHEC is not responsible for the content of the individual organization web pages found at these links.

EPA Region IV TMDL Program
SCDHEC Watershed Management Program

EPA BASINS Training for TMDL Development
Hosted by: Utah State University http://www.tmdl.org/basins/

Contact: Mihir Mehta

EG-183

The State of South Carolina's 2004 Integrated Report
Part I: Listing of Impaired Waters

INTRODUCTION

The South Carolina Department of Health and Environmental Control (Department) developed this priority list of waterbodies pursuant to Section 303(d) of the Federal Clean Water Act (CWA) and Federal Regulation 40 CFR 130.7 last revised in 1992. The listing identifies South Carolina waterbodies that do not currently meet State water quality standards after application of required controls for point and nonpoint source pollutants. Use attainment determinations were made using water quality data collected from 1998-2002. Pollution severity and the classified uses of waterbodies were considered in establishing priorities and targets. The list will be used to target waterbodies for further investigation, additional monitoring, and water quality improvement measures, including Total Maximum Daily Loads (TMDLs).

Over the past three decades, impacts from point sources to waterbodies have been substantially reduced through point source controls achieved via National Pollutant Discharge Elimination System (NPDES) permits. Since 1990, steady progress in controlling nonpoint source impacts has also been made through implementation of South Carolina's Nonpoint Source Management Program. In conjunction with TMDL development and implementation, the continued expansion and promotion of these and other state and local water quality improvement programs are expected to be effective in reducing the number of impaired waterbodies.

In compliance with 40 CFR 25.4(c), the Department issued a public notice in a statewide newspaper February 5, 2004, to ensure statewide notice of the Department's intent to update its list of impaired waterbodies. Public input was solicited. The notice included a person to contact for information regarding the development of the list and asked for comments regarding the draft listing and methodology. The notice allowed for a thirty-two day comment period in which to respond. The Department also provided notice to interested parties, including environmental groups, industries, private individuals, local governments, universities, research groups, other state agencies, and the USEPA. The Department also posted the public notice and the draft list on its Internet website.

Additional public input was solicited through regular interactions between Department staff, interested members of the public, and other resource agencies. Bureau of Water Watershed Managers have regular interaction with stakeholders throughout the eight major river basins during stakeholder meetings, educational events, and individual contact sessions. Through this process valuable information is received which supports list development and TMDL prioritization. Public participation in the §303(d) process will continue in accordance with the Department's watershed approach.

METHODOLOGY FOR DELISTING WATERBODIES FROM THE 2002 §303(d) LIST

The Department reviewed the final 2002 §303(d) list as the starting point for the development of the 2004 §303(d) list. All waterbodies on the 2002 §303(d) listing were evaluated for appropriate inclusion on the 2004 §303(d) list as defined in 40 CFR 130.2(j), and the August 27, 1997, EPA Guidance Memorandum, National Clarifying Guidance for State and Territory §303(d) Listing Decisions.

Good cause for delisting of waterbodies from the 2002 §303(d) list include the following: 1) the most recent data and information indicate that water quality standards are being met, 2) a TMDL has been developed and approved, and 3) the listing analysis conducted for the 2002 list contained errors (e.g., laboratory reporting error, QA/QC requirements not met, legal ruling). Any one or combination of these reasons may be used by the Department to delist waters.

Some waterbodies that were listed on the 2002 §303(d) list have been renamed or found to be in another watershed. These waterbodies appear on the 2004 §303(d) list under the new name or appropriate watershed. Waterbodies listed for "BIO" (biological impairment, cause unknown) on the 2002 list have been removed for BIO if a pollutant responsible for the impairment has been identified. These waterbodies remain on the list for that pollutant and TMDLs will be developed for the pollutant of concern. Other waterbodies have been removed from the list when biological data have shown full use support despite other chemical and/or physical standards excursions.

Waterbodies that appeared on the 2002 §303(d) list that do not meet these justifications delisting remain on the 2004 §303(d) list.

METHODOLOGY FOR LISTING: THE SOUTH CAROLINA 2004 §303(d) LIST

In accordance with federal guidelines, the Department evaluated waterbodies identified as impaired for appropriate inclusion on the 2004 §303(d) list. The Department uses a watershed approach, as encouraged in the August 8, 1997, EPA Guidance Memorandum: New Policies for Establishing and Implementing Total Maximum Daily Loads, to perform its permitting and water quality monitoring. This approach divides the state into five major river basin groups. Permitting and monitoring are performed according to a schedule that cycles through all basins in a five-year period. Information on SCDHEC's Watersheds Program can be found at: http://www.scdhec.gov/water.

The Department has an extensive fixed ambient surface water monitoring network throughout the state with more than 650 stations. The SCDHEC monitoring effort also includes 465 shellfish sanitation stations, 75 aquatic macroinvertebrate stations, approximately 100 fish tissue stations, and several phytoplankton stations. Since 2002 a set of probability based, or "random" sampling stations has been added to the Department's water quality monitoring strategy. The use of this sampling methodology enhances the ability to make statistically valid inferences about large watershed areas based on a relatively few sampling stations. In collaboration with USEPA, approximately 90 random stations per year were included in the Department's monitoring program. DHEC's total monitoring effort for the assessment used for this 303(d) list included over 1131 stations and 196,000 water quality tests. DHEC's monitoring strategy can be found on the Internet at http://www.scdhec.gov/eqc/water/pubs/strategy.pdf.

The cyclical nature of the Department's permitting, monitoring, and data analysis results in a dynamic §303(d) listing. As new waters are monitored, new impaired sites may be discovered which require listing. As a result of increased monitoring, some waterbodies have been added to the 2004 §303(d) list. In compliance with water quality standards (SC Regulation 61-68), waterbodies with standards excursions attributable solely to natural conditions are not included on South Carolina's 303(d) list.

The Department has considered the South Carolina Short List of waterbodies which was prepared in 1989 pursuant to Section §304(l) of the CWA. This "one-time" §304(l) Short List identified waterbodies where the State did not expect applicable water quality standards to be achieved after technology-based requirements had been met due entirely or substantially to point source discharges of §307(a) toxics. The §304(l) Short List was considered as required, but not used for development of the 2004 §303(d) list since those water quality problems have already been addressed. If current data and information on water quality for the specific water bodies included on the 1989 §304(l) list ever indicate less than full support of uses, they will be included on the 303(d) list.

Sources of Data and Information and Their Use

For this listing cycle, the Department actively solicited data and information for the specific purpose of §303(d) listing. The Department has a standing data solicitation year round. This solicitation can be found on DHEC's website at: http://www.scdhec.gov/water/html/tmdl.html

In addition, a solicitation notice was directly emailed to all state institutions known to collect environmental data (e.g., research universities). Traditionally multiple sources of information have been considered when compiling the South Carolina §303(d) list. The Department has reviewed a comprehensive assemblage of sources of readily available data and information, including federal agencies, local governments, other state agencies, 319 project grantees, academic institutions, NPDES compliance contractors, and volunteer monitoring groups. The following data sources were considered for the 2004 303(d) listing:

DHEC: Environmental Quality Control

- Water chemistry and biological data from over 740 surface water, and sediment monitoring sites
- Approximately 465 shellfish growing monitoring sites
- Fish, oyster, and crab tissue monitoring data
- Stream macroinvertebrate assessments
- Lake water quality assessment data (§314)
- Environmental Surveillance Oversight Program (Savannah River Site)
- State Nonpoint Source Management Plan (§319)
- §304(l) Short List
- State Watershed Water Quality Assessments
- Special studies or general knowledge

Other biological data

- Adler Biological Consulting
- Coastal Science Associates, Inc.
- E.T.T. Environmental, Inc.
- North Carolina Department of Environment and Natural Resources
- Shealy Environmental Services, Inc.
- South Carolina Public Service Authority (Santee Cooper)
- Swearingen Ecology Associates
- United States Fish and Wildlife Service
- South Carolina Department of Natural Resources

Other tissue data

- Georgia Department of Natural Resources
- National Marine Fisheries Service
- United States Environmental Protection Agency
- North Carolina Department of Environment and Natural Resources
- Florida Department of Environmental Protection
- University of Texas

Other chemical and bacteriological data

- United States Geological Survey
- Haile Mining Company
- Breedlove Dennis Young and Associates, Inc.
- Clemson University Extension Service
- Friends of Lake Keowee Society
- Lower Saluda River Scenic Advisory Council
- Coastal Carolina University
- University of South Carolina
- National Oceans and Atmospheric Administration
- Furman University
- Clemson University
- Newberry Soil and Water Conservation District
- Research Planning Institute Inc.
- Lancaster Soil and Water Conservation District
- Pee Dee RC&D Council
- City of Isle of Palms
- Horry County

Other Water Quality Information

- Lake Murray Association
- Wateree Homeowners Association

The Department's Quality Assurance Management Plan (QAMP) has been approved by the EPA as part of its requirements under Section 106 of the CWA. All data and information sources used for the 2004 §303(d) list were reviewed in accordance with the QAMP. All data and information used were readily accessible and met the Department's criteria for quality assurance. A checklist of QA/QC considerations used by the Department can be found at:

http://www.scdhec.gov/water/pubs/qaqc.pdf

The following is a brief description of how the above data and information were used by the Department to support determinations for aquatic life, recreation, and other designated uses.

DETERMINATION OF ATTAINMENT OF CLASSIFIED USES

Physical, chemical, and biological data were evaluated, as described below, to determine if water quality met the criteria established to protect the State classified uses as promulgated in Regulation 61-68, Water Classifications and Standards. These regulations are subject to a triennial review as required in section 303 of the Clean Water Act. To determine the appropriate classified uses and water quality criteria for specific waterbodies and locations, refer to Regulation 61-69, Classified Waters, in conjunction with Regulation 61-68. These regulations are located on the Internet at http://www.scdhec.gov/water under Laws and Regulations.

The use attainment decision process follows the basic approach set forth in the USEPA guidance for the preparation of state §305(b) water quality assessments.

Aquatic Life Use Support

One important goal of the Clean Water Act and state standards is to maintain the quality of surface waters to provide for the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Aquatic life use support is assessed by comparing important water quality characteristics to criteria. Support of aquatic life uses is determined based on the percentage of criteria excursions and, where data are available, the composition and functional integrity of the biological community. Among the parameters assessed are: dissolved oxygen, pH, toxicants (priority pollutants, heavy metals, chlorine, ammonia), nutrients, and turbidity. If the conclusion for any one parameter is that the criterion is not met, then it is concluded that aquatic life use is not supported and the waterbody is thus listed as impaired.

A number of waterbodies have been given waterbody-specific criteria for pH and dissolved oxygen, which reflect natural conditions. To determine the appropriate criteria and classified uses for specific waterbodies and locations, please refer to Regulation 61-68, Water Classifications and Standards, and Regulation 61-69, Classified Waters.

For DO and pH, if 10 percent or less of the samples contravene the appropriate criterion, then the criterion is said to be fully supported. A percentage of criterion excursions greater than 10% indicates impairment and results in inclusion on the current 303(d) listing, unless excursions are due to natural conditions. Blackwater systems in the Sandhills and Coastal Plain are frequently characterized by naturally low pH and dissolved oxygen concentrations, as are many tidally influenced systems along the coast.

For toxicants such as heavy metals, priority pollutants, chlorine, ammonia, etc., if the appropriate acute aquatic life criterion is exceeded more than once in five years, the waterbody is listed as impaired.

For turbidity in all waters, and for waters with numeric total phosphorus, total nitrogen, and/or chlorophyll-a criteria, if the appropriate criterion is exceeded in more that 25 percent of the samples, the criterion is not supported and the waterbody is listed as impaired.

For aquatic life uses, the goal of the standards is the protection of a balanced indigenous aquatic community. Therefore, biological data are the ultimate deciding factor, regardless of chemical conditions. If biological data indicated a healthy, balanced community, the use is considered supported even if chemical parameters do not meet all applicable criteria. Likewise, an impaired biological community results in a listing regardless of supporting aquatic chemistry. Aquatic and semi-aquatic macroinvertebrates are identified to the lowest practical taxonomic level depending on the condition and maturity of specimens collected. The EPT Index (Ephemeroptera, Plecoptera, Trichoptera) and the North Carolina Biotic Index (BI) are the main indices used in analyzing macroinvertebrate data.

Recreational Use Support

The degree to which the swimmable goal of the Clean Water Act is attained (Recreational Use Support) is based on the frequency of fecal coliform bacteria excursions. Standards for primary contact recreation were derived from public health data that estimate the potential risks to humans of contracting waterborne illnesses after swimming due to exposure to sewage related pathogens. For fecal coliform bacteria, an excursion is an occurrence of a concentration greater than 400/100 ml for all classes. If 10 percent or less of the samples are greater than 400/100 ml then recreational uses are said to be fully supported. A percentage of criteria excursions greater than 10% indicates impairment of recreational uses and the waterbody is listed.

Fish and Shellfish Consumption

Fish consumption use support is determined by the occurrence of advisories on human consumption for a given waterbody. For the support of consumption uses, an advisory which prohibits or restricts fish consumption indicates nonsupport of uses. Shellfish use support is determined by the harvesting status for a given shellfish harvesting area. For harvesting uses, an advisory that prohibits or restricts shellfish harvesting indicates nonsupport of uses.

Fish consumption advisories and shellfish sanitation information are updated periodically. For background information and the most up-to-date advisories please visit the DHEC Bureau of Water webpage at http://www.scdhec.gov/water/ and click on "Fish Advisories" beneath the Water Program Index. For shellfish growing area status reports click on “Shellfish Information”.

TMDL DEVELOPMENT: METHODOLOGY FOR TARGETING IMPAIRED WATERBODIES

The *Integrated Report Part I: Listing of Impaired Waters* serves to identify those sites that need additional management actions to meet water quality standards. TMDL (Total Maximum Daily Load) development is one way in which the Clean Water Act §303(d) was intended to promote these management actions. TMDLs will be developed for all §303(d) listed sites pursuant to EPA guidance.

A TMDL is a calculation of the maximum amount of a specific pollutant that a waterbody can receive and still meet water quality standards. It is the sum of the allowable loads of a given pollutant from all contributing point and nonpoint sources. It also incorporates a margin of safety and consideration of seasonal variation. For an impaired waterbody, the TMDL document specifies the level of pollutant reductions needed for waterbody use attainment. Targeting for TMDL development is necessary to focus limited technical and monetary resources. TMDLs targeted for completion over the next two years were based on the following factors:

> Severity of pollution
> Classified Use
>Aquatic endangered species: Species present and potentially adversely affected by a pollutant.
> Adequacy of existing and readily available data and information for TMDL development
> Adequacy of existing technical tools for TMDL development
> Hydrologic connection, allowing "nesting" or "bundling" of TMDLs
> Identified funding or cooperators
> Degree of public interest and support for improvement of the waterbody
> Ongoing activities and water quality related initiatives in the watershed
> Recreational, economic, and aesthetic importance
> Other national and departmental priorities and policies

In cooperation with EPA Region IV, SCDHEC Bureau of Water has developed TMDLs. At the time of publication of this list seventy-one TMDLs have been approved by EPA in South Carolina. An updated listing of approved and draft TMDLs can be found at DHEC's TMDL webpage: http://www.scdhec.gov/water/html/tmdl.html.

These approved TMDLs have been incorporated into the Department's Continuing Planning Process in accordance with Section 303(e) of the Clean Water Act. A program for accelerated TMDL development is currently underway.

TMDL IMPLEMENTATION

DHEC Watershed Program staff has initiated a process for implementation of approved TMDLs. The Department's TMDL implementation program also includes stakeholder involvement and funding assistance. Periodically, requests for proposals are made for projects that will implement the nonpoint source components of existing TMDLs. Interested persons may send a message to tmdl@dhec.sc.gov to be notified of grant opportunities.

As of April 2004 seven such TMDL implementation projects have been funded. Implementation of TMDLs involving point sources is occurring through departmental NPDES permitting mechanisms. South Carolina's TMDL implementation plan for nonpoint sources can be viewed on the web at:

http://www.scdhec.gov/eqc/water/html/npsplan.html

LIST OF IMPAIRED WATERS

The South Carolina 2004 §303(d) list follows. Waterbodies are listed by point locations; however, the impairment is considered to extend for some distance upstream and/or downstream of the point location listed. The extent of the impairment of the waterbodies is determined during TMDL development and implementation.

The column headings included on the South Carolina 2004 list of impaired waters refer to the following:

BASIN – One of eight major basins contained in the State

HYDROLOGIC UNIT – Sub-basin unit in which the water body is located

LOCATION – Name and brief description of the location of the impaired waterbodies

STATION – The Department's station code where samples were collected

COUNTY – County in which station is located

USE – Use support impairment for aquatic life and/or recreational uses

Aquatic Life Use: AL
Fish Consumption: FISH
(For information on the full extent of fish advisories, see the current Fish Consumption Advisories on our website at http://www.scdhec.gov/eqc/admin/html/fishadv.html)
Recreational Use (Swimming): REC
Shellfish Harvesting: SHELLFISH
(For information on the current shellfish harvesting areas status, see the current Annual Update Reports on our website at http://www.scdhec.gov/water/html/shellfish.html)

CAUSE – Pollutant(s) that resulted in impaired classified use. The parameters are denoted as follows:

Chlorophyll A: CHLA
Chromium: CR
Mercury: HG
Copper: CU
Dissolved Oxygen: DO
Fecal Coliform Bacteria: FC
Hydrogen Ion Concentration: PH
Total Nitrogen: TN
Cadmium: CD
Macroinvertebrate: BIO
Turbidity: TURBIDITY
Total Phosphorus: TP
Polychlorinated Biphenyls: PCB
Nickel: NI
Zinc: ZN
Organotins: ORGANOTINS

NOTE –
* TMDL to be developed within two years
# Further investigation planned

2004 SC List of Imp ers by 11-Digit HUC

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
BROAD	03050106020	TURKEY CK AT SC 9, 14 MI NW OF CHESTER	B-136	CHESTER	REC	FC	*
BROAD	03050106030	MENG CK AT SC 49 2.5 MI E OF UNION	B-064	UNION	REC	FC	*
BROAD	03050106030	BROWNS CK AT S-44-86, 8 MI E OF UNION	B-155	UNION	REC	FC	*
BROAD	03050106030	TRIB TO MENG CK AT CLVT ON S-44-384 3 MI E OF UNION	B-243	UNION	REC	FC	*
BROAD	03050106030	GREGORYS CK AT S-44-86, 8 MI E OF UNION	B-335	UNION	REC	FC	*
BROAD	03050106040	DRY FORK AT S-12-304 2 MI SW OF CHESTER	B-074	CHESTER	AL	DO	
BROAD	03050106040	DRY FORK AT S-12-304 2 MI SW OF CHESTER	B-074	CHESTER	REC	FC	*
BROAD	03050106040	SANDY RVR AT SC 215 2.5 MI AB JCT WITH BROAD RVR	B-075	CHESTER	REC	FC	*
BROAD	03050106050	HELLERS CRK. AT SR 97	B-151	NEWBERRY	AL	BIO	
BROAD	03050106050	MONTICELLO LK-LOWER IMPOUNDMENT BETWEEN LARGE ISLANDS	B-327	FAIRFIELD	AL	PH	
BROAD	03050106060	CRANE CREEK AT US 321	B-081	RICHLAND	AL	BIO	
BROAD	03050106060	ELIZABETH LAKE AT SPILLWAY ON US 21	B-110	RICHLAND	REC	FC	*
BROAD	03050106060	SMITH BR AT N MAIN ST (US 21) IN COLA	B-280	RICHLAND	AL	BIO	
BROAD	03050106060	SMITH BR AT N MAIN ST (US 21) IN COLA	B-280	RICHLAND	REC	FC	*
BROAD	03050106060	CRANE CK AT S-40-43 UNDER I-20 - N COLA	B-316	RICHLAND	REC	FC	*
BROAD	03050106060	BROAD RVR AT US 176 (BROAD RIVER RD) IN COLUMBIA	B-337	RICHLAND	REC	FC	*
BROAD	03050106060	CRIMS CRK. AT SC 213	B-800	NEWBERRY	AL	BIO	
BROAD	03050106060	WATEREE CRK. AT SR 698	B-801	RICHLAND	AL	BIO	
BROAD	03050106070	LITTLE RVR AT S-20-60 3.1 MI SE OF JENKINSVILLE	B-145	FAIRFIELD	REC	FC	*
BROAD	03050106070	LITTLE RVR AT SC 215, 1.5 MI NE OF CONFLUENCE WITH BROAD RVR	B-350	RICHLAND	REC	FC	
BROAD	03050106080	WINNSBORO BR BELOW PLANT OUTFALL	B-077	FAIRFIELD	REC	FC	*
BROAD	03050106080	JACKSON CK AT S-20-54, 5 MI W OF WINNSBORO	B-102	FAIRFIELD	AL	BIO	
BROAD	03050106080	JACKSON CK AT S-20-54, 5 MI W OF WINNSBORO	B-102	FAIRFIELD	REC	FC	*
BROAD	03050106080	WINNSBORO BR AT US 321-AB WINNSBORO MILLS OUTFALL	B-123	FAIRFIELD	REC	FC	*
BROAD	03050106080	MILL CK AT S-20-48, 10 MI SW OF WINNSBORO	B-338	FAIRFIELD	REC	FC	*
BROAD	03050107010	SOUTH TYGER RVR AT S-42-63	B-005	SPARTANBURG	AL	CU	
BROAD	03050107010	SOUTH TYGER RVR AT S-42-63	B-005	SPARTANBURG	REC	FC	*
BROAD	03050107010	SOUTH TYGER RIVER AT 293	B-005A	SPARTANBURG	AL	BIO	
BROAD	03050107010	S TYGER RVR AT SC 14 2.9 MI NNW OF GREER	B-149	GREENVILLE	REC	FC	
BROAD	03050107010	S TYGER RVR AT SC 290 3.7 MI E OF GREER	B-263	SPARTANBURG	REC	FC	*
BROAD	03050107010	MUSH CK AT SC 253 BL TIGERVILLE	B-317	GREENVILLE	REC	FC	*
BROAD	03050107010	S TYGER RVR AT S-42-86, 5 MI NE OF WOODRUFF	B-332	SPARTANBURG	REC	FC	
BROAD	03050107010	LAKE ROBINSON, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CL-100	GREENVILLE	AL	PH	
BROAD	03050107020	N TYGER RVR AT US 29 7.2 MI W OF SPARTANBURG	B-219	SPARTANBURG	REC	FC	*
BROAD	03050107020	TRIB TO N TYGER RVR AT UN# RD BL JACKSON #2 EFF	B-315	SPARTANBURG	REC	FC	*
BROAD	03050107020	LAKE COOLEY IN FOREBAY NEAR DAM	B-348	SPARTANBURG	AL	PH	
BROAD	03050107030	NORTH TYGER RVR AT S-42-231, 11 MI S OF SPARTANBURG	B-018A	SPARTANBURG	REC	FC	
BROAD	03050107040	MIDDLE TYGER RVR AT S-42-63	B-012	SPARTANBURG	REC	FC	
BROAD	03050107040	MIDDLE TYGER RVR AT S-42-64	B-014	SPARTANBURG	REC	FC	
BROAD	03050107040	BEAVERDAM CRK. AT SC 357	B-784	SPARTANBURG	AL	BIO	
BROAD	03050107050	TYGER RVR AT S-42-50 E. WOODRUFF	B-008	SPARTANBURG	REC	FC	*
BROAD	03050107050	JIMMIES CK AT S-42-201 2 MI E OF WOODRUFF	B-019	SPARTANBURG	REC	FC	*
BROAD	03050107050	TYGER RVR AT SC 72 5.5 MI SW OF CARLISLE	B-051	UNION	REC	FC	
BROAD	03050107050	TYGER RVR AT S-44-35 3.5 MI S OF CARLISLE	B-349	UNION	REC	FC	

2004 SC List of Impaire[illegible]s by 11-Digit HUC

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
BROAD	03050105090	BROAD RVR AT SC 18 4 MI NE GAFFNEY	B-042	CHEROKEE	REC	FC	*
BROAD	03050105090	BROAD RVR AT SC 211 12 MI SE OF GAFFNEY	B-044	CHEROKEE	REC	FC	*
BROAD	03050105090	CANOE CK AT S-11-245 1/2 MI W OF BLACKSBURG	B-088	CHEROKEE	REC	FC	*
BROAD	03050105090	PEOPLES CK AT S-11-50 6 MI E OF GAFFNEY	B-100	CHEROKEE	REC	FC	*
BROAD	03050105090	PEOPLES CK AT UNIMPROVED RD 2.3 MI E OF GAFFNEY	B-211	CHEROKEE	REC	FC	*
BROAD	03050105090	DOOLITTLE CK AT S-11-100 1.25 MI SE OF BLACKSBURG	B-323	CHEROKEE	REC	FC	*
BROAD	03050105090	GUYONMOORE CREEK AT S-46-233	B-330	YORK	REC	FC	*
BROAD	03050105100	BUFFALO CK AT SC 5 1 MI W OF BLACKSBURG	B-057	CHEROKEE	AL	CU	
BROAD	03050105100	BUFFALO CK AT SC 5 1 MI W OF BLACKSBURG	B-057	CHEROKEE	REC	FC	
BROAD	03050105100	BUFFALO CREEK AT S-11-213, 2.2 MI NNW OF BLACKSBURG	B-119	CHEROKEE	REC	FC	*
BROAD	03050105110	CHEROKEE CK AT US 29 3 MI E OF GAFFNEY	B-056	CHEROKEE	REC	FC	*
BROAD	03050105110	CHEROKEE CREEK AT SC 329	B-679	CHEROKEE	AL	BIO	
BROAD	03050105110	LAKE WELCHEL 2.7 M N OF GAFFNEY	RL-01029	CHEROKEE	AL	CHLA	
BROAD	03050105130	IRENE CK AT S-11-307 2.5 MI W OF GAFFNEY	B-059	CHEROKEE	REC	FC	*
BROAD	03050105130	THICKETTY CK AT SC 211 2 MI AB JCT WITH BROAD RVR	B-062	CHEROKEE	REC	FC	*
BROAD	03050105130	THICKETTY CREEK AT S-11-164	B-095	CHEROKEE	REC	FC	*
BROAD	03050105130	LIMESTONE CK AT S-11-301	B-128	CHEROKEE	REC	FC	*
BROAD	03050105130	THICKETTY CK AT SC 18 8.3 MI S OF GAFFNEY	B-133	CHEROKEE	REC	FC	*
BROAD	03050105130	GILKEY CK AT S-11-231, 9 MI SE OF GAFFNEY	B-334	CHEROKEE	REC	FC	
BROAD	03050105140	BULLOCK CK AT SC 97 4.8 MI S OF HICKORY GROVE	B-159	YORK	REC	FC	*
BROAD	03050105140	CLARK FORK INTO CRAWFORD LK ON UN# RD NEAR SC 161 & 705-KINGS MT	B-325	YORK	AL	DO	
BROAD	03050105140	CLARK FORK INTO CRAWFORD LK ON UN# RD NEAR SC 161 & 705-KINGS MT	B-325	YORK	REC	FC	*
BROAD	03050105140	LONG BRANCH ON SC 216 BL KINGS MTN PK REC AREA	B-326	YORK	REC	FC	
BROAD	03050105150	N PACOLET RVR AT S-42-956 6.5 MI E LANDRUM	B-026	SPARTANBURG	REC	FC	*
BROAD	03050105150	ON # 1 INLET LK LANIER IN GREENVILLE CO	B-099A	GREENVILLE	REC	FC	
BROAD	03050105150	N PACOLET RVR AT S-42-978, 1 MI SE OF FINGERVILLE	B-126	SPARTANBURG	REC	FC	*
BROAD	03050105150	PAGE CK AT S-42-1258 1.7 MI SE LANDRUM	B-301	SPARTANBURG	REC	FC	*
BROAD	03050105160	S PACOLET RVR AT S-42-866 1 MI SE CAMPOBELLO	B-302	SPARTANBURG	REC	FC	*
BROAD	03050105160	MOTLOW CRK. AT SR 888	B-790	SPARTANBURG	AL	BIO	
BROAD	03050105170	PACOLET RVR AT S-42-55 BL JCT OF N & S PACOLET R	B-028	SPARTANBURG	REC	FC	*
BROAD	03050105170	POTTER BR ON RD 30 BL OUTFALL FROM HOUSING PROJ COWPENS	B-191	SPARTANBURG	REC	FC	*
BROAD	03050105170	LITTLE BUCK CK AT UN# CO RD 2.3 MI SW OF CHESNEE	B-259	SPARTANBURG	REC	FC	*
BROAD	03050105180	LAWSONS FK CK AT S-42-40 BL INMAN MILL EFF	B-221	SPARTANBURG	AL	BIO	
BROAD	03050105180	LAWSONS FK CK AT S-42-40 BL INMAN MILL EFF	B-221	SPARTANBURG	REC	FC	
BROAD	03050105180	LAWSONS FORK CK AT S-42-218 2.7 MI SSE OF INMAN	B-277	SPARTANBURG	REC	FC	
BROAD	03050105180	LAWSONS FORK CK AT UN# RD BL MILLIKEN CHEM	B-278	SPARTANBURG	REC	FC	
BROAD	03050105180	LAWSONS FORK CK AT S-42-108	BL-001	SPARTANBURG	AL	BIO	
BROAD	03050105180	LAWSONS FORK CK AT S-42-108	BL-001	SPARTANBURG	REC	FC	
BROAD	03050105180	LAWSONS FORK CK AT S-42-79 AT VALLEY FALLS	BL-005	SPARTANBURG	REC	FC	
BROAD	03050105180	MEADOW CK AT S-42-822	RS-02320	SPARTANBURG	REC	FC	
BROAD	03050105190	PACOLET RVR AT SC 105 6 MI AB JCT WITH BROAD RVR	B-048	CHEROKEE	REC	FC	
BROAD	03050105190	MILL CREEK AT SR 73	B-780	UNION	AL	BIO	
BROAD	03050105190	PACOLET RVR AB DAM AT PACOLET MILLS	BP-001	SPARTANBURG	REC	FC	*
BROAD	03050106010	BROAD RVR AT SC 72/215/121 3 MI E OF CARLISLE	B-046	CHESTER	REC	FC	*
BROAD	03050106020	ROSS BR TO TURKEY CK AT SC 49 SW OF YORK	B-086	YORK	REC	FC	*

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
BROAD	03050107060	FAIRFOREST CK AT US 221 S OF SPARTANBURG	B-020	SPARTANBURG	REC	FC	*
BROAD	03050107060	FAIRFOREST CK AT SC 56	B-021	SPARTANBURG	AL	BIO	
BROAD	03050107060	FAIRFOREST CK AT SC 56	B-021	SPARTANBURG	REC	FC	
BROAD	03050107060	TOSCHS CK AT US 176 2 MI SW OF UNION	B-067A	UNION	REC	FC	*
BROAD	03050107060	TOSCHS CK AT RD TO SEWAGE PT OFF HWY S-44-92 SW OF UNION	B-067B	UNION	REC	FC	*
BROAD	03050107060	FAIRFOREST CK AT S-42-651 3.5 MI SSE OF SPARTANBURG	B-164	SPARTANBURG	REC	FC	
BROAD	03050107060	MITCHELL CK AT CO RD 233 2.3 MI SSW OF JONESVILLE	B-199	UNION	REC	FC	*
BROAD	03050107060	KELSEY CK AT S-42-321	B-235	SPARTANBURG	REC	FC	*
BROAD	03050107060	TINKER CK AT RD TO STP 1.3 MI SSE OF UNION	B-286	UNION	REC	FC	
BROAD	03050107060	TINKER CK AT UN# CO RD 1.7 MI SSE OF UNION	B-287	UNION	REC	FC	*
BROAD	03050107060	TRIB TO FAIRFOREST CK 200 FT BL S-42-65	B-321	SPARTANBURG	AL	DO, PH, ZN	
BROAD	03050107060	TRIB TO FAIRFOREST CK 200 FT BL S-42-65	B-321	SPARTANBURG	REC	FC	*
BROAD	03050107060	TINKER CK AT S-44-278, 9 MI SSE OF UNION	B-336	UNION	REC	FC	*
BROAD	03050107060	FAIRFOREST CK ON CO RD 12 SW OF JONESVILLE	BF-007	UNION	REC	FC	
BROAD	03050107060	FAIRFOREST CK AT S-44-16 SW OF UNION	BF-008	UNION	REC	FC	
BROAD	03050107060	LAKE JOHNSON AT SPILLWAY AT S-42-359	CL-035	SPARTANBURG	AL	PH	
BROAD	03050108010	DURBIN CK ON S-23-160 3 MI E OF SIMPSONVILLE	B-035	GREENVILLE	REC	FC	*
BROAD	03050108010	ENOREE RVR AT S-42-118 SW OF WOODRUFF	B-037	LAURENS	REC	FC	*
BROAD	03050108010	LICK CK AT S-42-118 1 1/4 MI SW WOODRUFF	B-038	SPARTANBURG	REC	FC	*
BROAD	03050108010	ENOREE RVR AT S-30-112	B-040	LAURENS	REC	FC	
BROAD	03050108010	DURBIN CREEK AT SC 418	B-097	LAURENS	AL	PH	
BROAD	03050108010	DURBIN CREEK AT SC 418	B-097	LAURENS	REC	FC	*
BROAD	03050108010	MOUNTAIN CK AT S-23-335	B-186	GREENVILLE	REC	FC	*
BROAD	03050108010	PRINCESS CREEK AT SUBER MILL RD, SECOND RD S OF US 29 OFF S-23-540	B-192	GREENVILLE	REC	FC	*
BROAD	03050108010	GILDER CK AT S-23-142 2.75 MI ENE OF MAULDIN	B-241	GREENVILLE	REC	FC	*
BROAD	03050108010	ABENERS CRK. AT BENNETTS RIDGE RD.	B-792	SPARTANBURG	AL	BIO	
BROAD	03050108010	HORSE PEN CRK. AT SR 145	B-793	GREENVILLE	AL	BIO	
BROAD	03050108010	BUCKHORN CRK. AT SR 562	B-795	GREENVILLE	AL	BIO	
BROAD	03050108010	BEAVERDAM CRK. AT SC 253	B-796	GREENVILLE	AL	BIO	
BROAD	03050108010	ENOREE R. AT PINE LOG FORD RD., 2ND CROSSING ABOVE SC 253 BRIDGE	B-797	GREENVILLE	AL	BIO	
BROAD	03050108010	ENOREE RVR AT UNNUM RD W US 25 N TRAVELERS REST	BE-001	GREENVILLE	AL	ZN	
BROAD	03050108010	ENOREE RVR AT UNNUM RD W US 25 N TRAVELERS REST	BE-001	GREENVILLE	REC	FC	*
BROAD	03050108010	ROCKY CK AT BRDG IN BATESVILLE 1 MI AB JCT WITH ENOREE	BE-007	GREENVILLE	AL	BIO	
BROAD	03050108010	ROCKY CK AT BRDG IN BATESVILLE 1 MI AB JCT WITH ENOREE	BE-007	GREENVILLE	REC	FC	*
BROAD	03050108010	MOUNTAIN CRK. AT SR 279	BE-008	GREENVILLE	AL	BIO	
BROAD	03050108010	BRUSHY CK AT S-23-164	BE-009	GREENVILLE	AL	BIO	
BROAD	03050108010	ENOREE RVR AT CO RD 164	BE-015	GREENVILLE	REC	FC	
BROAD	03050108010	ENOREE RVR AT SC 296, 7.5 MI NE OF MAULDIN	BE-017	GREENVILLE	REC	FC	
BROAD	03050108010	ENOREE RVR AT S-30-75	BE-018	LAURENS	AL	BIO	
BROAD	03050108010	ENOREE RVR AT S-30-75	BE-018	LAURENS	REC	FC	
BROAD	03050108010	ENOREE RIVER AT SC HWY 418	BE-019	LAURENS	AL	BIO	
BROAD	03050108010	GILDER CK AT S-23-143 1/4 MI AB JCT WITH ENOREE RVR	BE-020	GREENVILLE	AL	BIO	
BROAD	03050108010	GILDER CK AT S-23-143 1/4 MI AB JCT WITH ENOREE RVR	BE-020	GREENVILLE	REC	FC	*
BROAD	03050108010	BRUSHY CK AT HOWELL RD (S-23-273/335) APPROX 5 MI NE OF GREENVILLE (BIO B-798)	BE-035	GREENVILLE	AL	BIO	
BROAD	03050108010	BEAVERDAM CK AT RD 1967	BE-039	GREENVILLE	REC	FC	*
BROAD	03050108010	GILDER CK AT SC 14-AB GILDERS CK PT	BE-040	GREENVILLE	REC	FC	*
BROAD	03050108020	ENOREE RVR AT SC 49 SE OF WOODRUFF	B-041	LAURENS	REC	FC	
BROAD	03050108020	ENOREE RVR AT SC 72, 121, & US 176, 1 MI NE WHITMIRE	B-053	NEWBERRY	REC	FC	*
BROAD	03050108020	ENOREE RIVER AT US 221	BE-024	LAURENS	REC	FC	*
BROAD	03050108030	WARRIOR CK AT US 221, 8 MI NNE OF LAURENS	B-150	LAURENS	REC	FC	*
BROAD	03050108030	BEAVERDAM CK AT S-30-97, 7 MI NE OF GRAY COURT	B-246	LAURENS	REC	FC	*

2004 SC List of Impal .ers by 11-Digit HUC

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
BROAD	03050108040	DUNCAN CK AT US 176 1.5 MI SE OF WHITMIRE	B-072	NEWBERRY	REC	FC	*
BROAD	03050108040	BEARDS FORK CK AT US 276 (I-385) 3.7 MI NNE OF CLINTON	B-231	LAURENS	AL	DO	
BROAD	03050108040	BEARDS FORK CK AT US 276 (I-385) 3.7 MI NNE OF CLINTON	B-231	LAURENS	REC	FC	*
BROAD	03050108040	DUNCAN CREEK AT COUNTY RD 26, 4.5 M NE OF CLINTON	RS-01057	LAURENS	REC	FC	
BROAD	03050108050	ENOREE RVR AT S-36-45 3.5 MI AB JCT WITH BROAD RVR	B-054	NEWBERRY	REC	FC	*
CATAWBA	03050101180	CROWDERS CK AT S-46-564 NE CLOVER	CW-023	YORK	REC	FC	
CATAWBA	03050101180	CROWDERS CREEK AT S-46-1104	CW-024	YORK	AL	BIO	
CATAWBA	03050101180	CROWDERS CREEK AT S-46-1104	CW-024	YORK	REC	FC	
CATAWBA	03050101180	LK WYLIE, CROWDERS CK ARM AT SC 49 AND SC 274	CW-027	YORK	REC	FC	
CATAWBA	03050101180	BROWN CREEK AT S-46-228 (GUINN ST), 0.3 MI WEST OF OLD NORTH MAIN STREET IN CLOVER, SC	CW-105	YORK	AL	TURBIDITY	
CATAWBA	03050101180	SOUTH FORK CROWDERS CK AT S-46-79 4.5 MI NW OF CLOVER	CW-192	YORK	REC	FC	
CATAWBA	03050101180	LAKE WYLIE AB MILL CK ARM AT END OF S-46-557	CW-197	YORK	AL	CU	
CATAWBA	03050101190	ALLISON CK AT S-46-114	CW-249	YORK	REC	FC	
CATAWBA	03050103010	CATAWBA RVR AT US 21	CW-014	YORK	REC	FC	
CATAWBA	03050103010	FISHING CK RES 2 MI BL CANE CREEK	CW-016F	CHESTER	AL	TP, TURBIDITY	
CATAWBA	03050103010	CEDAR CK RESERVOIR 100 M N OF DAM	CW-033	LANCASTER	AL	TP	
CATAWBA	03050103010	CATAWBA RVR AT SC 5 AB BOWATER	CW-041	LANCASTER	AL	CU	
CATAWBA	03050103010	FISHING CK RES 75 FT AB DAM NR GREAT FALLS	CW-057	CHESTER	AL	TP	
CATAWBA	03050103010	CEDAR CK RESERVOIR AT UNIMP RD AB JCT WITH ROCKY CK	CW-174	CHESTER	AL	DO, TN, TP	
CATAWBA	03050103010	CEDAR CK RES 2.15 M SE OF GREAT FALLS	RL-01007	LANCASTER	AL	CHLA, DO	
CATAWBA	03050103010	FISHING CK RES 3.8 M S OF FORT LAWN OFF W SHORE OF THE TOWN OF LAKE VIEW	RL-01012	CHESTER	AL	CHLA	
CATAWBA	03050103010	CEDAR CK RES FROM W OF BIG ISL 7 MI BELOW ROCKY CK CONFL	RL-02319	CHESTER	AL	TP	
CATAWBA	03050103010	CEDAR CK RES 0.15 MI SE OF S TIP PICKETT ISLAND	RL-02452	LANCASTER	AL	TP	
CATAWBA	03050103020	STEELE CK AT S-46-22 N OF FORT MILL	CW-009	YORK	REC	FC	
CATAWBA	03050103020	STEELE CK AT S-46-270	CW-011	YORK	REC	FC	
CATAWBA	03050103020	SUGAR CREEK AT S-46-36	CW-036	LANCASTER	AL	CU	
CATAWBA	03050103020	MCALPINE CK AT S-29-64	CW-064	LANCASTER	AL	BIO	
CATAWBA	03050103020	STEELE CK AT S-46-98	CW-203	YORK	REC	FC	
CATAWBA	03050103020	SUGAR CK US OF CONFLUENCE W/ MCALPINE CK	CW-246	YORK	AL	BIO	
CATAWBA	03050103020	STEEL CR. AT US BY-PASS 21	CW-681	YORK	AL	BIO	
CATAWBA	03050103030	TWELVEMILE CK AT S-29-55 0.3 MI NW OF VAN WYCK	CW-083	LANCASTER	AL	CU, TURBIDITY	
CATAWBA	03050103030	TWELVEMILE CK AT S-29-55 0.3 MI NW OF VAN WYCK	CW-083	LANCASTER	REC	FC	*
CATAWBA	03050103030	WAXHAW CK AT S-29-29	CW-145	LANCASTER	AL	CU	
CATAWBA	03050103030	WAXHAW CK AT S-29-29	CW-145	LANCASTER	REC	FC	*
CATAWBA	03050103030	SIXMILE CREEK AT S-29-54	CW-176	LANCASTER	REC	FC	*
CATAWBA	03050103040	CANE CK AT S-29-50	CW-017	LANCASTER	AL	DO	
CATAWBA	03050103040	GILLS CK AT US 521 NNW OF LANCASTER	CW-047	LANCASTER	AL	DO	
CATAWBA	03050103040	BEAR CK AT S-29-292 1.6 MI W OF LANCASTER	CW-131	LANCASTER	AL	DO	
CATAWBA	03050103040	BEAR CK AT S-29-362 3.5 MI SE OF LANCASTER	CW-151	LANCASTER	AL	DO	
CATAWBA	03050103040	CANE CK AT SC 200 5 MI NNE OF LANCASTER	CW-185	LANCASTER	AL	DO	
CATAWBA	03050103040	CANE CR. AT SC 9 BYPASS	CW-210	LANCASTER	AL	BIO	
CATAWBA	03050103040	RUM CK AT S-29-187	CW-232	LANCASTER	AL	DO	
CATAWBA	03050103040	RUM CK AT S-29-187	CW-232	LANCASTER	REC	FC	
CATAWBA	03050103050	FISHING CK AT S-46-347 DS YORK WWTP	CW-005	YORK	AL	BIO	
CATAWBA	03050103050	FISHING CREEK AT S-46-503	CW-225	YORK	AL	CU	
CATAWBA	03050103060	LAKE OLIPHANT, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CL-021	CHESTER	AL	CHLA, PH	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
CATAWBA	03050103060	WILDCAT CK AT S-46-650	CW-006	YORK	AL	TURBIDITY	
CATAWBA	03050103060	SOUTH FORK OF FISHING CRK. AT SR 50	CW-007	CHESTER	AL	BIO	
CATAWBA	03050103060	WILDCAT CK AT S-46-998 9 MI ENE OF MCCONNELLS	CW-096	YORK	AL	TURBIDITY	
CATAWBA	03050103060	TOOLS FORK AT S-46-195 7 MI NW OF ROCK HILL	CW-212	YORK	AL	TURBIDITY	
CATAWBA	03050103060	FISHING CR. AT SR 655	CW-654	YORK	AL	BIO	
CATAWBA	03050103060	TAYLORS CRK. AT SR 735	CW-695	YORK	AL	BIO	
CATAWBA	03050103060	STONEY FORK CRK. AT SC 121 & 72	CW-697	YORK	AL	BIO	
CATAWBA	03050103060	MCFADDEN BRANCH AT COUNTY RD 525, 7 M S OF ROCK HILL	RS-01007	CHESTER	REC	FC	
CATAWBA	03050103070	TINKERS CK AT S-12-599	CW-234	CHESTER	AL	TURBIDITY	
CATAWBA	03050103090	ROCKY CK AT S-12-335 3.5 MI E OF CHESTER	CW-002	CHESTER	AL	CU	
CATAWBA	03050103090	GRASSY RUN BR AT SC 72 1.6 MI NE CHESTER	CW-088	CHESTER	AL	DO	
CATAWBA	03050103090	CEDAR CK RESERVOIR/ROCKY CK AT S-12-141 SE OF GREAT FALLS	CW-175	CHESTER	AL	DO, TP, TURBIDITY	
CATAWBA	03050103090	BEAVER DAM CRK. AT SR 555	CW-691	CHESTER	AL	BIO	
CATAWBA	03050104010	LK WATEREE IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CL-089	KERSHAW	AL	PH	
CATAWBA	03050104010	LITTLE WATEREE CK AT S-20-41 5 MI E OF WINNSBORO	CW-040	FAIRFIELD	AL	DO	
CATAWBA	03050104010	LITTLE WATEREE CK AT S-20-41 5 MI E OF WINNSBORO	CW-040	FAIRFIELD	REC	FC	*
CATAWBA	03050104010	LK WATEREE AT END OF S-20-291	CW-207	FAIRFIELD	AL	PH, TP	
CATAWBA	03050104010	LK WATEREE AT S-20-101 11 MI ENE WINNSBORO	CW-208	FAIRFIELD	AL	CHLA, PH, TP	
CATAWBA	03050104010	LK WATEREE AT SMALL ISLAND 2.3 MI N OF DAM	CW-209	KERSHAW	AL	PH, TP	
CATAWBA	03050104010	LK WATEREE HEADWATERS APPROX 50 YDS DS CONFL CEDAR CK	CW-231	LANCASTER	AL	TP, TURBIDITY	
CATAWBA	03050104010	LAKE WATEREE 1.0 MI SW FROM MOUTH OF BEAVER CK	RL-02314	KERSHAW	AL	PH, TP	
CATAWBA	03050104010	DUTCHMANS CK AT S-20-106	RS-02321	FAIRFIELD	REC	FC	
CATAWBA	03050104020	BIG WATEREE CK AT US 21	CW-072	FAIRFIELD	AL	DO, PH	
CATAWBA	03050104020	BIG WATEREE CK AT US 21	CW-072	FAIRFIELD	REC	FC	
CATAWBA	03050104030	WATEREE RVR AT US 1	CW-019	KERSHAW	AL	DO	
CATAWBA	03050104030	WATEREE RIVER BELOW LAKE WATEREE DAM	CW-039	KERSHAW	FISH	HG	
CATAWBA	03050104030	WATEREE RVR AT US 76 & 378	CW-206	RICHLAND	FISH	HG	
CATAWBA	03050104030	WATEREE RIVER AT I-20	CW-214	KERSHAW	AL	DO	
CATAWBA	03050104030	WATEREE RVR AT I-20	CW-214	KERSHAW	FISH	HG	
CATAWBA	03050104040	GRANNIES QUARTER CK AT SC 97	CW-237	KERSHAW	AL	PH	
CATAWBA	03050104040	GRANNIES QUARTER CK AT SC 97	CW-237	KERSHAW	REC	FC	
CATAWBA	03050104060	TWENTYFIVE MILE CK AT S-28-05 3.7 MI W OF CAMDEN	CW-080	KERSHAW	AL	BIO	
CATAWBA	03050104060	TWENTYFIVE MILE CK AT S-28-05 3.7 MI W OF CAMDEN	CW-080	KERSHAW	REC	FC	
CATAWBA	03050104060	BEAR CK AT S-40-82	CW-229	RICHLAND	AL	DO	
CATAWBA	03050104060	BEAR CK AT S-40-82	CW-229	RICHLAND	REC	FC	
CATAWBA	03050104070	LITTLE PINE TREE CREEK AT S-28-132	CW-223	KERSHAW	REC	FC	
CATAWBA	03050104080	SWIFT CK AT SC 261	CW-238	KERSHAW	AL	DO	
CATAWBA	03050104090	KELLY CK AT S-28-367 2.9 MI SE OF ELGIN	CW-154	KERSHAW	REC	FC	*
CATAWBA	03050104090	SPEARS CK AT US 601	CW-166	KERSHAW	REC	FC	*
EDISTO	03050203010	CHINQUAPIN CREEK AT SC 391 5.5 MI S BATESBURG	E-091	AIKEN	REC	FC	
EDISTO	03050203010	HORSE PEN CREEK AT UPSTREAM SIDE OF COUNTY RD 391, 1.5 M S OF BATESBURG	RS-01004	LEXINGTON	REC	FC	
EDISTO	03050203050	BULL SWP CK AT CLVT ON UNIMP RD 1.1 MI NW OF SWANSEA	E-034	LEXINGTON	AL	DO	
EDISTO	03050203050	BULL SWAMP CREEK AT SC 6	E-591	LEXINGTON	AL	BIO	

2004 SC List of Impa[illegible]rs by 11-Digit HUC

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
EDISTO	03050203060	N FORK EDISTO RVR AT S-38-74 NW ORANGEBURG	E-099	ORANGEBURG	REC	FC	
EDISTO	03050203070	CAW CAW SWAMP AT S-38-1032 (1148?)	E-105	ORANGEBURG	REC	FC	
EDISTO	03050203080	N FORK EDISTO RVR AT US 601 AT ORANGEBURG	E-007	ORANGEBURG	AL	PH	
EDISTO	03050203080	N FORK EDISTO RVR AT US 601 AT ORANGEBURG	E-007	ORANGEBURG	REC	FC	
EDISTO	03050203080	N FORK EDISTO RVR AT POWER LINE CROSSING 2 MI BL E-007	E-007A	ORANGEBURG	REC	FC	
EDISTO	03050203080	N FORK EDISTO RVR 4 MI BL E-007 AT A CABIN	E-007B	ORANGEBURG	REC	FC	
EDISTO	03050203080	N FORK EDISTO RVR AT POLICEMANS CAMP 6 MI BL E-007	E-007C	ORANGEBURG	AL	PH	
EDISTO	03050203080	N FORK EDISTO RVR AT POLICEMANS CAMP 6 MI BL E-007	E-007C	ORANGEBURG	FISH	HG	
EDISTO	03050203080	N FORK EDISTO RVR AT POLICEMANS CAMP 6 MI BL E-007	E-007C	ORANGEBURG	REC	FC	
EDISTO	03050203080	N FORK EDISTO RVR AT S-38-39 WSW OF ROWESVILLE	E-008	ORANGEBURG	FISH	HG	
EDISTO	03050203080	N FORK EDISTO RVR AT S-38-63	E-008A	ORANGEBURG	FISH	HG	
EDISTO	03050204010	S FORK EDISTO RVR AT S-19-57 BL JOHNSTON SWR OUTFALL	E-002	EDGEFIELD	REC	FC	
EDISTO	03050204010	ROCKY SPRING CREEK AT MOORE RD OFF COUNTY RD 264, 7 M NE OF AIKEN	RS-01034	AIKEN	REC	FC	
EDISTO	03050204020	SHAW CREEK AT S-02-26 4.2 MI NE AIKEN	E-094	AIKEN	AL	PH	
EDISTO	03050204030	SOUTH EDISTO RIVER @ AIKEN STATE PARK	E-585	AIKEN	FISH	HG	
EDISTO	03050204030	SOUTH EDISTO RIVER @ KEADLE'S BRIDGE	E-600	LEXINGTON	FISH	HG	
EDISTO	03050204050	S FORK EDISTO RVR AT SC 39	E-011	BARNWELL	FISH	HG	
EDISTO	03050204050	WINDY HILL CRK. AT SR 38	E-029	BARNWELL	AL	BIO	
EDISTO	03050204050	SOUTH EDISTO RIVER @ SC 365	E-501	BAMBERG	FISH	HG	
EDISTO	03050204060	GOODLAND CK AT SC 4 2.1 MI E OF SPRINGFIELD	E-036	ORANGEBURG	REC	FC	*
EDISTO	03050204060	GOODLAND CREEK AT SC 4 2.1 MI E OF SPRINGFIELD	E-598	ORANGEBURG	AL	BIO	
EDISTO	03050204070	ROBERTS SWAMP AT SC 332	E-039	ORANGEBURG	REC	FC	
EDISTO	03050204070	ROBERTS SWAMP AT SR 690	E-592	ORANGEBURG	AL	BIO	
EDISTO	03050205020	CATTLE CK AT S-18-19	E-108	DORCHESTER	AL	BIO	
EDISTO	03050205020	CATTLE CK AT S-18-19	E-108	DORCHESTER	REC	FC	
EDISTO	03050205030	EDISTO RVR AT US 15 S OF ST GEORGE	E-014	COLLETON	FISH	HG	
EDISTO	03050205040	POLK SWP AT UNIMP RD S-18-180 2 MI S OF ST GEORGE	E-016	DORCHESTER	AL	DO	
EDISTO	03050205040	POLK SWP AT UNIMP RD S-18-180 2 MI S OF ST GEORGE	E-016	DORCHESTER	REC	FC	
EDISTO	03050205040	INDIAN FIELD SWAMP AT S-18-19	E-032	DORCHESTER	AL	DO	
EDISTO	03050205040	INDIAN FIELD SWAMP AT S-18-19	E-032	DORCHESTER	REC	FC	
EDISTO	03050205040	POLK SWAMP AT S-18-19	E-109	DORCHESTER	AL	DO	
EDISTO	03050205040	POLK SWAMP AT S-18-19	E-109	DORCHESTER	REC	FC	
EDISTO	03050205040	INDIAN FIELDS CRK. AT US 78	E-597	DORCHESTER	AL	BIO	
EDISTO	03050205050	EDISTO RIVER @ MARS OLDFIELD	E-601	COLLETON	FISH	HG	
EDISTO	03050205060	FISHING CREEK AT SANDY CREEK CONFLUENCE OF SHINGLE CREEK AND BAILEY CREEK	13-05	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205060	FISHING CREEK AT POLLUTION LINE	13-10	COLLETON	SHELLFISH	FC	
EDISTO	03050205060	SCOTT CREEK, HEADWATERS AT JEREMY INLET AT BOAT LANDING	13-22	COLLETON	SHELLFISH	FC	
EDISTO	03050205060	JEREMY INLET AT ATLANTIC OCEAN	13-23	COLLETON	SHELLFISH	FC	
EDISTO	03050205060	EDISTO RIVER ABOVE HWY 17 (MARTINS LANDING)	CSTL-589	CHARLESTON	FISH	HG	
EDISTO	03050205060	EDISTO RVR AT SC 61 AT GIVHANS FERRY ST PK	E-015	COLLETON	FISH	HG	
EDISTO	03050205060	EDISTO RIVER @ SULLIVANS FERRY	E-087	COLLETON	FISH	HG	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
EDISTO	03050205060	EDISTO RIVER @ GOOD HOPE LANDING	E-602	COLLETON	FISH	HG	
EDISTO	03050205060	EDISTO RVR AT US 17 12.5 MI NW RAVENEL	MD-119	CHARLESTON	AL	PH	#
EDISTO	03050205060	S EDISTO RVR BELOW ST PIERRE CK	MD-244	CHARLESTON	AL	TURBIDITY	
EDISTO	03050205060	S EDISTO RVR AT NORTHERN CONFLUENCE WITH ALLIGATOR CREEK (13-20)	MD-260	CHARLESTON	AL	CU, TURBIDITY	
EDISTO	03050205060	SOUTH EDISTO RIVER, 1 M MW OF EDISTO BEACH	RO-01123	COLLETON	AL	TURBIDITY	
EDISTO	03050205070	BOHICKET CREEK AT FICKLING CREEK	12A-13	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	BOHICKET CREEK S.C.AT HIGHWAY 700 BRIDGE	12A-14	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	BOHICKET CREEK OPPOSITE HOOPSTICK ISLAND	12A-20	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	RAVEN POINT CREEK AT CONFLUENCE WITH CHURCH CREEK	12A-29	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	CHURCH CREEK AT DRAINAGE DISCHARGE 1/8 MILE EAST OF POWER LINES, NORTH BANK OF	12A-38	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	CHURCH CREEK ~ 350 YDS WEST S.C. HWY.700 BRIDGE	12A-39	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	PINE CREEK AT FIRST FORK	12A-40	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	TOOGOODOO CREEK LOWER, AT PUBLIC BOAT RAMP	12B-35	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	SAND CREEK BRIDGE AT HIGHWAY 174	12B-47	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	SAND CREEK AT INTAKE TO WESTENDORF CLAM FARM	12B-50	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	WHOOPING ISLAND CREEK AT CONFLUENCE OF STEAMBOAT CREEK	12B-52	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	DAWHO RIVER, MARKER #126	12B-53	CHARLESTON	SHELLFISH	FC	
EDISTO	03050205070	DAWHO RVR AT SC 174 9 MI N OF EDISTO BCH SP	MD-120	CHARLESTON	AL	DO, TURBIDITY	
EDISTO	03050205070	CHURCH CR AT SC 700 1 MI SW OF CEDAR SPRINGS	MD-195	CHARLESTON	AL	DO	
EDISTO	03050205070	BOHICKET CK AT FICKLING CK	MD-209	CHARLESTON	AL	DO	
EDISTO	03050205070	YONGES ISLAND CREEK, MARKER #90 (12-03)	MD-261	CHARLESTON	AL	TURBIDITY	
EDISTO	03050205070	DAWHO RIVER, 10.5 M N OF EDISTO BEACH	RT-01665	CHARLESTON	AL	DO, TURBIDITY	
EDISTO	03050205070	FISHING CK NEAR JEHOSSEE ISLAND	RT-02005	CHARLESTON	AL	TURBIDITY	
EDISTO	03050206010	GRAMLING CK AT CLVT ON SC 33 2 MI E OF ORANGEBURG	E-022	ORANGEBURG	AL	DO	
EDISTO	03050206010	GRAMLING CK AT CLVT ON SC 33 2 MI E OF ORANGEBURG	E-022	ORANGEBURG	REC	FC	
EDISTO	03050206010	LITTLE BULL CK CK AT SC 33-BL UTICA TOOL CO	E-076	ORANGEBURG	AL	DO, PH	
EDISTO	03050206010	LITTLE BULL CK CK AT SC 33-BL UTICA TOOL CO	E-076	ORANGEBURG	REC	FC	
EDISTO	03050206010	GRAMBLING CRK. AT SR 154	E-589	ORANGEBURG	AL	BIO	
EDISTO	03050206010	BULL SWAMP AT SR 65	E-590	ORANGEBURG	AL	BIO	
EDISTO	03050206020	FOUR HOLE SWP AT S-38-50 5.2 MI SE OF CAMERON	E-059	ORANGEBURG	REC	FC	
EDISTO	03050206020	FOUR HOLE SWAMP AT SC 210	E-111	ORANGEBURG	AL	DO	
EDISTO	03050206020	FOUR HOLE SWAMP AT SC 210	E-111	ORANGEBURG	REC	FC	
EDISTO	03050206020	GOODBYS SWAMP AT US 176 6 M SW OF ELLOREE	RS-01036	ORANGEBURG	AL	BIO	
EDISTO	03050206020	GOODBYS SWAMP AT US 176 6 M SW OF ELLOREE	RS-01036	ORANGEBURG	REC	FC	
EDISTO	03050206030	COW CASTLE CK AT S-38-170	E-050	ORANGEBURG	REC	FC	
EDISTO	03050206040	FOUR HOLE SWAMP AT SC 453	E-112	DORCHESTER	AL	DO	
EDISTO	03050206050	PROVIDENCE SWP AT E FRONTAGE RD TO I-95 NW OF HOLLY HILL	E-051	ORANGEBURG	AL	DO	
EDISTO	03050206050	PROVIDENCE SWP AT E FRONTAGE RD TO I-95 NW OF HOLLY HILL	E-051	ORANGEBURG	REC	FC	
EDISTO	03050206050	HORSE RANGE SWAMP AT US 176	E-052	ORANGEBURG	REC	FC	
EDISTO	03050206050	HORSE RANGE SWAMP AT S-38-1264	RS-02303	ORANGEBURG	REC	FC	
EDISTO	03050206060	CEDAR SWAMP AT CEMENT BRIDGE RD. OFF SR 640	E-596	ORANGEBURG	AL	BIO	
EDISTO	03050206070	4 HOLE SWP AT US 78 E OF DORCHESTER	E-100	DORCHESTER	AL	CR	
PEEDEE	03040201030	WESTFIELD CREEK AT US 52	PD-339	CHESTERFIELD	AL	DO, PH	
PEEDEE	03040201050	PEE DEE RVR AT US 1 NE CHERAW	PD-012	MARLBORO	FISH	HG	
PEEDEE	03040201050	GREAT PEE DEE RVR AT US 15 & 401	PD-015	DARLINGTON	FISH	HG	

2004 SC List of Impai ...ers by 11-Digit HUC

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
PEEDEE	03040201050	GREAT PEE DEE RVR AT US 15 & 401	PD-015	DARLINGTON	REC	FC	
PEEDEE	03040201050	PEE DEE RVR AT SC 34 11 MI NE DARLINGTON	PD-028	DARLINGTON	AL	CU	
PEEDEE	03040201050	PEE DEE RVR AT SC 34 11 MI NE DARLINGTON	PD-028	DARLINGTON	FISH	HG	
PEEDEE	03040201050	LOUTHER'S LAKE	PD-666	DARLINGTON	FISH	HG	
PEEDEE	03040201060	DEEP CRK. AT SR 47	PD-671	CHESTERFIELD	AL	BIO	
PEEDEE	03040201060	THOMPSON CRK. AT SC 109	PD-673	CHESTERFIELD	AL	BIO	
PEEDEE	03040201060	DEEP CREEK 75 FT UPSTREAM OF SC 9, 5.5 M W OF CHESTERFIELD	RS-01013	CHESTERFIELD	AL	TURBIDITY	
PEEDEE	03040201060	DEEP CREEK 75 FT UPSTREAM OF SC 9, 5.5 M W OF CHESTERFIELD	RS-01013	CHESTERFIELD	REC	FC	
PEEDEE	03040201060	CLAY CREEK AT S-13-55	RS-02305	CHESTERFIELD	AL	DO	
PEEDEE	03040201070	CROOKED CREEK AT SC 912	PD-063	MARLBORO	AL	DO	
PEEDEE	03040201090	GREAT PEE DEE RIVER @ BLUE'S LANDING	PD-242	MARLBORO	FISH	HG	
PEEDEE	03040201100	LK ROBINSON AT S-13-346 5 MI E MCBEE BY BOAT	PD-327	CHESTERFIELD	FISH	HG	
PEEDEE	03040201110	BLACK CK AT S-16-18 1 MI NNE HARTSVILLE	PD-021	DARLINGTON	AL	PH	
PEEDEE	03040201110	BLACK CK AT S-16-133 2.25 MI NE OF DARLINGTON	PD-025	DARLINGTON	AL	PH	
PEEDEE	03040201110	BLACK CK AT S-16-133 2.25 MI NE OF DARLINGTON	PD-025	DARLINGTON	REC	FC	
PEEDEE	03040201110	60" TILE DISCHARGING TO DITCH ACROSS RD AT DARLINGTON STP	PD-141	DARLINGTON	REC	FC	
PEEDEE	03040201110	SNAKE BR AT RR AVE IN HARTSVILLE	PD-258	DARLINGTON	AL	DO, PH	
PEEDEE	03040201110	SNAKE BR AT RR AVE IN HARTSVILLE	PD-258	DARLINGTON	REC	FC	
PEEDEE	03040201110	BLACK CREEK @ SC 327	PD-623	FLORENCE	FISH	HG	
PEEDEE	03040201110	TRIBUTARY TO SWIFT CREEK AT COUNTY RD 213 JUST NORTH OF DARLINGTON	RS-01023	DARLINGTON	AL	CU	
PEEDEE	03040201110	TRIBUTARY TO SWIFT CREEK AT COUNTY RD 213 JUST NORTH OF DARLINGTON	RS-01023	DARLINGTON	REC	FC	
PEEDEE	03040201110	BLACK CREEK NEAR DIRT ROAD OFF COUNTY RD 41, 6 M NE OF HARTSVILLE	RS-01043	DARLINGTON	AL	CU	
PEEDEE	03040201120	GREAT PEE DEE RVR AT US 301/76	PD-337	FLORENCE	AL	CU	
PEEDEE	03040201120	GREAT PEE DEE RVR AT US 301/76	PD-337	FLORENCE	FISH	HG	
PEEDEE	03040201130	GULLEY BR AT S-21-13, TIMROD PARK	PD-065	FLORENCE	REC	FC	*
PEEDEE	03040201130	MIDDLE SWP AT SC 51 3.5 MI SSE OF FLORENCE	PD-230	FLORENCE	AL	DO	
PEEDEE	03040201130	JEFFRIES CK AT SC 340 6.8 MI SSW OF DARLINGTON	PD-255	DARLINGTON	AL	DO	
PEEDEE	03040201130	JEFFRIES CK AT S-21-112 4.8 MI W OF FLORENCE	PD-256	FLORENCE	AL	DO	
PEEDEE	03040201130	WILLOW CREEK AT SC 327	PD-630	FLORENCE	AL	BIO	
PEEDEE	03040201140	GREAT PEE DEE RVR AT US 378	PD-076	FLORENCE	FISH	HG	
PEEDEE	03040201140	GREAT PEE DEE RIVER @ DEWITT BLUFF	PD-622	FLORENCE	FISH	HG	
PEEDEE	03040201140	GREAT PEE DEE RIVER @ BOSTICK	PD-662	FLORENCE	FISH	HG	
PEEDEE	03040201150	SMITH SWP AT US 501 1.9 MI SSE OF MARION	PD-187	MARION	AL	DO	
PEEDEE	03040201150	SMITH SWP AT US 501 1.9 MI SSE OF MARION	PD-187	MARION	REC	FC	*
PEEDEE	03040201150	SMITH SWP AT S-34-19 1 MI E OF MARION	PD-320	MARION	AL	DO	
PEEDEE	03040201150	SMITH SWP AT S-34-19 1 MI E OF MARION	PD-320	MARION	REC	FC	*
PEEDEE	03040201160	PEE DEE RVR AT PETERS FIELD LANDING OFF S-22-36 US IP PUMP STATION	PD-060	GEORGETOWN	FISH	HG	
PEEDEE	03040201160	CLARKS CREEK @ SNOW LAKE	PD-317	WILLIAMSBURG	FISH	HG	
PEEDEE	03040201160	GREAT PEE DEE RIVER @ STAPLES LAKE	PD-621	WILLIAMSBURG	FISH	HG	
PEEDEE	03040201170	GREAT PEE DEE RIVER ABOVE HWY 701 BRIDGE	CSTL-559	HORRY	FISH	HG	
PEEDEE	03040201170	WINYAH BAY AT JCT OF PEE DEE & WACCAMAW AT MARKER 92	MD-080	GEORGETOWN	AL	PH	#
PEEDEE	03040201170	GREAT PEE DEE RIVER @ SAMWORTH WMA	PD-663	GEORGETOWN	FISH	HG	
PEEDEE	03040202020	HILLS CREEK AT S-13-105	PD-333	CHESTERFIELD	REC	FC	*
PEEDEE	03040202020	HILLS CREEK AT S-13-545	PD-366	CHESTERFIELD	AL	DO	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
PEEDEE	03040202020	HILLS CRK. AT SR 105	PD-672	CHESTERFIELD	AL	BIO	
PEEDEE	03040202030	LYNCHES RVR AT SC 9 W OF PAGELAND	PD-113	CHESTERFIELD	AL	CU	
PEEDEE	03040202030	LYNCHES RVR AT SC 9 W OF PAGELAND	PD-113	CHESTERFIELD	REC	FC	*
PEEDEE	03040202030	N BR WILDCAT CK AT S-29-39 1 MI S OF TRADESVILLE	PD-179	LANCASTER	REC	FC	*
PEEDEE	03040202030	S BR WILDCAT CK AT S-29-39 2 MI S OF TRADESVILLE	PD-180	LANCASTER	AL	BIO	
PEEDEE	03040202030	S BR WILDCAT CK AT S-29-39 2 MI S OF TRADESVILLE	PD-180	LANCASTER	REC	FC	*
PEEDEE	03040202040	FLAT CREEK AT S-29-123	PD-342	LANCASTER	AL	CU	*
PEEDEE	03040202040	FLAT CREEK AT S-29-123	PD-342	LANCASTER	REC	FC	
PEEDEE	03040202050	LYNCHES RVR AT S-13-42	PD-066	CHESTERFIELD	REC	FC	*
PEEDEE	03040202060	FORK CK AT SC 151	PD-067	CHESTERFIELD	REC	FC	*
PEEDEE	03040202060	FORK CK AT UN# RD 1.5 MI SW JEFFERSON	PD-068	CHESTERFIELD	AL	BIO	
PEEDEE	03040202060	FORK CK AT UN# RD 1.5 MI SW JEFFERSON	PD-068	CHESTERFIELD	REC	FC	*
PEEDEE	03040202060	LITTLE FORK CK AT S-13-265 1.5 MI SW JEFFERSON	PD-215	CHESTERFIELD	AL	CU	
PEEDEE	03040202070	TODD'S BR AT S-29-564 1.5 MI NE OF KERSHAW	PD-005	LANCASTER	REC	FC	
PEEDEE	03040202070	LITTLE LYNCHES RVR AT US 601 2 MI NE KERSHAW	PD-006	LANCASTER	REC	FC	
PEEDEE	03040202070	HORTON CREEK AT S-29-95	PD-335	LANCASTER	REC	FC	
PEEDEE	03040202070	HANGING ROCK CRK. AT SR 770	PD-669	LANCASTER	AL	BIO	
PEEDEE	03040202080	LITTLE LYNCHES RIVER AT S-28-42	PD-343	KERSHAW	AL	PH	
PEEDEE	03040202090	LYNCHES RVR AT US 15/SC 34	PD-071	LEE	FISH	HG	
PEEDEE	03040202090	LYNCHES RVR AT S-28-15 4.5 MI SE BETHUNE	PD-080	KERSHAW	REC	FC	
PEEDEE	03040202090	LYNCHES RIVER AT S-21-55	PD-093	FLORENCE	AL	PH	
PEEDEE	03040202090	COUSAR BR 1/4 MI BELOW BISHOPVILLE FINISHING CO	PD-112	LEE	AL	PH	
PEEDEE	03040202090	LYNCHES RIVER AT SC 403	PD-319	FLORENCE	AL	PH	
PEEDEE	03040202090	LYNCHES RIVER AT US 401	PD-364	DARLINGTON	FISH	HG	
PEEDEE	03040202100	SPARROW SWP AT S-16-697 2.5 MI E OF LAMAR	PD-072	DARLINGTON	REC	FC	
PEEDEE	03040202100	NEWMAN SWP AT S-16-449 0.9 MI NE OF LAMAR	PD-229	DARLINGTON	AL	DO	
PEEDEE	03040202120	LYNCHES RVR AT US 52 NEAR EFFINGHAM	PD-041	FLORENCE	AL	PH	
PEEDEE	03040202120	LYNCHES RIVER @ JOHNSONVILLE	PD-048	FLORENCE	FISH	HG	
PEEDEE	03040202120	LYNCHES RVR AT S-21-49 5 MI NW JOHNSONVILLE	PD-281	FLORENCE	AL	CU, PH	
PEEDEE	03040202120	LYNCHES RIVER @ US 52	PD-624	FLORENCE	FISH	HG	
PEEDEE	03040202130	BIG SWP AT S-21-360 1.1 MI W OF PAMPLICO	PD-168	FLORENCE	AL	DO	
PEEDEE	03040202130	BIG SWP AT US 378 & SC 51 0.9 MI W OF SALEM	PD-169	FLORENCE	AL	DO	
PEEDEE	03040202130	BIG SWP AT US 378 & SC 51 0.9 MI W OF SALEM	PD-169	FLORENCE	REC	FC	
PEEDEE	03040202130	CYPRESS BRANCH AT S-21-164	PD-631	FLORENCE	AL	BIO	
PEEDEE	03040202140	CAMP BRANCH AT S-21-278	PD-346	FLORENCE	AL	DO	
PEEDEE	03040202150	LAKE SWAMP ON SC 341	PD-086A	FLORENCE	AL	DO	
PEEDEE	03040202160	SINGLETON SWAMP AT S-21-67	PD-314	FLORENCE	AL	DO, PH	
PEEDEE	03040203180	LUMBER RVR AT US 76 AT NICHOLS	PD-038	HORRY	FISH	HG	
PEEDEE	03040203180	LUMBER RIVER @ CAUSEY LANDING	PD-664	HORRY	FISH	HG	
PEEDEE	03040203210	ASHPOLE SWAMP AT PRIVATE ROAD (SEE LAKE VIEW QUAD)	PD-347	DILLON	AL	DO	
PEEDEE	03040203210	BEAR SWAMP AT S-17-56	PD-368	DILLON	AL	DO	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
PEEDEE	03040204030	LITTLE PEE DEE RVR AT S-17-23	PD-029E	DILLON	REC	FC	*
PEEDEE	03040204030	MAPLE SWP AT SC 57	PD-030	DILLON	AL	DO	
PEEDEE	03040204030	MAPLE SWP AT SC 57	PD-030	DILLON	REC	FC	
PEEDEE	03040204030	LITTLE PEE DEE RVR BELOW JCT WITH MAPLE SWP	PD-030A	DILLON	FISH	HG	
PEEDEE	03040204030	LITTLE PEE DEE RVR BELOW JCT WITH MAPLE SWP	PD-030A	DILLON	REC	FC	*
PEEDEE	03040204030	LITTLE PEE DEE RIVER @ MOCOCASIN'S BLUFF	PD-283	DILLON	FISH	HG	
PEEDEE	03040204030	LITTLE PEE DEE RIVER @ FLOYDALE BRIDGE	PD-618	DILLON	FISH	HG	
PEEDEE	03040204050	BUCK SWP AT S-17-33	PD-031	DILLON	AL	DO	
PEEDEE	03040204050	BUCK SWP AT S-17-33	PD-031	DILLON	REC	FC	
PEEDEE	03040204050	BUCK SWAMP AT S-17-42	PD-349	DILLON	AL	DO	
PEEDEE	03040204060	LITTLE PEE DEE AT S-34-60	PD-052	MARION	AL	CU	
PEEDEE	03040204060	LITTLE PEE DEE RIVER @ GILCREST LANDING	PD-053	MARION	FISH	HG	
PEEDEE	03040204070	WHITE OAK CK AT S-34-31	PD-037	MARION	AL	DO	
PEEDEE	03040204070	WHITE OAK CK AT S-34-31	PD-037	MARION	REC	FC	*
PEEDEE	03040204070	LITTLE PEE DEE RVR AT US 501, GALIVANT'S FERRY	PD-042	HORRY	AL	CU	
PEEDEE	03040204070	LITTLE PEE DEE RIVER @ SANDY BLUFF	PD-054	HORRY	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE RIVER OFF END OF S-26-135 AT PUNCHBOWL LANDING	PD-350	HORRY	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE RIVER @ GALAVANTS FERRY	PD-619	MARION	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE RIVER @ HWY 378	PD-620	HORRY	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE RIVER @ RED BLUFF	PD-654	MARION	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE RIVER @ DAVIS LANDING	PD-655	MARION	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE RIVER @ LOCUST TREE LANDING	PD-656	MARION	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE RIVER @ GUNTER'S LAKE	PD-657	HORRY	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE RIVER @ SAMPSON LANDING	PD-658	MARION	FISH	HG	
PEEDEE	03040204070	RUSS CREEK @ PARKERS LANDING	PD-665	MARION	FISH	HG	
PEEDEE	03040204070	RUSS CREEK @ PARKERS LANDING	PD-665	MARION	FISH	HG	
PEEDEE	03040204070	LITTLE PEE DEE @ HUGHES LANDING	PD-691	HORRY	FISH	HG	
PEEDEE	03040204080	CEDAR CREEK AT S-26-23	PD-351	HORRY	AL	DO	
PEEDEE	03040204090	CHINNERS SWAMP AT GUNTERS ISLAND RD OFF S-26-99	PD-352	HORRY	REC	FC	*
PEEDEE	03040205020	UNNAMED DRAINAGE CANAL TO ATKINS CANAL AT SC 527 (3/4 MI N OF US 76)	PD-354	LEE	AL	DO, PH	
PEEDEE	03040205030	SCAPE ORE SWAMP AT S-31-108	PD-355	LEE	REC	FC	
PEEDEE	03040205030	BEAVER DAM CREEK AT S-31-313	PD-636	LEE	AL	BIO	
PEEDEE	03040205040	MECHANICSVILLE SWAMP AT S-31-500	PD-356	LEE	AL	DO	
PEEDEE	03040205040	MECHANICSVILLE SWAMP AT S-31-500	PD-356	LEE	REC	FC	
PEEDEE	03040205040	MCGIRTS CREEK AT COUNTY RD 73, 7.5 M SW OF BISHOPVILLE	RS-01017	LEE	AL	DO, TURBIDITY	
PEEDEE	03040205040	MCGIRTS CREEK AT COUNTY RD 73, 7.5 M SW OF BISHOPVILLE	RS-01017	LEE	REC	FC	
PEEDEE	03040205070	BLACK RVR AT S-14-40 E OF MANNING	PD-116	CLARENDON	AL	DO	
PEEDEE	03040205080	GREEN SWP AT S-43-33	PD-039	SUMTER	AL	DO	
PEEDEE	03040205080	TURKEY CREEK AT US 521	PD-040	SUMTER	FISH	HG	
PEEDEE	03040205080	TURKEY CREEK AT US 521	PD-040	SUMTER	REC	FC	*
PEEDEE	03040205080	POCOTALIGO RVR AT US 15 3.5 MI S SUMTER	PD-091	SUMTER	AL	DO	
PEEDEE	03040205080	TURKEY CK AT LIBERTY ST IN SUMTER ABOVE SANTEE PRINT WORKS	PD-098	SUMTER	REC	FC	*
PEEDEE	03040205080	NASTY BR AT S-43-251 7.5 MI SW OF SUMTER	PD-239	SUMTER	AL	DO	
PEEDEE	03040205080	NASTY BR AT S-43-251 7.5 MI SW OF SUMTER	PD-239	SUMTER	REC	FC	*

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
PEEDEE	03040205090	POCOTALIGO RVR AT S-14-50 9.5 MI NE MANNING	PD-043	CLARENDON	AL	DO	
PEEDEE	03040205090	POCOTALIGO RVR AT S-14-50 9.5 MI NE MANNING	PD-043	CLARENDON	FISH	HG	
PEEDEE	03040205090	POCOTALIGO RVR AT 3RD BRDG N OF MANNING ON US 301	PD-115	CLARENDON	AL	DO	
PEEDEE	03040205090	POCOTALIGO RVR AT S-43-32 9 MI SSE OF SUMTER	PD-202	SUMTER	AL	DO	
PEEDEE	03040205090	BRIAR BRANCH AT S-43-459	PD-617	SUMTER	AL	BIO	
PEEDEE	03040205100	BLACK RIVER @ PINE TREE LANDING	PD-046	GEORGETOWN	FISH	HG	
PEEDEE	03040205110	DOUGLAS SWAMP OFF THIGPEN ROAD BEHIND WHITE HOUSE, 3.5 M E OF TURBEVILLE	RS-01002	FLORENCE	AL	DO	
PEEDEE	03040205120	CLAPP SWAMP AT SC 527	RS-02325	WILLIAMSBURG	AL	DO	
PEEDEE	03040205140	BLACK RVR AT US 52 AT KINGSTREE	PD-044	WILLIAMSBURG	FISH	HG	
PEEDEE	03040205140	OX SWAMP AT US 521	PD-629	WILLIAMSBURG	AL	BIO	
PEEDEE	03040205150	BLACK RVR AT SC 51 11.6 MI NE OF ANDREWS	PD-170	GEORGETOWN	AL	CU, DO	
PEEDEE	03040205150	BLACK RVR AT SC 51 11.6 MI NE OF ANDREWS	PD-170	GEORGETOWN	FISH	HG	
PEEDEE	03040205150	BLACK RIVER AT S-45-30	PD-359	WILLIAMSBURG	AL	DO	
PEEDEE	03040205150	BLACK RIVER @ PUMPHOUSE LANDING	PD-626	WILLIAMSBURG	FISH	HG	
PEEDEE	03040205150	BLACK RIVER @ OLD PUMP STATION	PD-659	GEORGETOWN	FISH	HG	
PEEDEE	03040205150	BLACK RIVER @ PEA HOUSE LANDING	PD-692	GEORGETOWN	FISH	HG	
PEEDEE	03040205170	BLACK MINGO CK AT SC 41 14 MI NE OF ANDREWS	PD-172	GEORGETOWN	FISH	HG	
PEEDEE	03040205170	BLACK MINGO CREEK AT S-45-121	PD-360	WILLIAMSBURG	AL	DO	
PEEDEE	03040205180	BLACK RIVER @ PETER'S CREEK	PD-171	GEORGETOWN	FISH	HG	
PEEDEE	03040205180	BLACK RVR AT S-22-489 4 MI NE GEORGETOWN	PD-325	GEORGETOWN	AL	TURBIDITY	*
PEEDEE	03040205180	BLACK RIVER @ ROCKY POINT	PD-660	GEORGETOWN	FISH	HG	
PEEDEE	03040205180	BLACK RIVER @ PRINGLE'S FERRY	PD-661	GEORGETOWN	FISH	HG	
PEEDEE	03040206090	WACCAMAW RVR AT SC 9 7.0 MI W OF CHERRY GROVE	MD-124	HORRY	AL	CU	
PEEDEE	03040206090	WACCAMAW RVR AT SC 9 7.0 MI W OF CHERRY GROVE	MD-124	HORRY	FISH	HG	
PEEDEE	03040206100	BUCK CREEK AT SC 905	PD-362	HORRY	AL	DO	
PEEDEE	03040206110	SIMPSON CREEK AT SC 905	PD-363	HORRY	AL	ZN	
PEEDEE	03040206120	WACCAMAW RIVER @ SC 31	CSTL-553	HORRY	FISH	HG	
PEEDEE	03040206120	WACCAMAW RIVER @ SEC RD 105	CSTL-554	HORRY	FISH	HG	
PEEDEE	03040206120	WACCAMAW RIVER @ SEC RD 901	CSTL-555	HORRY	FISH	HG	
PEEDEE	03040206130	CRAB TREE SWAMP AT LONG ST BL OUTFALL OF CONWAY #1 POND	MD-158	HORRY	REC	FC	
PEEDEE	03040206140	WACCAMAW RIVER @ PITCH LANDING	CSTL-556	HORRY	FISH	HG	
PEEDEE	03040206140	INTRACOASTAL WATERWAY @ SOCASTEE	CSTL-558	HORRY	FISH	HG	
PEEDEE	03040206140	WACCAMAW RVR 1/4 MI UPSTRM OF JCT WITH INTRACOASTAL WTRWY	MD-136	HORRY	FISH	HG	
PEEDEE	03040206140	WACCAMAW RIVER @ TODDVILLE	MD-144	HORRY	FISH	HG	
PEEDEE	03040206140	WACCAMAW RVR 1 MI DS OF BUCKSVILLE LANDING AT BIG BEND IN RVR	MD-145	HORRY	FISH	HG	
PEEDEE	03040206140	BEAR SWAMP AT S-26-110	PD-638	HORRY	AL	BIO	
PEEDEE	03040206150	WACCAMAW RIVER @ BUCKSPORT LANDING	CSTL-557	HORRY	FISH	HG	
PEEDEE	03040207020	DUNN SOUND CREEK MOUTH	01-02	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	DUNN SOUND CREEK AT BIG BEND	01-05	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	DUNN SOUND BRIDGE TO WAITES ISLAND	01-06	HORRY	SHELLFISH	FC	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
PEEDEE	03040207020	HOG INLET	01-07	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	HOUSE CREEK	01-17	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	HOUSE CREEK INLET AT 53RD AVENUE BRIDGE ON CANAL	01-17A	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	DUNN SOUND AT HOG INLET	01-18	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	MAIN CREEK AT 53RD AVENUE	01-19	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	WHITE POINT SWASH	02-01	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	SINGLETON SWASH	02-02	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	CANEPATCH SWASH	02-03	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	WITHERS SWASH	03-01	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	MIDWAY SWASH - PEBBLE BEACH	03-02	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	MAIN CREEK AT ATLANTIC AVENUE BRIDGE	04-01	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	MAIN CREEK AT STANLEY DRIVE (D9-02)	04-01A	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	MAIN CREEK AT MICKEY SPILLANE'S HOME	04-02	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207020	ALLSTON CREEK AT WESTON FLAT	04-06	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207020	PARSONAGE CREEK AT NANCE'S DOCK	04-08	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207020	PARSONAGE CREEK AT CHICKEN FARM DITCH	04-16	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207020	GARDEN CITY CANAL AT THE "OLD BOAT WRECK"	04-26	HORRY	SHELLFISH	FC	
PEEDEE	03040207020	MAIN CREEK, OPPOSITE ENTRANCE TO MT. GILEAD CANAL	04-27	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207020	INTRACOASTAL WTRWY (LITTLE RVR) ON SC 9 (US 17)	MD-125	HORRY	AL	CU	
PEEDEE	03040207020	INTRACOASTAL WATERWAY @ NORTH MYRTLE	MD-163	HORRY	FISH	HG	
PEEDEE	03040207020	HOUSE CK AT 53RD AVE OUT FROM BOAT LANDING (01-19)	MD-276	HORRY	AL	CU	
PEEDEE	03040207030	SAMPIT RVR OPP AMER CYANAMID CHEM CO	MD-073	GEORGETOWN	AL	PH	#
PEEDEE	03040207030	SAMPIT RVR AT CHANNEL MARKER #30	MD-074	GEORGETOWN	AL	PH	#
PEEDEE	03040207030	SAMPIT RVR BTWN MOUTHS OF PORTS CK & PENNY ROYAL CK	MD-075	GEORGETOWN	AL	DO	#
PEEDEE	03040207030	SAMPIT RVR AT US 17	MD-077	GEORGETOWN	AL	DO	#
PEEDEE	03040207030	WHITES CK 100 YDS UPSTRM OF JCT WITH SAMPIT RVR	MD-149	GEORGETOWN	AL	CU	#
PEEDEE	03040207030	SAMPIT RIVER 1.4 MI W US 17 BRIDGE	PD-628	GEORGETOWN	FISH	HG	
PEEDEE	03040207040	CLUBHOUSE CREEK AT LITCHFIELD BOULEVARD BRIDGE	04-09	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	PAWLEY'S ISLAND CREEK SHELL AVENUE AND	04-10	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	PAWLEY'S ISLAND CREEK NORTH CAUSEWAY BRIDGE	04-11	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	PAWLEY'S ISLAND CREEK AT SOUTH CAUSEWAY BRIDGE	04-12	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	PAWLEY'S INLET	04-13	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	CLUBHOUSE CREEK AT DOCK END OF SPORTSMAN BOULEVARD	04-14	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	CLUBHOUSE CREEK - FIRST BEND SOUTH OF SALT MARSH COVE	04-19	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	PAWLEY'S ISLAND SOUND, INLET SOUTH BOAT LANDING	04-21	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	JONES CREEK AT NANCY CREEK	05-01	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	OYSTER BAY NEAR CUTOFF CREEK	05-05	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	MUD BAY AT NO MAN'S FRIEND CREEK	05-06	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	JONES CREEK AT MUD BAY	05-07	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	TOWN CREEK AT SOUTHERN REACH OF CLAMBANK CREEK	05-09	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	DEBIDUE CREEK AT BOAT BASIN	05-13	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	WINYAH BAY MAIN CHANNEL, BUOY 19A, RANGE E	05-20	GEORGETOWN	SHELLFISH	FC	
PEEDEE	03040207040	WINYAH BAY, TIP OF WESTERN CHANNEL ISLAND	05-25	GEORGETOWN	SHELLFISH	FC	
SALKEHATCHIE	03050207030	SALKEHATCHIE RVR AT SC 278 2.5 MI S BARNWELL	CSTL-003	BARNWELL	REC	FC	
SALKEHATCHIE	03050207030	WELLS BRCH AT SC 300	RS-02472	ALLENDALE	REC	FC	
SALKEHATCHIE	03050207040	SALKEHATCHIE RVR AT 601 9 MI NE HAMPTON	CSTL-006	COLLETON	AL	PH	
SALKEHATCHIE	03050207040	SALKEHATCHIE RVR AT 601 9 MI NE HAMPTON	CSTL-006	COLLETON	REC	FC	
SALKEHATCHIE	03050207040	SALKEHATCHIE RIVER AT U.S. 301 & 321	CSTL-048	ALLENDALE	FISH	HG	
SALKEHATCHIE	03050207040	SALKEHATCHIE RIVER AT U.S. 301 & 321	CSTL-048	ALLENDALE	REC	FC	
SALKEHATCHIE	03050207040	SAVANNAH CREEK AT S.R.-87	CSTL-053	BAMBERG	AL	BIO	
SALKEHATCHIE	03050207040	SALKEHATCHIE RIVER @ SC 641	CSTL-105	BAMBERG	FISH	HG	
SALKEHATCHIE	03050207040	SALKEHATCHIE RIVER @ US 601	CSTL-562	HAMPTON	FISH	HG	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SALKEHATCHIE	03050207040	RICEPATCH CRK. AT SC 63	CSTL-569	COLLETON	AL	BIO	
SALKEHATCHIE	03050207060	LITTLE SALKEHATCHIE @ SC 70	CSTL-566	BAMBERG	FISH	HG	
SALKEHATCHIE	03050207070	LEMON CREEK AT S-05-541	CSTL-116	BAMBERG	REC	FC	
SALKEHATCHIE	03050207070	LEMON CREEK AT S-74	CSTL-576	BAMBERG	AL	BIO	
SALKEHATCHIE	03050207080	LITTLE SALKEHATCHIE RIVER AT SC 64	CSTL-117	COLLETON	REC	FC	
SALKEHATCHIE	03050207090	BUCKHEAD CREEK AT SC 212	CSTL-119	COLLETON	REC	FC	
SALKEHATCHIE	03050207100	WILLOW CRK. AT SR 42	CSTL-570	COLLETON	AL	BIO	
SALKEHATCHIE	03050207110	LITTLE SALKEHATCHIE RIVER AT SC 63	CSTL-120	COLLETON	AL	ZN	
SALKEHATCHIE	03050207110	LITTLE SALKEHATCHIE RIVER AT SC 63	CSTL-120	COLLETON	FISH	HG	
SALKEHATCHIE	03050207110	SANDY RUN CREEK AT US 21	CSTL-585	COLLETON	AL	BIO	
SALKEHATCHIE	03050208010	COMBAHEE RVR AT US 17 10 MI ESE YEMASSEE	CSTL-098	BEAUFORT	AL	DO	
SALKEHATCHIE	03050208010	COMBAHEE RVR AT US 17 10 MI ESE YEMASSEE	CSTL-098	BEAUFORT	FISH	HG	
SALKEHATCHIE	03050208010	COMBAHEE RIVER @ SEC RD 756	CSTL-561	COLLETON	FISH	HG	
SALKEHATCHIE	03050208010	REMICK SWAMP CRK. AT SR 41	CSTL-584	COLLETON	AL	BIO	
SALKEHATCHIE	03050208010	COOSAW RVR NEAR MOUTH OF COMBAHEE RVR	RO-02001	BEAUFORT	AL	TURBIDITY	
SALKEHATCHIE	03050208010	COOSAW RVR NEAR MOUTH OF BULL RVR	RO-02005	BEAUFORT	AL	CU, TURBIDITY	
SALKEHATCHIE	03050208010	CHEHAW RVR AT OLD CHEHAW BOAT LANDING ON S-15-161	RT-02017	COLLETON	AL	ZN	
SALKEHATCHIE	03050208020	IRELAND CK AT S-15-116 5 1/2 MI N OF WALTERBORO	CSTL-044	COLLETON	REC	FC	
SALKEHATCHIE	03050208020	ASHEPOO RVR AT SC 303 10 MI SSW OF WALTERBORO	CSTL-068	COLLETON	AL	ZN	
SALKEHATCHIE	03050208020	ASHEPOO RVR AT SC 303 10 MI SSW OF WALTERBORO	CSTL-068	COLLETON	REC	FC	
SALKEHATCHIE	03050208030	CHESSIE CREEK @ CHESSIE LANDING	CSTL-070	COLLETON	FISH	HG	
SALKEHATCHIE	03050208030	HORSESHOE CREEK AT SC 64	CSTL-071	COLLETON	AL	ZN	
SALKEHATCHIE	03050208030	HORSESHOE CREEK AT SC 64	CSTL-071	COLLETON	FISH	HG	
SALKEHATCHIE	03050208030	CHESSEY CREEK AT S.R. 45	CSTL-580	COLLETON	AL	BIO	
SALKEHATCHIE	03050208030	FULLER SWAMP CRK. AT US 17A	CSTL-581	COLLETON	AL	BIO	
SALKEHATCHIE	03050208040	MOSQUITO CREEK AT CONFLUENCE OF ASHEPOO RIVER	14-21	COLLETON	SHELLFISH	FC	
SALKEHATCHIE	03050208040	ASHEPOO RVR AT US 17 3.4 MI ESE OF GREEN POND	CSTL-069	COLLETON	AL	DO	
SALKEHATCHIE	03050208040	ASHEPOO RVR AT US 17 3.4 MI ESE OF GREEN POND	CSTL-069	COLLETON	FISH	HG	
SALKEHATCHIE	03050208040	ASHEPOO RVR AT US 17 3.4 MI ESE OF GREEN POND	CSTL-069	COLLETON	REC	FC	
SALKEHATCHIE	03050208040	ASHEPOO RIVER AT S-15-26	MD-251	COLLETON	AL	TURBIDITY	*
SALKEHATCHIE	03050208040	ASHEPOO RIVER AT PUBLIC OYSTER GROUND (14-19)	MD-253	COLLETON	AL	CU, TURBIDITY	#
SALKEHATCHIE	03050208040	TRIB TO PINE ISLAND CK W OF PINE ISLAND	RT-02019	COLLETON	AL	CU	
SALKEHATCHIE	03050208050	COOSAWHATCHIE RVR AT S-03-47	CSTL-110	ALLENDALE	AL	DO	
SALKEHATCHIE	03050208050	COOSAWHATCHIE RIVER AT SC 363	CSTL-121	HAMPTON	AL	DO	
SALKEHATCHIE	03050208050	DUCK CREEK AT THE DOWNSTREAM SIDE OF US 278, 2.6 M SE OF ALLENDALE	RS-01025	ALLENDALE	AL	DO	
SALKEHATCHIE	03050208060	LAKE GEORGE WARREN IN FOREBAY NEAR DAM	CL-062	HAMPTON	AL	ZN	
SALKEHATCHIE	03050208070	SANDERS BR AT SC 278	CSTL-010	HAMPTON	REC	FC	
SALKEHATCHIE	03050208070	SANDERS BR AT S-25-50	CSTL-011	HAMPTON	AL	BIO	
SALKEHATCHIE	03050208070	SANDERS BR AT S-25-50	CSTL-011	HAMPTON	REC	FC	
SALKEHATCHIE	03050208070	SANDERS BRANCH AT SC RD 363	CSTL-108	HAMPTON	REC	FC	
SALKEHATCHIE	03050208070	COOSAWHATCHIE RVR AT S-25-27 2.5 MI SW CUMMINGS	CSTL-109	HAMPTON	AL	PH	
SALKEHATCHIE	03050208070	SANDERS BR FROM BRIDGE AT PAVED RD FROM SC 363 N	RS-02488	HAMPTON	AL	ZN	
SALKEHATCHIE	03050208070	SANDERS BR FROM BRIDGE AT PAVED RD FROM SC 363 N	RS-02488	HAMPTON	REC	FC	

2004 SC List of Impai rs by 11-Digit HUC

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SALKEHATCHIE	03050208080	CYPRESS CREEK AT SC 3	CSTL-582	JASPER	AL	BIO	
SALKEHATCHIE	03050208090	COOSAWHATCHIE RIVER @ SEC RD 36	CSTL-077	JASPER	FISH	HG	
SALKEHATCHIE	03050208090	COOSAWHATCHIE RVR AT US 17 AT COOSAWHATCHIE	CSTL-107	JASPER	AL	DO, PH	
SALKEHATCHIE	03050208090	POCOTALIGO RVR AT US 17 AT POCOTALIGO	MD-007	BEAUFORT	AL	DO, PH	
SALKEHATCHIE	03050208090	POCOTALIGO RVR AT US 17 AT POCOTALIGO	MD-007	BEAUFORT	REC	FC	
SALKEHATCHIE	03050208090	CHECHESSEE RVR AT SC 170 10.5 MI SW OF BEAUFORT	MD-117	BEAUFORT	AL	DO	
SALKEHATCHIE	03050208090	BEES CK AT SC 462 5.9 MI NE OF RIDGELAND	MD-128	JASPER	AL	DO, PH	
SALKEHATCHIE	03050208090	BEES CK AT SC 462 5.9 MI NE OF RIDGELAND	MD-128	JASPER	REC	FC	
SALKEHATCHIE	03050208090	BROAD RVR AT MOUTH OF ARCHER CK ON SW SIDE OF USMC	MD-172	BEAUFORT	AL	DO	
SALKEHATCHIE	03050208090	COLLETON RVR AT COLLETON NECK-AT JCT WITH CHECHESSEE RV	MD-176	BEAUFORT	AL	DO	
SALKEHATCHIE	03050208090	COLLETON RVR NEAR MOUTH (SHELLFISH STATION 18-5)	MD-245	BEAUFORT	AL	DO	
SALKEHATCHIE	03050208090	COLLETON RIVER AT MOUTH OF CALLAWASSIE CREEK, 4.5 M N OF BLUFFTON	RO-01125	BEAUFORT	AL	DO	
SALKEHATCHIE	03050208090	CHECHESEE RIVER, 6.5 M WEST OF PORT ROYAL	RO-01146	BEAUFORT	AL	DO	
SALKEHATCHIE	03050208100	BATTERY CREEK - BATTERY POINT COMMUNITY DOCK	15-31	BEAUFORT	SHELLFISH	FC	
SALKEHATCHIE	03050208100	BATTERY CREEK - UNDER POWER LINE	15-32	BEAUFORT	SHELLFISH	FC	
SALKEHATCHIE	03050208100	ROCK SPRINGS CREEK,UPPER REACHES	16A-19	BEAUFORT	SHELLFISH	FC	
SALKEHATCHIE	03050208100	COFFIN CREEK, HEADWATERS AT SHRIMP DOCKS	16A-28	BEAUFORT	SHELLFISH	FC	
SALKEHATCHIE	03050208100	BEAUFORT RVR AB BEAUFORT AT CHANNEL MARKER 231	MD-001	BEAUFORT	AL	DO	*
SALKEHATCHIE	03050208100	BEAUFORT RVR AT DRAWBRDG ON US 21	MD-002	BEAUFORT	AL	DO	*
SALKEHATCHIE	03050208100	BEAUFORT RVR BL BEAUFORT AT CHANNEL MARKER 244	MD-003	BEAUFORT	AL	DO	*
SALKEHATCHIE	03050208100	BEAUFORT RVR AT JCT WITH BATTERY CK NR MARKER 42	MD-004	BEAUFORT	AL	DO	*
SALKEHATCHIE	03050208100	SAINT HELENA SOUND, 7 M SW OF EDISTO BEACH	RO-01163	BEAUFORT	AL	TURBIDITY	
SALKEHATCHIE	03050208100	BEAUFORT RVR NEAR SPANISH POINT	RO-02003	BEAUFORT	AL	DO	
SALKEHATCHIE	03050208100	TRIBUTARY TO BULL RIVER, 7.5 M NE OF BEAUFORT	RT-01643	BEAUFORT	AL	TURBIDITY	
SALKEHATCHIE	03050208100	TIDAL CK NEAR CONFL OF COOSAW AND BULL RVRS CHISOLM ISL	RT-02015	BEAUFORT	AL	CU, TURBIDITY	
SALKEHATCHIE	03050208100	TRIB TO SPARROW NEST CK NEAR DATHA ISLAND	RT-02027	BEAUFORT	AL	CU	
SALKEHATCHIE	03050208110	CREEK BEHIND LYNN SMITH'S OYSTER PLANT AT BROAD CREEK	20-16	BEAUFORT	SHELLFISH	FC	
SALKEHATCHIE	03050208110	FISH HAUL CREEK AT PORT ROYAL SOUND	20-27	BEAUFORT	SHELLFISH	FC	
SALKEHATCHIE	03050208130	NEW RVR AT SC 170 9 MI W OF BLUFFTON	MD-118	JASPER	FISH	HG	
SALKEHATCHIE	03050208130	NEW RVR AT SC 170 9 MI W OF BLUFFTON	MD-118	JASPER	REC	FC	
SALKEHATCHIE	03050208130	GREAT SWAMP AT U.S. 17	MD-129	JASPER	AL	ZN	
SALKEHATCHIE	03050208130	GREAT SWAMP AT U.S. 17	MD-129	JASPER	REC	FC	
SALUDA	03050109010	N SALUDA RVR AT BRDG AB JCT WITH SALUDA RVR E OF SC 186	S-004	GREENVILLE	AL	BIO	
SALUDA	03050109010	N SALUDA RVR AT BRDG AB JCT WITH SALUDA RVR E OF SC 186	S-004	GREENVILLE	REC	FC	*
SALUDA	03050109010	NORTH SALUDA R. AT US HWY 25	S-773	GREENVILLE	AL	BIO	
SALUDA	03050109020	SOUTH SALUDA RVR AT SC 186	S-299	GREENVILLE	REC	FC	*
SALUDA	03050109030	ADAMS CK AT UNPVD RD FROM SC 8 AND END OF S-39-34	RS-02330	PICKENS	AL	TURBIDITY	
SALUDA	03050109040	GROVE CK AT S-23-52	RS-02462	GREENVILLE	REC	FC	
SALUDA	03050109040	SALUDA RVR AT SC 81 SW OF GREENVILLE	S-007	ANDERSON	REC	FC	*
SALUDA	03050109040	GROVE CK AT UN# RD BELOW J P STEVENS ESTES PLANT	S-171	GREENVILLE	REC	FC	*
SALUDA	03050109040	SALUDA LAKE AT FARRS BRDG ON SC 183 7 MI NE EASLEY	S-250	GREENVILLE	REC	FC	*
SALUDA	03050109040	TRIB TO SALUDA RVR 350 FT BL W PELZER STP ON S-23-53	S-267	ANDERSON	AL	DO	
SALUDA	03050109040	TRIB TO SALUDA RVR 350 FT BL W PELZER STP ON S-23-53	S-267	ANDERSON	REC	FC	*
SALUDA	03050109040	MILL CK AT BENT BRIDGE RD, BL CAROLINA PLATING	S-315	GREENVILLE	AL	CR, CU	
SALUDA	03050109040	GROVE CR. AT SEC. RD. 541	S-774	GREENVILLE	AL	BIO	
SALUDA	03050109050	BR OF GEORGES CK AT S-39-192, 2.6 MI NE EASLEY	S-005	PICKENS	REC	FC	*

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SALUDA	03050109050	GEORGES CK AT S-39-28	S-300	PICKENS	REC	FC	*
SALUDA	03050109060	BIG BRUSHY CK AT S-04-143	S-301	ANDERSON	AL	BIO	
SALUDA	03050109060	BIG BRUSHY CK AT S-04-143	S-301	ANDERSON	REC	FC	*
SALUDA	03050109070	BIG CK AT S-04-116	S-302	ANDERSON	REC	FC	*
SALUDA	03050109080	LAKE GREENWOOD 1.0 MI NW OF SEABOARD RR CROSSING	RL-02311	GREENWOOD	AL	PH	
SALUDA	03050109080	REEDY FORK OF LK GREENWOOD AT S-30-29	S-022	LAURENS	AL	PH	
SALUDA	03050109080	LAKE GREENWOOD, HEADWATERS, JUST US S-30-33	S-024	LAURENS	AL	PH	
SALUDA	03050109080	LAKE GREENWOOD - CANE CK ARM AT SC 72 3.1 MI SW CROSS HILL	S-097	LAURENS	AL	DO, TP, TURBIDITY	
SALUDA	03050109080	LAKE GREENWOOD - CANE CK ARM AT SC 72 3.1 MI SW CROSS HILL	S-097	LAURENS	REC	FC	
SALUDA	03050109080	SALUDA RVR AT US 25 BYPASS 1.5 MI ESE WARE SHOALS	S-125	LAURENS	REC	FC	
SALUDA	03050109080	LK GREENWOOD AT US 221 7.6 MI NNW 96	S-131	GREENWOOD	AL	TP	
SALUDA	03050109080	LAKE GREENWOOD 200 FT US OF DAM	S-303	GREENWOOD	AL	PH	
SALUDA	03050109080	TURKEY CREEK AT SR 96	S-858	GREENWOOD	AL	BIO	
SALUDA	03050109090	BROAD MOUTH CK AT US 76	S-010	ANDERSON	REC	FC	*
SALUDA	03050109090	BROAD MOUTH CK AT S-04-267 - BL BELTONS MARSHALL PLANT	S-289	ANDERSON	REC	FC	*
SALUDA	03050109090	BROAD MOUTH CK AT S-01-111	S-304	ABBEVILLE	REC	FC	*
SALUDA	03050109090	TRIB.BROAD MOUTH CR. AT SEC. RD.205	S-776	ANDERSON	AL	BIO	
SALUDA	03050109100	REEDY RVR AT S-23-30 3.9 MI SE GREENVILLE	S-013	GREENVILLE	REC	FC	
SALUDA	03050109100	REEDY RVR AT S-23-448 1.75 MI SE CONESTEE	S-018	GREENVILLE	REC	FC	
SALUDA	03050109100	BRUSHY CK ON GREEN ST EXT BL DUNEAN MILL ON SC 20	S-067	GREENVILLE	REC	FC	
SALUDA	03050109100	REEDY RVR ON HWY 418 AT FORK SHOALS	S-072	GREENVILLE	REC	FC	
SALUDA	03050109100	REEDY RVR AT UN# RD OFF US 276 .75 MI W TRAVELERS REST	S-073	GREENVILLE	REC	FC	
SALUDA	03050109100	ROCKY CK AT S-23-453 3.5 MI SW OF SIMPSONVILLE	S-091	GREENVILLE	AL	BIO	
SALUDA	03050109100	ROCKY CK AT S-23-453 3.5 MI SW OF SIMPSONVILLE	S-091	GREENVILLE	REC	FC	
SALUDA	03050109100	LANGSTON CK AT SC 253	S-264	GREENVILLE	REC	FC	
SALUDA	03050109100	REEDY RVR AT RIVERS ST, DOWNTOWN GREENVILLE	S-319	GREENVILLE	REC	FC	
SALUDA	03050109100	REEDY RVR AT S-23-316 3.5 MI SSW OF MAULDIN	S-323	GREENVILLE	AL	CU	
SALUDA	03050109100	REEDY RVR AT S-23-316 3.5 MI SSW OF MAULDIN	S-323	GREENVILLE	REC	FC	
SALUDA	03050109100	BRUSHY CREEK AT SR 30	S-867	GREENVILLE	AL	BIO	
SALUDA	03050109100	REEDY RIVER AT SR 133	S-868	GREENVILLE	AL	BIO	
SALUDA	03050109100	REEDY RIVER AT SR 88	S-928	GREENVILLE	AL	BIO	
SALUDA	03050109110	HUFF CK AT SC 418 1.6 MI NW FORK SHOALS	S-178	GREENVILLE	REC	FC	
SALUDA	03050109110	HUFF CREEK AT SR 459	S-863	GREENVILLE	AL	BIO	
SALUDA	03050109120	REEDY RVR AT S-30-06 E WARE SHOALS	S-021	LAURENS	AL	CU	
SALUDA	03050109120	REEDY RVR AT U.S. 76	S-070	LAURENS	REC	FC	
SALUDA	03050109120	LAKE GREENWOOD, REEDY RVR ARM, 150 YDS US RABON CK	S-308	LAURENS	AL	PH, TP	
SALUDA	03050109120	BOYD MILL POND .6 KM W DAM	S-311	LAURENS	AL	PH, TN, TP	
SALUDA	03050109120	REEDY R. AT SEC. RD. 68	S-778	GREENVILLE	AL	BIO	
SALUDA	03050109130	RABON CK AT S-30-54 8.8 MI NW CROSS HILL	S-096	LAURENS	REC	FC	*
SALUDA	03050109130	LAKE RABON, S RABON CK ARM, JUST DS S-30-312	S-312	LAURENS	AL	PH	
SALUDA	03050109130	NORTH RABON CK AT S-30-32	S-321	LAURENS	REC	FC	*
SALUDA	03050109130	SOUTH RABON CK ON DIRT RD BETWEEN SC 101 & S-30-76	S-322	LAURENS	REC	FC	*
SALUDA	03050109140	CORONACA CK AT S-24-100 4 MI NW OF 96	S-092	GREENWOOD	AL	DO, PH	
SALUDA	03050109140	NINETY SIX CK AT SC 702 5.2 MI ESE OF 96	S-093	GREENWOOD	AL	CU	
SALUDA	03050109140	NINETY SIX CK AT SC 702 5.2 MI ESE OF 96	S-093	GREENWOOD	REC	FC	
SALUDA	03050109140	CORONACA CREEK AT SC HWY 221	S-184	GREENWOOD	AL	BIO	
SALUDA	03050109140	WILSON CK AT S-24-101	S-233	GREENWOOD	REC	FC	

2004 SC List of Impai[illegible]rs by 11-Digit HUC

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SALUDA	03050109140	WILSON CK AT S-24-124	S-235	GREENWOOD	AL	BIO	
SALUDA	03050109140	WILSON CK AT S-24-124	S-235	GREENWOOD	REC	FC	
SALUDA	03050109150	BUSH RIVER AT COUNTY RD 395, 3 M S OF NEWBERRY	RS-01044	NEWBERRY	AL	BIO	
SALUDA	03050109150	BUSH RIVER AT SC 560 S OF JOANNA	S-042	NEWBERRY	AL	DO	
SALUDA	03050109150	SCOTT CK AT SC 34 SW OF NEWBERRY	S-044	NEWBERRY	AL	DO	
SALUDA	03050109150	SCOTT CK AT SC 34 SW OF NEWBERRY	S-044	NEWBERRY	REC	FC	*
SALUDA	03050109150	SALUDA RVR AT SC 121	S-047	NEWBERRY	AL	PH	
SALUDA	03050109150	SALUDA RVR AT SC 121	S-047	NEWBERRY	FISH	HG	
SALUDA	03050109150	SALUDA RIVER @ SC 395	S-105	NEWBERRY	FISH	HG	
SALUDA	03050109150	BLACKS BR, LK MURRAY AT SC 391	S-223	NEWBERRY	AL	PH, TP	
SALUDA	03050109150	SALUDA RIVER AT S.C. ROUTE 39	S-295	SALUDA	AL	CU	
SALUDA	03050109150	LAKE MURRAY, BUSH RVR ARM, 4.6 KM US SC 391	S-309	NEWBERRY	AL	PH, TP	
SALUDA	03050109150	LAKE MURRAY, SALUDA RVR ARM, US BUSH RVR, 3.8 KM US SC 391	S-310	NEWBERRY	AL	PH	
SALUDA	03050109150	BEAVERDAM CREEK AT SR 83	S-852	NEWBERRY	AL	BIO	
SALUDA	03050109160	LITTLE RVR AT US 76 BUS IN LAURENS ABOVE STP	S-034	LAURENS	REC	FC	*
SALUDA	03050109160	NORTH CK AT JCT WITH US 76 2.8 MI W OF CLINTON	S-135	LAURENS	REC	FC	*
SALUDA	03050109160	LITTLE RVR AT SC ROUTE 127	S-297	LAURENS	REC	FC	*
SALUDA	03050109160	LITTLE RVR AT SC 34	S-305	NEWBERRY	AL	PH	
SALUDA	03050109160	LITTLE RVR AT SC 34	S-305	NEWBERRY	REC	FC	*
SALUDA	03050109170	LITTLE SALUDA RVR AT US 378 E SALUDA	S-050	SALUDA	AL	DO	
SALUDA	03050109170	LITTLE SALUDA RVR AT US 378 E SALUDA	S-050	SALUDA	REC	FC	*
SALUDA	03050109170	LITTLE SALUDA RVR AT S-41-39 5.2 MI NE SALUDA	S-123	SALUDA	AL	CU, DO	
SALUDA	03050109170	LITTLE SALUDA RVR AT S-41-39 5.2 MI NE SALUDA	S-123	SALUDA	REC	FC	*
SALUDA	03050109170	LAKE MURRAY, LITTLE SALUDA ARM AT SC 391	S-222	SALUDA	AL	TP	
SALUDA	03050109170	BIG CREEK AT SR 122	S-855	SALUDA	AL	BIO	
SALUDA	03050109180	CLOUDS CK AT S-41-26 4 MI NW BATESBURG	S-255	SALUDA	AL	DO, PH	
SALUDA	03050109180	CLOUDS CK AT S-41-26 4 MI NW BATESBURG	S-255	SALUDA	REC	FC	
SALUDA	03050109180	CLOUDS CK AT US 378	S-324	SALUDA	REC	FC	
SALUDA	03050109190	LK MURRAY AT DAM AT SPILLWAY (MARKER 1)	S-204	LEXINGTON	AL	PH	
SALUDA	03050109190	HOLLANDS LANDING LK MURRAY OFF S-36-26 AT END OF S-36-3	S-211	NEWBERRY	AL	PH	
SALUDA	03050109190	MACEDONIA LANDING LK MURRAY AT END OF S-36-26 MACEDONIA	S-212	NEWBERRY	AL	PH	
SALUDA	03050109190	LK MURRAY AT MARKER 63	S-279	LEXINGTON	AL	PH	
SALUDA	03050109190	CAMPING CK S-36-202 BLW GA PACIFIC	S-290	NEWBERRY	REC	FC	*
SALUDA	03050109200	HOLLOW CK AT S-32-54	S-306	LEXINGTON	REC	FC	*
SALUDA	03050109210	RAWLS CREEK AT COUNTY RD 175, 0.25 M W OF IRMO	RS-01012	LEXINGTON	AL	BIO	
SALUDA	03050109210	RAWLS CREEK AT COUNTY RD 175, 0.25 M W OF IRMO	RS-01012	LEXINGTON	REC	FC	
SALUDA	03050109210	TWELVEMILE CK AT S-32-106	RS-02457	LEXINGTON	REC	FC	
SALUDA	03050109210	TWELVE MILE CREEK AT SR 106	S-052	LEXINGTON	AL	BIO	
SALUDA	03050109210	SALUDA RVR AT MEPCO ELECT. PLANT WATER INTAKE SSE IRMO	S-149	LEXINGTON	REC	FC	*
SALUDA	03050109210	LORICK BR AT PT UPSTRM OF JCT WITH SALUDA RVR	S-150	LEXINGTON	REC	FC	
SALUDA	03050109210	SALUDA RVR JUST BELOW LK MURRAY DAM	S-152	LEXINGTON	AL	PH	
SALUDA	03050109210	KINLEY CK AT S-32-36 (ST. ANDREWS RD) IN IRMO	S-260	LEXINGTON	AL	DO	
SALUDA	03050109210	KINLEY CK AT S-32-36 (ST. ANDREWS RD) IN IRMO	S-260	LEXINGTON	REC	FC	
SALUDA	03050109210	RAWLS CREEK AT S-32-107	S-287	LEXINGTON	AL	BIO	
SALUDA	03050109210	TWELVEMILE CREEK AT U.S. ROUTE 378	S-294	LEXINGTON	REC	FC	
SALUDA	03050109210	FOURTEEN MILE CREEK AT SR 28	S-848	LEXINGTON	AL	BIO	
SALUDA	03050110010	MILL CK AT SC 262	C-021	RICHLAND	REC	FC	
SALUDA	03050110010	REEDER POINT BR AT SC 48	C-073	RICHLAND	AL	DO, PH	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SALUDA	03050110010	REEDER POINT BR AT SC 48	C-073	RICHLAND	REC	FC	
SALUDA	03050110010	CONGAREE RVR, WEST BOUNDARY OF CONGAREE SWAMP MONUMENT	C-074	RICHLAND	AL	CU	
SALUDA	03050110010	CONGAREE RVR, WEST BOUNDARY OF CONGAREE SWAMP MONUMENT	C-074	RICHLAND	REC	FC	
SALUDA	03050110020	SIXMILE CK ON US 21 S OF CAYCE	C-005	LEXINGTON	AL	DO	
SALUDA	03050110020	SIXMILE CK ON US 21 S OF CAYCE	C-005	LEXINGTON	REC	FC	*
SALUDA	03050110020	LK CAROLINE SPILLWAY AT PLATT SPRINGS RD	C-025	LEXINGTON	AL	PH	
SALUDA	03050110020	LK CAROLINE SPILLWAY AT PLATT SPRINGS RD	C-025	LEXINGTON	REC	FC	*
SALUDA	03050110020	SAVANA BR AT S-32-72 1.7 MI NNW OF S CONGAREE	C-061	LEXINGTON	REC	FC	
SALUDA	03050110020	RED BANK CK HWY 6 TO DURHAM POND (INCLUDING CRYSTAL LAKE).	C-066	LEXINGTON	FISH	ORGANOTINS	
SALUDA	03050110020	RED BANK CK AT SANDY SPRINGS RD BTWN S-32-104 & SC 602	C-067	LEXINGTON	REC	FC	*
SALUDA	03050110030	GILLS CK AT BRDG ON US 76 (GARNERS FERRY ROAD)	C-001	RICHLAND	REC	FC	
SALUDA	03050110030	GILLS CK AT SC 48 (BLUFF ROAD)	C-017	RICHLAND	AL	DO	
SALUDA	03050110030	GILLS CK AT SC 48 (BLUFF ROAD)	C-017	RICHLAND	REC	FC	
SALUDA	03050110030	SESQUICENTENNIAL STATE PARK	C-046	RICHLAND	FISH	HG	
SALUDA	03050110030	WINDSOR LK SPILLWAY ON WINSDOR LK BLVD	C-048	RICHLAND	AL	DO, PH	
SALUDA	03050110050	CEDAR CREEK AT S-40-66	C-069	RICHLAND	REC	FC	
SALUDA	03050110060	TOMS CK AT SC 48	C-072	RICHLAND	REC	FC	
SALUDA	03050110060	TOMS CREEK AT POWER LINE AND RR TRACK	C-579	RICHLAND	AL	BIO	
SALUDA	03050110070	CONGAREE RVR AT US 601 (SC-001)	C-007	CALHOUN	AL	CU	*
SALUDA	03050110070	CONGAREE RVR AT US 601 (SC-001)	C-007	CALHOUN	FISH	HG	
SANTEE	03050111010	LAKE MARION @ TREZVANT'S LANDING	C-007K	CALHOUN	FISH	HG	
SANTEE	03050111010	LAKE MARION @ DANIELS 4H CAMP	C-057	CALHOUN	FISH	HG	
SANTEE	03050111010	LAKE MARION AT SEABOARD RR TRESTLE AT LONESTAR	SC-008	SUMTER	AL	TP	
SANTEE	03050111010	SPRING GROVE CR AT SECONDARY RD 76 BRDG	SC-009	CLARENDON	REC	FC	
SANTEE	03050111010	BIG POPLAR CR AT SECONDARY RD 105 BRDG	SC-011	ORANGEBURG	REC	FC	
SANTEE	03050111010	LAKE MARION, HEADWATERS OF CHAPEL BRANCH CR.	SC-014	ORANGEBURG	AL	CHLA, PH, TN, TP	
SANTEE	03050111010	LK MARION AT END OF S-14-64 AT CAMP BOB COOPER	ST-024	CLARENDON	FISH	HG	
SANTEE	03050111010	LK MARION AT OLD US 301/15 BRDG AT SANTEE (SC-015)	ST-025	ORANGEBURG	AL	TP	
SANTEE	03050111010	LAKE MARION @ DAM	ST-027	CLARENDON	FISH	HG	
SANTEE	03050111010	LAKE MARION @ RIMINI	ST-519	SUMTER	FISH	HG	
SANTEE	03050111010	LAKE MARION @ LOW FALLS LANDING	ST-529	CALHOUN	FISH	HG	
SANTEE	03050111020	HALFWAY SWP CK AT SC 33 (SC-007)	C-015	CALHOUN	REC	FC	
SANTEE	03050111020	LK INSPIRATION - ST MATTHEWS (FRONT OF HEALTH DEPT)	C-058	CALHOUN	AL	DO, PH, TN, TP, TURBIDITY	
SANTEE	03050111020	LK INSPIRATION - ST MATTHEWS (FRONT OF HEALTH DEPT)	C-058	CALHOUN	REC	FC	*
SANTEE	03050111020	HALFWAY SWP CK AT S-09-43 3 MI E OF ST MATTHEWS	C-063	CALHOUN	REC	FC	*
SANTEE	03050111020	HALFWAY SWP CK AT S-09-72	CW-241	CALHOUN	REC	FC	
SANTEE	03050111020	WARLEY CREEK AT SC HGY 267 BRDG 5 KM N LONE STAR	SC-006	CALHOUN	REC	FC	*
SANTEE	03050111020	HALFWAY SWAMP CREEK AT SC HGY 33 BRDG	SC-007	CALHOUN	REC	FC	*
SANTEE	03050111020	LYONS CREEK AT SC 6	ST-533	CALHOUN	AL	BIO	
SANTEE	03050111020	HALFWAY SWAMP CREEK AT SR 157	ST-534	CALHOUN	AL	BIO	
SANTEE	03050111030	BIG BRANCH AT S-14-41 (SC-047)	CW-243	CLARENDON	AL	DO	
SANTEE	03050111030	BIG BRANCH AT S-14-41 (SC-047)	CW-243	CLARENDON	REC	FC	
SANTEE	03050111040	TAWCAW CK AT S-14-127 3.2 MI S OF SUMMERTON (SC-018)	ST-018	CLARENDON	AL	DO	
SANTEE	03050111040	TAWCAW CK AT S-14-127 3.2 MI S OF SUMMERTON (SC-018)	ST-018	CLARENDON	REC	FC	
SANTEE	03050111050	WHITE OAK CREEK AT COUNTY RD 345, 4.5 M ESE OF SUMMERTON	RS-01051	CLARENDON	REC	FC	
SANTEE	03050111050	POTATO CK AT S-14-127 3.2 MI S OF SUMMERTON (SC-020)	ST-035	CLARENDON	AL	DO, PH	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SANTEE	03050111050	POTATO CK AT S-14-127 3.2 MI S OF SUMMERTON (SC-020)	ST-035	CLARENDON	REC	FC	
SANTEE	03050112010	SANTEE RIVER @ US 52 (HWY 52 LANDING)	ST-528	WILLIAMSBURG	FISH	HG	
SANTEE	03050112010	SANTEE RIVER BELOW LAKE MARION (WILSONS)	ST-532	BERKELEY	FISH	HG	
SANTEE	03050112010	BENNETTS BRANCH AT SR 351	ST-536	CLAREDON	AL	BIO	
SANTEE	03050112010	DOCTOR BRANCH AT SR 48	ST-537	CLAREDON	AL	BIO	
SANTEE	03050112020	REDIVERSION CANAL AT US 52 (SC-037A)	ST-031	BERKELEY	FISH	HG	
SANTEE	03050112030	ECHAW CK AT PITCH LANDING FRANCIS MARION NATL FOREST	RS-02467	BERKELEY	REC	FC	
SANTEE	03050112030	SANTEE RVR AT SC 41/US 17A NE OF JAMESTOWN	ST-001	BERKELEY	FISH	HG	
SANTEE	03050112050	WAMBAW CK AT EXTENSION OF S-10-857 (BRIDGE NEAR BOAT LANDING)	CSTL-112	CHARLESTON	FISH	HG	
SANTEE	03050112050	WAMBAW CK AT EXTENSION OF S-10-857 (BRIDGE NEAR BOAT LANDING)	CSTL-112	CHARLESTON	REC	FC	
SANTEE	03050112060	SOUTH SANTEE RIVER AT ALLIGATOR CREEK	06A-01	GEORGETOWN	SHELLFISH	FC	
SANTEE	03050112060	NORTH SANTEE RIVER AT BEACH CREEK	06A-03	GEORGETOWN	SHELLFISH	FC	
SANTEE	03050112060	NORTH SANTEE RIVER AND MOSQUITO CREEK	06A-05	GEORGETOWN	SHELLFISH	FC	
SANTEE	03050112060	AIWW AT MINUM CREEK	06A-11	GEORGETOWN	SHELLFISH	FC	
SANTEE	03050112060	ALLIGATOR CREEK NEAREST S. SANTEE RVR BTWN MRKRS 24&25	06B-13	CHARLESTON	SHELLFISH	FC	
SANTEE	03050112060	NORTH SANTEE RIVER @ HARRIS LANDING	CSTL-593	GEORGETOWN	FISH	HG	
SANTEE	03050112060	CEDAR CREEK AT CNTY RD 857 HAMPTON PLANTATION STATE PARK	RS-01056	CHARLESTON	REC	FC	
SANTEE	03050112060	MINIM CREEK, 9 M S OF GEORGETOWN	RT-01654	GEORGETOWN	AL	TURBIDITY	
SANTEE	03050112060	N SANTEE RVR AT US 17	ST-005	GEORGETOWN	FISH	HG	
SANTEE	03050112060	S SANTEE RVR AT US 17	ST-006	CHARLESTON	AL	TURBIDITY	*
SANTEE	03050112060	S SANTEE RVR AT US 17	ST-006	CHARLESTON	FISH	HG	
SANTEE	03050112060	S SANTEE RVR AT US 17	ST-006	CHARLESTON	REC	FC	
SANTEE	03050201010	TAIL RACE CANAL AT US 52 & 17A BELOW LAKE MOULTRIE (SC-033)	CSTL-062	BERKELEY	FISH	HG	
SANTEE	03050201010	DIVERSION CANAL AT SC 45 12.6 MI W OF ST STEPHENS (SC-025)	CSTL-079	BERKELEY	FISH	HG	
SANTEE	03050201010	LAKE MOULTRIE @ DAM	CSTL-080	BERKELEY	FISH	HG	
SANTEE	03050201010	LAKE MOULTRIE @ FRED L. DAY LANDING	ST-530	BERKELEY	FISH	HG	
SANTEE	03050201010	LAKE MOULTRIE @ HATCHERY LANDING	ST-531	BERKELEY	FISH	HG	
SANTEE	03050201020	WADBOO SWP AT SC 402	CSTL-113	BERKELEY	FISH	HG	
SANTEE	03050201020	WADBOO SWP AT SC 402	CSTL-113	BERKELEY	REC	FC	
SANTEE	03050201020	WADBOO SWAMP AT S-08-447 THIRD BRIDGE FROM WEST	RS-02461	BERKELEY	REC	FC	
SANTEE	03050201020	WALKER SW AT US 52 2.5 MI S ST STEPHENS	ST-007	BERKELEY	REC	FC	
SANTEE	03050201040	EAST FORK OF COOPER RIVER NEAR QUINBYCR	CSTL-564	BERKELEY	FISH	HG	
SANTEE	03050201040	TURKEY CK AT FOREST SERVICE RD 251 IRISHTOWN FM SC 402	RS-02483	BERKELEY	REC	FC	
SANTEE	03050201050	FILBIN CREEK AT VIRGINIA AVE, NORTH CHARLESTON	MD-249	CHARLESTON	AL	DO	
SANTEE	03050201050	FILBIN CREEK AT VIRGINIA AVE, NORTH CHARLESTON	MD-249	CHARLESTON	REC	FC	
SANTEE	03050201060	BACK RIVER RES IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CSTL-124	BERKELEY	AL	CU, DO	
SANTEE	03050201060	COOPER RIVER @ BUSHY PARK	MD-042	BERKELEY	FISH	HG	
SANTEE	03050201060	COOPER RVR AT S-08-503 6.2 MI ESE OF GOOSE CK	MD-152	BERKELEY	FISH	HG	
SANTEE	03050201060	DURHAM CK AT S-08-9 BRIDGE	MD-217	BERKELEY	FISH	HG	
SANTEE	03050201060	FOSTER CREEK AT CHARLESTON CPW WATER INTAKE	MD-240	BERKELEY	AL	DO	
SANTEE	03050201070	GOOSE CK AT S-08-136 BRIDGE	MD-039	BERKELEY	REC	FC	
SANTEE	03050201070	GOOSE CK AT US 52 N CHTN	MD-114	CHARLESTON	AL	DO	
SANTEE	03050201070	GOOSE CK AT US 52 N CHTN	MD-114	CHARLESTON	REC	FC	
SANTEE	03050201070	GOOSE CK RES 2.3 M S OF GOOSE CREEK TOWN CENTER	RL-01008	BERKELEY	AL	DO	
SANTEE	03050201070	GOOSE CREEK RESERVOIR 100 M US OF DAM	ST-032	BERKELEY	AL	CHLA, PH, TP	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SANTEE	03050201070	GOOSE CK RESERVOIR AT 2ND POWERLINES US OF BOAT RAMP	ST-033	BERKELEY	AL	CHLA, CU, PH, TP	
SANTEE	03050201080	WANDO RIVER AT DEEP CREEK	09B-04	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	WANDO RIVER OPPOSITE BIG PARADISE ISLAND	09B-05	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	WANDO RIVER AT PARADISE BOAT LANDING	09B-06	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	BOONE HALL CREEK OPPOSITE COUNTY RECREATION AREA	09B-07	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	DEEP CREEK - 1 MILE FROM CONFLUENCE WITH WANDO RIVER	09B-09	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	WANDO RIVER AT ALSTON CREEK CONFLUENCE	09B-10	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	WANDO RIVER AT GUERIN CREEK	09B-11	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	GUERIN CREEK AT OLD HOUSE CREEK	09B-12	BERKLEY	SHELLFISH	FC	
SANTEE	03050201080	NOWELL CREEK, AT CONFLUENCE WITH MARTIN CREEK	09B-16	BERKLEY	SHELLFISH	FC	
SANTEE	03050201080	RAT HALL CRK AT CONFLUENCE WITH WANDO RVR.	09B-18	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	FOSTER CREEK AT CONFLUENCE WITH WANDO RIVER	09B-19	CHARLESTON	SHELLFISH	FC	
SANTEE	03050201080	WANDO RVR AT SC 41	MD-115	BERKELEY	AL	CU	
SANTEE	03050202010	WASSAMASSAW SWP AT US 176	CSTL-063	BERKELEY	AL	CU	
SANTEE	03050202010	WASSAMASSAW SWP AT US 176	CSTL-063	BERKELEY	REC	FC	
SANTEE	03050202010	CYPRESS SWP AT US 78	CSTL-078	DORCHESTER	AL	ZN	
SANTEE	03050202010	CYPRESS SWP AT US 78	CSTL-078	DORCHESTER	REC	FC	
SANTEE	03050202020	ASHLEY RVR AT SC 165 4.8 MI SSW OF SUMMERVILLE	CSTL-102	DORCHESTER	REC	FC	
SANTEE	03050202030	DORCHESTER CK AT SC 165	CSTL-013	DORCHESTER	AL	DO	
SANTEE	03050202030	SAWMILL BR AT SC 78 E OF SUMMERVILLE	CSTL-043	DORCHESTER	AL	DO	
SANTEE	03050202030	EAGLE CK AT SC 642 5 MI SSE OF SUMMERVILLE	CSTL-099	DORCHESTER	AL	TURBIDITY	
SANTEE	03050202030	EAGLE CK AT SC 642 5 MI SSE OF SUMMERVILLE	CSTL-099	DORCHESTER	REC	FC	
SANTEE	03050202040	ASHLEY RVR AT MAGNOLIA GARDENS	MD-049	CHARLESTON	AL	CU, NI, TURBIDITY	
SANTEE	03050202040	ASHLEY RVR AT MAGNOLIA GARDENS	MD-049	CHARLESTON	REC	FC	
SANTEE	03050202040	CHURCH CK MOUTH	MD-246	CHARLESTON	REC	FC	
SANTEE	03050202050	STONO RIVER (AIWW) AT MARKER #27	11-12	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202050	STONO RIVER (AIWW) AT MARKER #51	11-16	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202050	RANTOWLES CREEK AT CONFLUENCE OF STONO RIVER	11-18	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202050	STONO RIVER AT MOUTH OF PENNY CREEK NEAR MARKER #25	11-27	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202050	MOUTH OF ELLIOTT CUT AT EDGE WTR DR (S-10-26 OFF HW 17)	MD-025	CHARLESTON	AL	DO	
SANTEE	03050202050	LOG BRIDGE CK AT SC 162	MD-121	CHARLESTON	REC	FC	
SANTEE	03050202050	STONO RVR AT S-10-20 2 MI UPSTRM OF CLEMSON EXP STA	MD-202	CHARLESTON	AL	CU, DO	
SANTEE	03050202060	ALLIGATOR CREEK AT MARKER #26	06B-07	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	CASINO CREEK AT MARKER #29	06B-08	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	DUPREE CREEK - 500 FEET N. OF NEW DOCK (S.OF MRKR #30)	06B-09	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	GRAHAM CREEK AT MARKER #64	07-02	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	GRAHAM CREEK AND BULLS BAY	07-02A	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	AWENDAW CREEK AT MARKER #57	07-03	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	TIBWIN CREEK AT MARKER #42	07-05	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	DOEHALL CREEK-THIRD BEND	07-14	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	SANDY POINT CREEK - 4TH BEND	07-15	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	AIWW 1.5 MILES SOUTHWEST OF GRAHAM CREEK (C4-99)	07-19	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	CONCH CREEK STATE SHELLFISH GROUND - SULLIVANS ISLAND SIDE	09A-17A	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	AIWW AT 25TH STREET - ISLE OF PALMS	09A-19	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	CONCH CREEK AT LOFTON CREEK	09A-20	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	CONCH CREEK UPPER REACHES	09A-23	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	INLET CREEK UPPER REACHES	09A-24	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	SWINTON CREEK WEST OF AIWW AT SECOND BEND	09A-28	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	HAMLIN CREEK AT SITE OF NEW BRIDGE (ISLE OF PALMS CONNECTOR)	09A-29	CHARLESTON	SHELLFISH	FC	

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SANTEE	03050202060	INLET CREEK, UPPER AT JENNIE CREEK	09A-30	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	INLET CREEK, BAY AT UPPER END	09A-31	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	AIWW AT CONFLUENCE WITH SULLIVANS ISLAND NARROWS (ACROSS FROM ECOMC DOCK)	09A-34	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202060	JEREMY CK NEAR BOAT LANDING AT MCCLELLANVILLE TOWN HALL	MD-203	CHARLESTON	AL	DO, TURBIDITY	
SANTEE	03050202060	JEREMY CK NEAR BOAT LANDING AT MCCLELLANVILLE TOWN HALL	MD-203	CHARLESTON	REC	FC	
SANTEE	03050202060	AWENDAW CREEK AT US 17	MD-250	CHARLESTON	REC	FC	
SANTEE	03050202060	TRIBUTARY TO MATHEWS CREEK, 1 M S OF MCLELLANVILLE	RT-01623	CHARLESTON	AL	TURBIDITY	
SANTEE	03050202060	E FORK OF DEVILS DEN CK HEADWATERS	RT-02016	CHARLESTON	AL	CU	*
SANTEE	03050202070	RAT ISLAND CREEK AT CONFLUENCE WITH FIRST CREEK ON LEFT FROM LIGHTHOUSE CREEK	10A-11	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202070	CLARK SOUND AT OCEAN VIEW FLATS	10A-16	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202070	FLUDD'S CREEK AT CLARK SOUND	10A-16A	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202070	SCHOONER CREEK, RIGHT FORK AT MIDDLE OF DOCKS, ACRESS FROM PARROT POINT DEVELOPMENT	10A-35	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202070	ABBAPOOLA CREEK AT CONFLUENCE WITH SMALL CREEK ON WEST BANK AT SEVENTH BEND	11-06A	CHARLESTON	SHELLFISH	FC	
SANTEE	03050202070	STONO RVR AT SC 700	MD-026	CHARLESTON	AL	CU, DO	
SANTEE	03050202070	INTRACOASTAL WATERWAY AT SC 703 E MT PLEASANT	MD-069	CHARLESTON	AL	CU	
SANTEE	03050202070	SHEM CK AT BRDG ON US 17	MD-071	CHARLESTON	AL	CU	*
SANTEE	03050202070	SHEM CK AT BRDG ON US 17	MD-071	CHARLESTON	REC	FC	
SANTEE	03050202070	CHAS HBR AT FT JOHNSON PIER AT MARINE SCI LAB	MD-165	CHARLESTON	AL	CU	*
SANTEE	03050202070	STONO RIVER AT ABBAPOOLA CREEK	MD-206	CHARLESTON	AL	DO	
SANTEE	03050202070	TRIBUTARY TO STONO INLET, 11 M SW OF CHARLESTON	RT-01642	CHARLESTON	AL	TURBIDITY	
SAVANNAH	03060101010	LAKE JOCASSEE TOXAWAY RIVER ARM	CL-018	OCONEE	FISH	HG	
SAVANNAH	03060101020	LAKE JOCASSEE @ END OF SEC RD 25	SV-313	OCONEE	FISH	HG	
SAVANNAH	03060101040	LAKE HARTWELL 6 M NNW OF ANDERSON	RL-01020	ANDERSON	AL	PH	
SAVANNAH	03060101040	MARTIN CK ARM OF LAKE HARTWELL AT S-37-65 N OF CLEMSON	SV-106	OCONEE	FISH	PCB	
SAVANNAH	03060101040	LAKE HARTWELL AT S-37-184 6.5 MI SSE OF SENECA	SV-236	OCONEE	AL	PH	
SAVANNAH	03060101040	LAKE ISSAQUEENA, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	SV-360	PICKENS	AL	PH	
SAVANNAH	03060101040	LAKE HARTWELL @ CONEROSS CREEK	SV-799	OCONEE	FISH	PCB	
SAVANNAH	03060101050	BURGESS CK AT S-37-171	RS-02466	OCONEE	REC	FC	
SAVANNAH	03060101050	CANE CREEK AT S-37-133	SV-342	OCONEE	REC	FC	*
SAVANNAH	03060101050	LITTLE CANE CREEK AT S-37-133	SV-343	OCONEE	REC	FC	*
SAVANNAH	03060101060	TWELVE MILE CK AT S-39-137	SV-362	PICKENS	REC	FC	
SAVANNAH	03060101070	LAKE HARTWELL - TWELVE MI CK ARM AT SC 133	SV-107	PICKENS	FISH	PCB	
SAVANNAH	03060101080	CONEROSS CK AT SC 59	SV-004	OCONEE	AL	CU, PH	
SAVANNAH	03060101080	CONEROSS CK AT S-37-13	SV-333	OCONEE	AL	CU	
SAVANNAH	03060101090	EIGHTEENMILE CK AT UNNUMBERED CO RD 2.25 MI SSW OF EASLEY	SV-017	PICKENS	REC	FC	*
SAVANNAH	03060101090	EIGHTEENMILE CK AT S-39-93 S OF CENTRAL	SV-135	ANDERSON	REC	FC	*
SAVANNAH	03060101090	EIGHTEENMILE CK AT 2-04-279	SV-233	ANDERSON	REC	FC	
SAVANNAH	03060101090	WOODSIDE BR AT US 123 1.5 MI E OF LIBERTY	SV-241	PICKENS	REC	FC	*
SAVANNAH	03060101090	EIGHTEENMILE CK AT S-39-27 3.3 MI S OF LIBERTY	SV-245	PICKENS	REC	FC	*
SAVANNAH	03060101090	LAKE HARTWELL - EIGHTEEN MILE CK ARM AT S-04-1098	SV-268	ANDERSON	AL	PH, TP	
SAVANNAH	03060101090	LAKE HARTWELL - EIGHTEEN MILE CK ARM AT S-04-1098	SV-268	ANDERSON	REC	FC	*
SAVANNAH	03060101100	THREE & TWENTY CREEK AT S-04-280	SV-111	ANDERSON	REC	FC	*

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SAVANNAH	03060102030	WHETSTONE CREEK, UPSTREAM PORTION NEAR MOUTH	MC-03	OCONEE	AL	BIO	
SAVANNAH	03060102060	LAKE YONAH	CL-015	OCONEE	FISH	HG	
SAVANNAH	03060102060	LAKE YONAH, 50% BETWEEN CENTER OF SPILLWAY AND OPPOSITE SHORE	SV-358	OCONEE	AL	TP	
SAVANNAH	03060102060	TUGALOO LAKE	SV-599	OCONEE	FISH	HG	
SAVANNAH	03060102130	CHOESTOEA CREEK AT S-37-49	SV-108	OCONEE	REC	FC	
SAVANNAH	03060102130	CHAUGA R @ TUGALOO R (TABOR ACCESS LK HARTWELL)	SV-234	OCONEE	FISH	PCB	
SAVANNAH	03060102130	NORRIS CK AT S-37-435 1 MI S OF WESTMINSTER	SV-301	OCONEE	REC	FC	
SAVANNAH	03060102130	BEAVERDAM CREEK AT S-37-66	SV-345	OCONEE	AL	BIO	
SAVANNAH	03060102130	TRIBUTARY OF CHOESTOEA CRK. AT SR 429	SV-790	OCONEE	AL	BIO	
SAVANNAH	03060103020	LK HARTWELL, MAIN BODY AT USACE WQ BUOY BTWN MRKRS 11 & 12	SV-340	ANDERSON	AL	CU	
SAVANNAH	03060103030	LAKE RUSSELL @ VAN CREEK	CL-096	ABBEVILLE	FISH	HG	
SAVANNAH	03060103030	LAKE RUSSELL @ DAM	CL-097	ABBEVILLE	FISH	HG	
SAVANNAH	03060103030	DEVILS FORK CK AT BUSBY RD OFF S-04-22	RS-02490	ANDERSON	REC	FC	
SAVANNAH	03060103030	LAKE RUSSELL AT SC 181 6.5 MI SW STARR	SV-100	ANDERSON	FISH	HG	
SAVANNAH	03060103030	BIG GENEROSTEE CR. AT SC 187	SV-101	ANDERSON	AL	BIO	
SAVANNAH	03060103030	BIG GENEROSTEE CK AT CO RD 104	SV-316	ANDERSON	REC	FC	*
SAVANNAH	03060103030	LAKE RUSSELL, ROCKY RVR ARM BETWEEN MARKERS 48 & 49, DS FELKEL	SV-357	ABBEVILLE	AL	PH	
SAVANNAH	03060103030	LAKE HARTWELL @ DAM	SV-642	ANDERSON	FISH	PCB	
SAVANNAH	03060103070	ROCKY RVR AT S-04-263 2.7 MI SE ANDERSON AT STP	SV-031	ANDERSON	AL	PH	
SAVANNAH	03060103070	ROCKY RVR AT S-04-263 2.7 MI SE ANDERSON AT STP	SV-031	ANDERSON	REC	FC	*
SAVANNAH	03060103070	ROCKY RVR AT S-04-152 BL ROCKY RVR STP	SV-041	ANDERSON	REC	FC	*
SAVANNAH	03060103070	CHEROKEE CK AT S-04-318 4 MI S OF BELTON	SV-043	ANDERSON	REC	FC	*
SAVANNAH	03060103070	CUPBOARD CK AT S-04-733 AB BREAZEALE ST PLANT & BL BLAIR HILL	SV-139	ANDERSON	AL	DO, PH	
SAVANNAH	03060103070	CUPBOARD CK AT S-04-733 AB BREAZEALE ST PLANT & BL BLAIR HILL	SV-139	ANDERSON	REC	FC	*
SAVANNAH	03060103070	CUPBOARD CK AT S-04-209 BL EFF FROM BELTON 2 PLANT	SV-140	ANDERSON	AL	PH	
SAVANNAH	03060103070	CUPBOARD CK AT S-04-209 BL EFF FROM BELTON 2 PLANT	SV-140	ANDERSON	REC	FC	*
SAVANNAH	03060103070	BROADWAY CREEK AT US 76 BTWN ANDERSON & BELTON	SV-141	ANDERSON	AL	BIO	
SAVANNAH	03060103070	BROADWAY CK AT US 76 BTWN ANDERSON & BELTON	SV-141	ANDERSON	REC	FC	*
SAVANNAH	03060103070	LK SECESSION, 1 1/4 MI BELOW SC ROUTE 28	SV-331	ANDERSON	AL	PH	
SAVANNAH	03060103070	ROCKY RIVER AT S-04-244	SV-346	ANDERSON	REC	FC	
SAVANNAH	03060103070	BROADWAY CRK. AT SR 48	SV-791	ANDERSON	AL	BIO	
SAVANNAH	03060103080	WILSON CREEK AT S-04-294	SV-347	ANDERSON	REC	FC	*
SAVANNAH	03060103100	CLARKS HILL RESERVOIR AT US 378 7 MI SW MCCORMICK	SV-291	MCCORMICK	AL	TP	
SAVANNAH	03060103100	STEVENS CK RESERVOIR HEADWATERS AT CLARKS HILL DAM BOAT RAMP	SV-294	MCCORMICK	AL	DO, PH	
SAVANNAH	03060103140	CALHOUN CREEK AT SC 28, 1.5 M NW OF ABBEVILLE	RS-01049	ABBEVILLE	AL	DO	
SAVANNAH	03060103140	CALHOUN CREEK AT SC 28, 1.5 M NW OF ABBEVILLE	RS-01049	ABBEVILLE	REC	FC	
SAVANNAH	03060103140	SAWNEY CK AT CO RD 1.5 MI SE OF CALHOUN FALLS	SV-052	ABBEVILLE	AL	DO	
SAVANNAH	03060103140	SAWNEY CK AT CO RD 1.5 MI SE OF CALHOUN FALLS	SV-052	ABBEVILLE	REC	FC	*
SAVANNAH	03060103140	LITTLE RIVER AT S-01-24	SV-164	ABBEVILLE	AL	PH	
SAVANNAH	03060103140	LITTLE RIVER AT S-01-24	SV-164	ABBEVILLE	REC	FC	*
SAVANNAH	03060103140	LITTLE RIVER AT S-33-19	SV-192	MCCORMICK	REC	FC	*
SAVANNAH	03060103140	LITTLE RIVER AT S-01-32	SV-348	ABBEVILLE	AL	BIO	
SAVANNAH	03060103140	LITTLE RIVER AT S-01-32	SV-348	ABBEVILLE	REC	FC	*
SAVANNAH	03060103150	BLUE HILL CK ON S MAIN ST ABBEVILLE	SV-053B	ABBEVILLE	AL	TURBIDITY	
SAVANNAH	03060103150	BLUE HILL CK ON S MAIN ST ABBEVILLE	SV-053B	ABBEVILLE	REC	FC	*
SAVANNAH	03060103150	DOUBLE BRANCH AT S-01-33	SV-054	ABBEVILLE	AL	BIO	
SAVANNAH	03060103150	LONG CANE CR. AT SR 33	SV-056	ABBEVILLE	AL	BIO	

2004 SC List of Impaire ...s by 11-Digit HUC

BASIN	11 DIGIT HUC	LOCATION	STATION	COUNTY	USE	CAUSE	NOTES
SAVANNAH	03060103150	LONG CANE CK AT S-33-117 7.0 MI NW MCCORMICK	SV-318	MCCORMICK	AL	BIO	
SAVANNAH	03060103150	LONG CANE CK AT S-33-117 7.0 MI NW MCCORMICK	SV-318	MCCORMICK	REC	FC	
SAVANNAH	03060103150	LONG CANE CREEK AT S-01-159	SV-349	ABBEVILLE	REC	FC	*
SAVANNAH	03060103150	BIG CURLY TAIL CREEK AT US FOREST RD 509	SV-732	ABBEVILLE	AL	BIO	
SAVANNAH	03060103150	JOHNS CREEK AT SR 159	SV-734	ABBEVILLE	AL	BIO	
SAVANNAH	03060106050	SAVANNAH RVR AT US 1 1.5 MI SW N. AUGUSTA	SV-251	AIKEN	REC	FC	*
SAVANNAH	03060106050	SAVANNAH RVR AT SC 28 1.6 MI NNW OF BEECH ISLAND	SV-252	AIKEN	REC	FC	*
SAVANNAH	03060106050	SAVANNAH RIVER @ JACKSON LANDING	SV-691	AIKEN	FISH	HG	#
SAVANNAH	03060106050	SAVANNAH RIVER @ N. AUGUSTA ST. PARK	SV-800	AIKEN	FISH	HG	#
SAVANNAH	03060106060	SAND RVR AT OLD US 1 1.2 MI SE WARRENVILLE	SV-069	AIKEN	REC	FC	*
SAVANNAH	03060106060	HORSE CK AT S-02-145	SV-072	AIKEN	REC	FC	*
SAVANNAH	03060106060	LITTLE HORSE CK AT SC 421 BL EFF OF CLEARWTR FIN	SV-073	AIKEN	REC	FC	*
SAVANNAH	03060106060	HORSE CK AT SC 125 1.5 MI SW CLEARWATER	SV-250	AIKEN	REC	FC	*
SAVANNAH	03060106060	LANGLEY POND	SV-531	AIKEN	FISH	HG	#
SAVANNAH	03060106060	VAUCLUSE POND	SV-685	AIKEN	FISH	HG	#
SAVANNAH	03060106060	FLAT ROCK POND IN FOREBAY NEAR DAM	SV-686	AIKEN	FISH	HG	#
SAVANNAH	03060106070	HOLLOW CREEK AT S-02-5	SV-350	AIKEN	REC	FC	*
SAVANNAH	03060106110	FOURMILE BR AT SRS RD A-13 USE LOCATION ESOP SITE SV-2039	RS-02470	CHEROKEE	REC	FC	*
SAVANNAH	03060106110	FOURMILE BRANCH AT SRP ROAD A-7	SV-326	BARNWELL	AL	PH	#
SAVANNAH	03060106110	SAVANNAH RIVER @ LITTLE HELL LANDING	SV-690	ALLENDALE	FISH	HG	#
SAVANNAH	03060106110	SAVANNAH RIVER @ STEEL CREEK	SV-801	BARNWELL	FISH	HG	#
SAVANNAH	03060106130	LOWER THREE RUNS CK AT S-06-20 7.5 MI SW BARNWELL	SV-328	BARNWELL	REC	FC	*
SAVANNAH	03060106140	BRIAR CRK. AT S-102	SV-745	ALLENDALE	AL	BIO	#
SAVANNAH	03060106140	SAVANNAH RIVER @ COHEN'S BLUFF	SV-802	ALLENDALE	FISH	HG	#
SAVANNAH	03060106140	SAVANNAH RIVER @ JOHNSONG'S LANDING	SV-803	ALLENDALE	FISH	HG	#
SAVANNAH	03060107010	HARD LABOR CREEK AT S-24-164 BRIDGE	SV-151	GREENWOOD	AL	DO	
SAVANNAH	03060107010	HARD LABOR CREEK AT S-24-164 BRIDGE	SV-151	GREENWOOD	REC	FC	*
SAVANNAH	03060107010	CUFFYTOWN CREEK AT S-33-138	SV-351	MCCORMICK	REC	FC	*
SAVANNAH	03060107010	STEVENS CREEK AT S-33-138	SV-365	MCCORMICK	AL	DO	
SAVANNAH	03060107010	ROCKY CRK. AT SR 87	SV-730	MCCORMICK	AL	BIO	
SAVANNAH	03060107010	HARD LABOR CREEK AT SR 23	SV-731	MCCORMICK	AL	BIO	
SAVANNAH	03060107020	TURKEY CREEK AT S-33-227/S-19-68	SV-352	EDGEFIELD	REC	FC	
SAVANNAH	03060107020	TURKEY CREEK AT SR 100	SV-729	EDGEFIELD	AL	BIO	
SAVANNAH	03060107040	STEVENS CREEK AT S-33-88/S-19-143	SV-354	EDGEFIELD	AL	CU	
SAVANNAH	03060107040	STEVENS CREEK AT S-33-88/S-19-143	SV-354	EDGEFIELD	REC	FC	
SAVANNAH	03060107040	CHEVES CREEK AT SR 34	SV-725	EDGEFIELD	AL	BIO	
SAVANNAH	03060109050	SAVANNAH RIVER @ STOKES BLUFF LANDING	SV-687	HAMPTON	FISH	HG	
SAVANNAH	03060109050	SAVANNAH RIVER @ B & C LANDING	SV-804	JASPER	FISH	HG	
SAVANNAH	03060109060	SAVANNAH RVR AT US 17 8.9 MI SSW OF HARDEEVILLE (BOAT)	SV-191	JASPER	AL	ZN	*
SAVANNAH	03060109060	SAVANNAH RVR AT US 17 8.9 MI SSW OF HARDEEVILLE (BOAT)	SV-191	JASPER	REC	FC	
SAVANNAH	03060109060	SAVANNAH RIVER @ BECK'S FERRY	SV-209	JASPER	FISH	HG	
SAVANNAH	03060109060	CYPRESS CREEK AT S-27-119	SV-356	JASPER	AL	DO	
SAVANNAH	03060109060	CYPRESS BRANCH AT US 321	SV-744	JASPER	AL	BIO	
SAVANNAH	03060109060	SAVANNAH RIVER @ MILLSTONE LANDING	SV-805	JASPER	FISH	HG	

Ref 2.3 Ref 28

PROMOTE PROTECT PROSPER

South Carolina Water Use Report 2004 Summary

South Carolina Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201

Compiled by:
Jack M. Childress
Paul L. Bristol, PG
Groundwater Management Section

Bureau of Water
Alton C. Boozer, Chief

Water Monitoring, Assessment, and Protection Division
David Baize, Director

Groundwater Management Section
Robert Devlin, Manager

Technical Document Number: 004-05

Bureau of Water
July 2005

Forward

The South Carolina Department of Health and Environmental Control (DHEC) is committed to the responsible management of South Carolina's water resources by encouraging continued conservation and reasonable use to ensure a sustainable supply for present and future demands. The South Carolina *Surface Water Withdrawal and Reporting Act*, §49-4-10 et. seq., and the South Carolina *Groundwater Use and Reporting Act*, §49-5-10 et. seq., require water users that withdraw three (3) million gallons or greater in any month to register with and report that use annually to the Water Use Program at DHEC.

Water Use data is used by the State of South Carolina to better define the distribution and demand for our surface and groundwater resources across the state. Data from the Water Use Program at DHEC is shared between other local, state, and federal regulatory and scientific agencies to establish a common understanding of the demands placed upon our water resources. This common database has proven critical in water management decisions and water use conflict resolution.

Statistics utilized in this report represent data obtained from registered users of the Water Use Program. Consumptive use from private domestic wells, small surface water irrigation intakes, facilities that do not meet the reporting threshold, or data from facilities failing to report their annual water use are not included in this annual summary.

If you have questions about this or previous Annual Water Use Reports, or would like to obtain further information about reported water withdrawals in South Carolina, please contact:

Water Use Program
SCDHEC Bureau of Water
2600 Bull Street
Columbia, SC 29201
www.scdhec.net/water

Table of Contents

Appendices

Table of Figures

Introduction

South Carolinians have enjoyed an available fresh water supply that is clean, abundant, easily attainable and, for all practical purposes, inexhaustible. In South Carolina today, close to 1.2 million people rely on groundwater and 2.8 million people rely on surface water for their drinking water and sundry uses. According to the U.S. Census Bureau, South Carolina will increase its population by 600,000 people by 2025 and the U.S. Department of Agriculture reports development converts approximately 100,000 acres per year to urban uses. This growth and development in the state has placed increasing demand on our water supplies. With limited and sporadic rainfall events, groundwater systems and surface water bodies under continuous natural discharge and human use (pumpage) showed steady and, at times, drastic water level declines with numerous waterways reaching record low flow conditions. Due to the low flow conditions, excursions of saltwater inland along coastal waterways threatened some surface water intakes. Some homeowners relying on shallow water wells have been forced to drill deeper wells or seek alternate sources of water supply.

In conjunction with natural conditions, the continued impact to groundwater systems through human induced contamination (physical and chemical) or natural impact demonstrate the vulnerability of this finite resource and the continuing need to closely monitor, manage and preserve the resource in South Carolina for current and future generations. The state General Assembly declared that,

"…the groundwater resources of the State be put to beneficial use to the fullest extent to which they [are] capable and to provide and maintain conditions which are conducive to the development and use of all water resources."

Consistent and accurate data collection is requisite in establishing water use trends and implementing reasonable management strategies. Water use reporting outside of designated Capacity Use Areas has been historically voluntary. As of January 1, 2001, anyone withdrawing groundwater or surface water in excess of three (3) million gallons per month (in any month) must register and report that use annually to the South Carolina Department of Health and Environmental Control (Department). Registration and reporting is now a requirement of law and the Department has authority to take enforcement action against those not reporting.

Purpose and Methodology

The purpose of the annual *South Carolina Water Use Report* is to summarily present reported water use in South Carolina by county and use category during calendar year 2004. The Department maintains and continually updates the water use and facility databases utilized in this report. Water use data were collected by annual reporting of water use by registered users, as required and mandated by state law, and are reported in **million gallons** unless stated otherwise.

South Carolina Climate

The climate in South Carolina is affected by many factors, notably its location in the mid-latitudes and its proximity to the Atlantic Ocean. During the summer, ocean current-driven air masses such as the Bermuda High routinely push tropical air from the Gulf of Florida upland from the coast. These warm, moist currents collide with cooler, drier air masses to generate rainfall, and at times, severe thunderstorms. In contrast, the Appalachian region in the northwest portion of the state experiences cooler temperatures, owing in part to orographic lifting of air masses and subsequent cooling effect provided by the increase in altitude. Altitude change also causes the additional phenomenon of down slope heating as air masses from the mountains settle and compress over the eastern Blue Ridge and Piedmont region. During the winter months, the highlands of the Blue Ridge escarpment deflect northerly cold air to the southwest, often lessening the impact of major cold fronts and winter storms.

The vast majority of the state is classified as humid subtropical except in the Blue Ridge physiographic province, where it is humid continental. Average temperature varies from the mid-50's in the mountains to low-60's along the coast. The average annual precipitation is approximately 48 inches, with an annual total in the mountains of 70 to 80 inches, an annual total in the Midlands of 42 to 47 inches and an annual total along the coast of 50 to 52 inches. According to the South Carolina State Climatology Office, no month in South Carolina averages less than two inches of precipitation, regardless of location within the state. Measurable snowfall is rare, occurring one to three times a year with accumulations seldom remaining more than a day or two. Since 1900 severe droughts have occurred statewide in 1925, 1933, 1954, 1977, 1983, 1986, 1990, 1993, and most recently 1998. The latest multiyear drought was one of the most severe in South Carolina's history, with average precipitation, groundwater levels, and stream flows at or near record lows. The drought that officially began in June 1998 abated in the late summer of 2002 with the onset of more seasonal (and in some locations torrential) precipitation for many parts of South Carolina.

South Carolina Geography and Hydrology

Geography and Physiography

South Carolina has a distinct natural beauty and an ecological diversity covering nearly 31,189 square miles, with approximately 30,111 square miles land area, 1,078 square miles inland or coastal waterways and 135 miles of coastline. The diversity we experience is resultant of climatic conditions, geology and three major physiographic regions: the Blue Ridge, the Piedmont and the Coastal Plain (**Figure 1**). The physiographic regions exhibit variations in topography, geology, hydrology and vegetation that directly affect the quantity, quality and availability of water resources in South Carolina.

Blue Ridge

The Blue Ridge physiographic province is located in the extreme northwest portion of Oconee and Pickens counties, and is distinguished from other parts of South Carolina by greater elevations (1,000 – 3,300 feet) and surface relief. Dissected mountains, rugged hills and thick forest regions characterize the land surface. Surface water in the Blue Ridge takes the form of high gradient creeks and streams and natural or man-made lakes, while groundwater occurs in the fractures of the bedrock and a thin veneer of soil and saprolite. In general, water quality of streams and groundwater is excellent in the Blue Ridge owing to the constant replenishment from abundant local rainfall.

Piedmont

The Piedmont physiographic province includes all counties, or portions of counties, northwest of and to the Fall Line, exclusive of those counties within the Blue Ridge province. Although similar to the Blue Ridge, the region demonstrates lower topographic relief, and therefore lower gradient streams, while elevations range from between 450 to 1000 feet above sea level. Counties in the Piedmont and Blue Ridge physiographic provinces depend primarily on the abundant regional rainfall that recharges lakes, reservoirs and major river systems. These surface water bodies constitute the primary source of water for public supply, industry, agriculture, and power production in the Piedmont Region.

Coastal Plain

The Coastal Plain physiographic province includes all counties, or portions of counties, extending from the Fall Line east to the Atlantic Ocean. Elevations of the exposed Coastal Plain range between 450 feet to sea level. Once below the Fall Line, rivers and streams assume a different character than found in the Piedmont. Where streams once rolled across exposed Piedmont rocks and tumbled down the occasional stretch of whitewater, the Coastal Plain dictates a slower pace and quiet meandering river channels with adjacent wetlands are common. Regional geology of the Coastal Plain is characterized by aquifers developed in layers of sands, silts, or high-permeability limestone confined by units of clay and silts or low-permeability limestone. The vast majority of South Carolina's water resources are contained as groundwater in the Coastal Plain, and in general, reliance on groundwater for irrigation, industrial uses, and public water supply increases dramatically east of the Fall Line (**Figure 7**). A generalized cross-section for the Coastal Plain aquifers is presented as **Figure 2**, and a brief outline of the major aquifers in South Carolina follows.

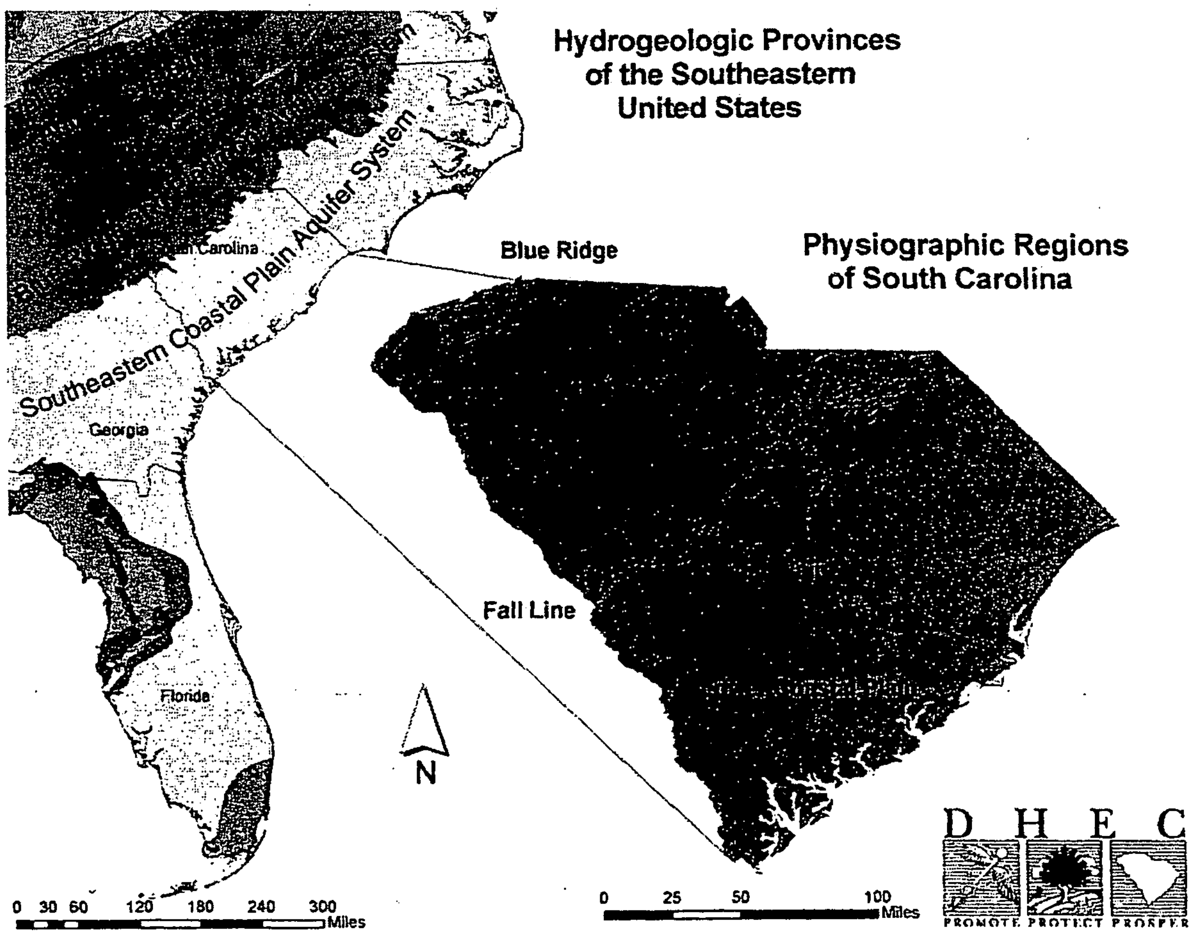


Figure 1: Hydrogeologic and Physiographic Setting for Water Use in South Carolina

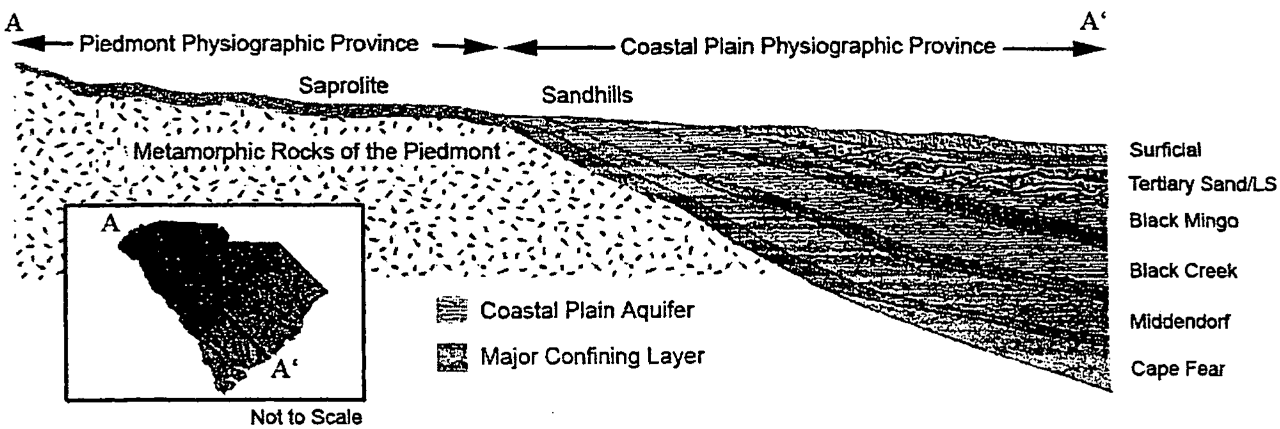


Figure 2: Generalized Hydrogeologic Cross-Section from the Blue Ridge through the Lower Coastal Plain in South Carolina

Groundwater Resources

Groundwater resources are found throughout the subsurface of South Carolina in varying quantities, qualities, and depths that reflect the nature of the geologic materials that host the respective aquifers. The following is a brief description of the State's major groundwater resources.

Crystalline Rock Aquifer System of the Blue Ridge and Piedmont

Geology of the Blue Ridge is typically characterized by clayey saprolite, ranging in depth from several feet to tens of feet, overlying metamorphic crystalline rock. The saprolite grades downward through a highly permeable transition zone to unaltered parent bedrock. Groundwater conditions of the bedrock are dependent on the number of fractures and degree of interconnection of the fracture systems. Groundwater moves slowly through the saprolite and discharges to surface water bodies, wells, or is released from storage to the underlying bedrock through fractures. Geology of the Piedmont is similar to that of the Blue Ridge, but the diminished relief allows for greater thickness of saprolite development. In general, wells in the Blue Ridge and Piedmont regions yield little water when compared to wells drilled in the Coastal Plain owing to the inherently low porosity and permeability of the crystalline rock present in the upstate.

Surficial Aquifer System

Shallow sands that comprise the Surficial aquifer are among the youngest of the Coastal Plain sediments and are found exclusively in the Lower Coastal Plain (**Figure 1**). This system is capable of producing water in modest amounts for irrigation and private drinking water supply, but is especially susceptible to contamination due to its shallow, unconfined nature. The Surficial sands are highly influenced by local precipitation and river stage and are especially prone to dramatic water level declines during times of drought.

Tertiary Limestone/Sand Aquifer System (Floridan Aquifer System)

In the southern half of the Coastal Plain, Tertiary aquifers consisting of sand grade southeastward into an ever thickening wedge of limestone. Development of the aquifer system is common in the Charleston, Dorchester, and Berkeley County area. Southwest of the Combahee and Salkehatchie Rivers, upper sections of the limestone become increasingly permeable owing to abundant voids created from dissolved marine fossils, and are capable of storing and supplying tremendous amounts of water. The majority of utilization of the aquifer occurs near the upper, highly permeable zone that supplies the majority of residential wells in Beaufort and Jasper Counties, and is the primary source of water for public supply, irrigation, and industry in the Low Country. This southern section of the Tertiary Limestone correlates regionally with the Upper Floridan Aquifer that extends from southern South Carolina to the southern keys of Florida.

Black Mingo Aquifer

Development of the Black Mingo is common in the vicinity of Charleston, Dorchester, and Berkeley counties, but has been largely overlooked south of Dorchester County owing to the increasingly prolific nature of the more shallow Tertiary Limestone (Floridan Aquifer System). Like the majority of Coastal Plain sediments, the nature of the aquifer differs dramatically from one area to the next. In the Charleston area, the aquifer is composed of permeable sand and limestone, while within the Upper Coastal Plain the Black Mingo is often a poorly producing aquifer composed of fine silt and clay, and therefore is unused in favor of the Middendorf or Tertiary Sand Aquifer.

Pee Dee Aquifer

The Pee Dee aquifer, where present, generally produces quality water at moderate rates. The aquifer matrix is composed of sand and silt separated by discontinuous intervals of clay. Development of the Pee Dee aquifer usually takes place in conjunction with the more prolific Black Creek aquifer and has become an excellent alternative to the often-overburdened Black

Creek for many uses, especially irrigation. The Pee Dee aquifer is most utilized in the northeast portion of the State, with the most demand centered between Florence and Horry Counties.

Black Creek Aquifer

Though present throughout much of the Coastal Plain, development of the Black Creek aquifer has been conducted primarily in the mid-to-northern portions of the Coastal Plain. The aquifer is composed of silt and fine sand with, with coarse sand in the Upper Coastal Plain. The Black Creek aquifer is an important source of water for public supply, irrigation, and industry from Marion County southeast to Georgetown County.

Middendorf Aquifer

The Middendorf Aquifer is a prolific source of water throughout the majority of the coastal plain and consists of coarse-grained fluvial sands near the Fall Line that grade to fine-grained marine sands and clay in the northern and eastern Lower Coastal Plain. The majority of the Pee Dee region, including Chesterfield, Darlington, Florence, and Marlboro Counties, as well as Orangeburg and Sumter Counties rely heavily on the Middendorf for irrigation, public supply, and industrial use. In the past decade, use of the Middendorf has increased along the southern coast in areas such as Charleston County.

Cape Fear Aquifer

Little information exists from this deep sand aquifer owing to the few wells that have penetrated the formation. In general, water quality from the Cape Fear aquifer is poor over much of its extent owing to ancient unflushed (connate) seawater and extensive mineralization. In South Carolina, the Cape Fear aquifer is largely unused.

Surface Water Resources

South Carolina's land surface is drained by eight (8) major river basins, all of which are critical to public water supply, irrigation, industry, and/or power generation. These major watersheds are shown as **Figure 3**, and a brief description of each major watershed follows.

Broad River Basin

The Broad River Watershed encompasses portions of North and South Carolina and drains the majority of Cherokee, Union, Spartanburg, and Greenville Counties. Portions of Chester, Fairfield, Richland and York counties are also included in the basin, and are drained by the Enoree, Pacolet, and Tyger Rivers, major tributary streams to the Broad River.

Catawba River Basin

Similar to the Broad River Basin, the watershed of the Catawba River drains counties in North and South Carolina east of a hydrologic divide in York, Chester, and Fairfield Counties. All or portions of the following counties lie within the basin: Chester, Fairfield, Kershaw, Lancaster, Richland, Sumter and York. The Catawba basin hosts Lake Wylie, Fishing Creek Reservoir, Lake Wateree, the Catawba and Wateree Rivers and associated tributary streams.

Edisto River Basin

The Edisto River Basin encompasses nearly all of Orangeburg County and portions of Aiken, Berkeley, Calhoun, Dorchester, and Lexington counties. The basin drains the central Coastal Plain and contains the North and South Forks of the Edisto River and tributaries, as well as numerous ecologically important wetland areas.

Pee Dee River Basin

The Pee Dee River Basin is the largest of South Carolina's watersheds and drains all or portions of Chesterfield, Darlington, Dillon, Georgetown, Horry, Kershaw, Lancaster, Lee, Marion, Marlboro, Williamsburg counties, and portions of southeastern North Carolina. The

Greater Pee Dee Watershed encompasses 5.1 million acres and includes the Pee Dee, Lynches, Waccamaw, and Sampit watersheds, as well as the Intracoastal Waterway and Winyah Bay.

Salkehatchie River Basin

The Salkehatchie basin is located entirely in the Coastal Plain and drains portions of Bamberg, Barnwell, Beaufort, Colleton, Hampton, and Jasper counties. The Coosawhatchie, Salkehatchie and Little Salkehatchie Rivers, along with their associated tributaries and local wetlands drain the basin and form tide-dominated distributary channels near the coast.

Saluda River Basin

The Saluda River Basin drains the central portion of South Carolina's Piedmont Region and encompasses major portions of Greenville and Pickens counties, as well as portions of Abbeville, Greenwood, Laurens, Lexington, Richland, and Saluda Counties. The basin includes all tributary streams to the Saluda River and Lakes Greenwood and Murray, the latter being a critical source for public water supply and hydroelectric power in central South Carolina.

Santee River Basin

The Santee River basin originates near the confluence of the Catawba and Broad River Basins and includes two of the State's largest reservoirs, Lake Marion and Lake Moultrie. These two major surface water resources are important power generating assets for the South Carolina. The basin drains Berkeley, Calhoun, Charleston, Clarendon, Dorchester, and small portions of Georgetown and Sumter Counties via tributaries of the Cooper, Santee and Ashley Rivers.

Savannah River Basin

The Savannah River Basin stretches from the Blue Ridge to the Atlantic Ocean and encompasses the border counties of South Carolina. The watershed drains major portions of Abbeville, Aiken, Allendale, Anderson, Edgefield, Greenwood, Hapton, McCormick, Oconee, and Pickens County, as well as adjacent counties in Georgia. The watershed includes the Savannah, Chatooga, Seneca, Little River, Stevens Creek, Rocky, and Tugaloo Rivers, and discharges approximately 8.0 billion gallons per day.

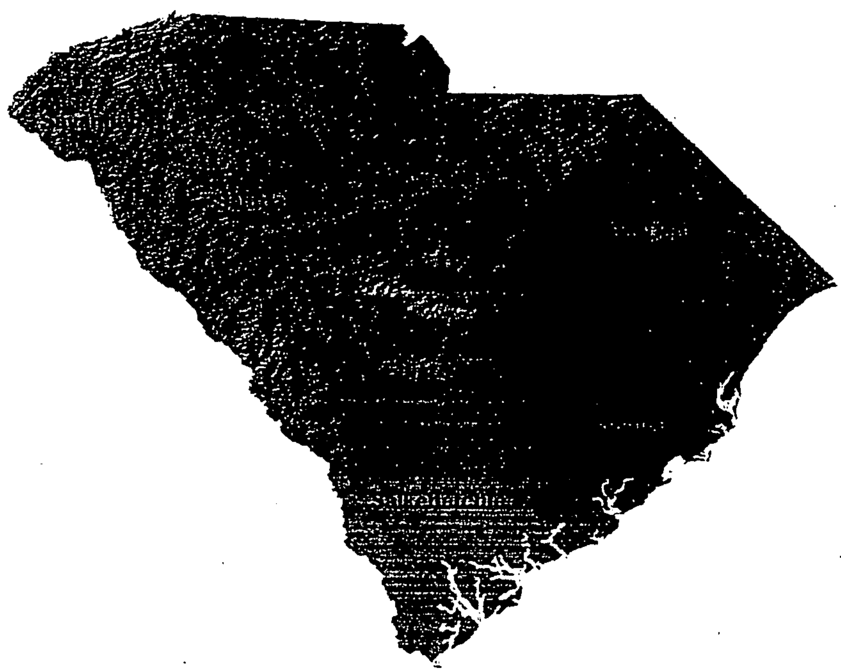


Figure 3: Major River Basins of South Carolina

Demographics

According to the 2000 Census, South Carolina's estimated population is 4,012,012. Approximately 54.6% of the population resides in an urban setting and approximately 45.4% reside in rural communities (**Figure 4**). South Carolina has approximately 25,000 farms, occupying 4,588,000 acres (7,170 square miles). Of this, approximately 2,500,000 acres (3,905 square miles) are cropland[1]. Major manufacturing industries are located along the I-26/I-85 corridor, specifically in the Greenville-Spartanburg Metropolitan Statistical Area (MSA), Columbia MSA, Charlotte-Gastonia-Rock Hill MSA and the Charleston MSA. Other manufacturing concentrations are located in the Augusta-Aiken MSA, and the Florence area[2]. South Carolina is served by 47 electric utilities and nine (9) generating utility companies with 51 power plants (206 generators) with a total rating capacity of 18,827.4 megawatts. Power production in the State (2004) totaled 94,363 million kilowatt hours[3].

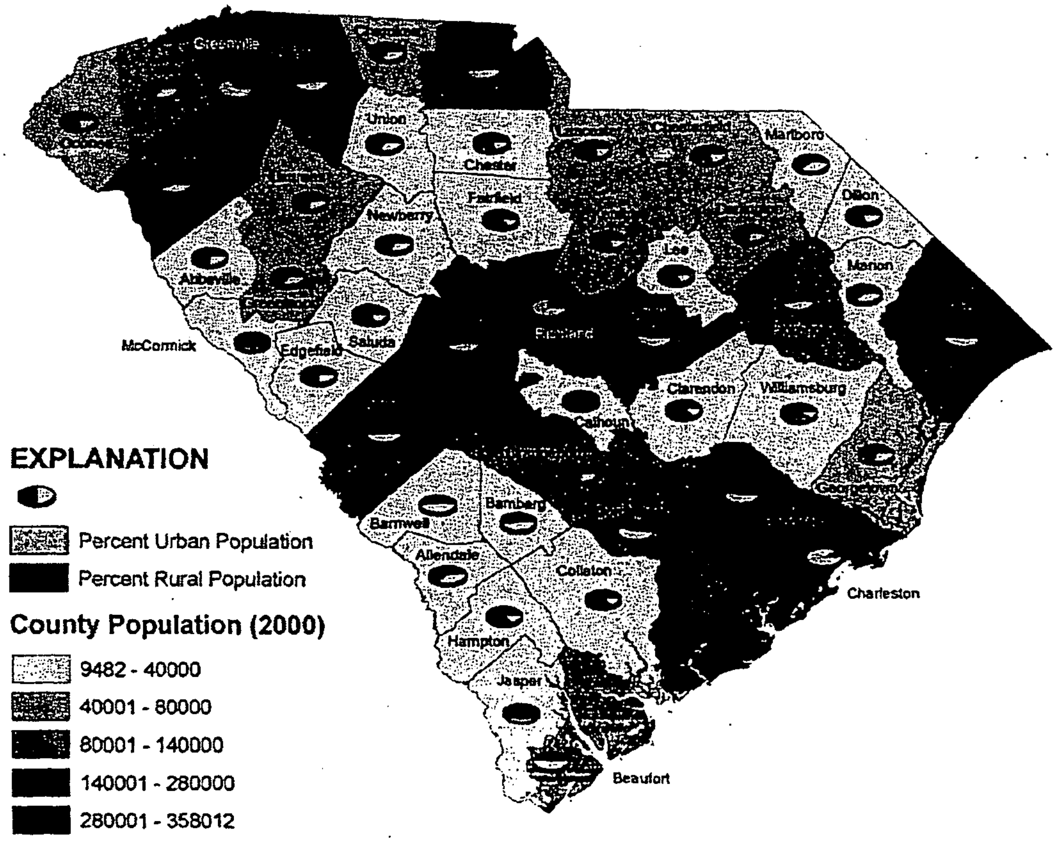


Figure 4: Population by County in South Carolina, 2000

---

[1] 1997 Census of Agriculture, Volume 1 Geographic Area Series, "Table 1. County Summary Highlights: 1997."

[2] S.C. Department of Commerce, 2000/2001 "South Carolina Industrial Directory."

[3] S.C. Budget and Control Board Statistical Abstract 2004

2004 Water Use Profile

Surface and Groundwater Use Summary by Category and County in South Carolina, 2004

The following section outlines all reported water use for the State of South Carolina for the calendar year 2004. Water use is summarized by category, and further tabulated on a county-by-county basis. Where appropriate, the spatial distribution of the magnitude of water use is demonstrated on an accompanying map with a breakdown chart of groundwater and surface water use as a percentage of total use for the category.

Reporting Water Withdrawers

For the reporting year 2004, South Carolina had registered 848 water withdrawers with 2425 sources, 481 surface water facilities with 712 sources and 536 groundwater facilities with 1,713 sources. It should be noted 169 facilities utilized both groundwater and surface water sources.

Water Use Category	Facilities	GW Source	SW Source
Golf Course	257	291	284
Water Supply	223	745	82
Irrigation	201	413	226
Industrial	94	209	55
Hydroelectric	30	1	31
Thermoelectric	19	13	22
Mining	12	13	4
Aquaculture	10	12	8
Other	2	16	NR
Total	**848**	**1713**	**712**

NR = None Reported

Total Reported Water Use

Total water use reported for 2004 was more than 18.8 trillion gallons from 848 reporting facilities. Surface water withdrawal from 481 facilities accounted for approximately 18.7 trillion gallons, approximately 99% of total water use. Groundwater withdrawal from 536 reporting facilities accounted for approximately 67.6 billion gallons or approximately 1%.

Water Use Category	Groundwater	Surface Water	Total	Percentage
Aquaculture	238.249	1,117.382	1,355.631	0.01%
Golf Courses	3,699.103	9,531.359	13,230.462	0.07%
Industrial	11,794.443	145,514.581	157,309.024	0.83%
Irrigation	13,992.558	10,127.311	24,119.869	0.13%
Mining	2,456.623	785.000	3,241.623	0.02%
Other	85.505	NR	85.505	0.0005%
Hydroelectric	1.181	15,202,999.340	15,203,000.521	80.68%
Thermoelectric	2,040.139	3,230,063.932	3,232,104.071	17.15%
Water Supply	39,764.832	169,699.471	209,464.303	1.11%

NR = None Reported

Water Use	1999	2000	2001	2002	2003	2004
Hydroelectric	12,160,642.62	10,281,681.91	9,796,267.91	11,415,081.44	18,958,207.77	15,203,000.521
Thermoelectric	2,326,627.77	2,240,508.37	1,624,984.88	2,467,042.32	3,558,474.88	3,232,104.071
Water Supply	221,911.79	148,265.21	193,525.29	212,402.79	197,088.27	209,464.303
Industrial	172,314.14	157,463.33	180,579.90	167,051.34	168,334.76	157,309.024
Irrigation	9,470.97	3,182.73	27,121.14	29,668.39	12,172.86	24,119.869
Golf Course	6,323.77	6,806.35	13,302.54	14,022.92	10,373.47	13,230.462
Mining	2,546.92	3,056.08	2,691.75	3,159.88	4,935.07	3,241.623
Aquaculture	35.97	13.67	865.17	2,283.95	1,451.98	1,355.631
Other	367.06	223.61	204.84	106.22	59.033	85.505
Total	14,900,241.01	12,841,201.26	11,839,543.42	14,310,819.25	22,911,098.09	18,843,911.009
Facilities	717	577	931	848	833	848

Water Use in Power Production

According to the 2001 Energy Use Profile, South Carolina has 9 power generating utility companies with 51 power plants containing 206 generators with a total rating capacity of 18,827.4 megawatts (2000). The type generators are as follows:

- 96- Hydraulic Turbine (conventional)
- 54- Gas Combustion Turbine
- 37- Steam Turbine (boiler)
- 16- Hydraulic Turbine (pump storage)
- 3- Internal Combustion (diesel)

The primary energy source for the generators is as follows:

- 112- Water
- 32- Diesel Fuel Oil
- 28- Coal
- 25- Natural Gas
- 7- Nuclear
- 2- Residual Fuel Oil

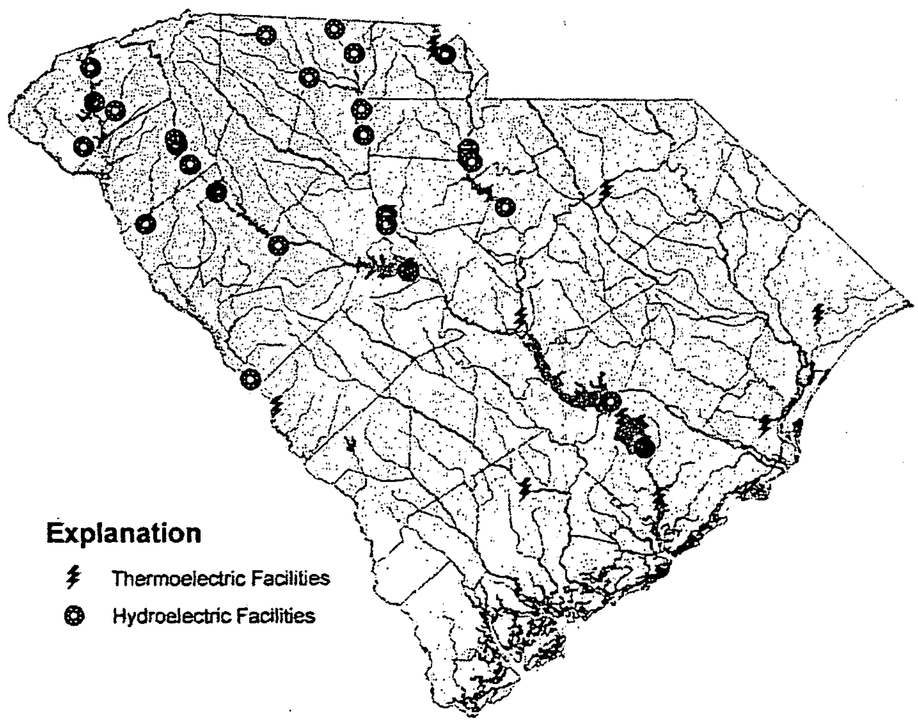


Figure 5: Distribution of Hydroelectric and Thermoelectric Facilities in South Carolina

Hydroelectric Water Use

Hydroelectric facilities employ energy from flowing water to generate electricity. Hydroelectric facilities utilize *impoundments* (reservoirs), *diversion* (run-of river), *or pumped storage* (reversible turbines). Water use is typically non-consumptive flow-through, with temporary diversion from down stream users. Reported water use for 31 hydroelectric sources accounted for approximately 15.203 trillion gallons, approximately 82.44% of reported water use for power production and 80.68% of total reported water use for the year.

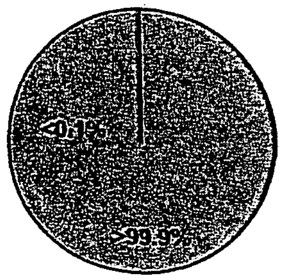
County	Surface Water	Groundwater	County Total
Abbeville	28,619.000	NR	28,619.000
Anderson	274.193	NR	274.193
Berkeley	1,213,836.312	1.181	1,213,837.493
Cherokee	455,113.000	NR	455,113.000
Chester	2,171,229.000	NR	2,171,229.000
Edgefield	999,809.310	NR	999,809.310
Fairfield	3,025,896.060	NR	3,025,896.060
Greenville	140,851.000	NR	140,851.000
Greenwood	317,017.000	NR	317,017.000
Kershaw	1,207,267.000	NR	1,207,267.000
Lancaster	1,093,794.000	NR	1,093,794.000
Laurens	149.400	NR	149.400
Lexington	201,784.930	NR	201,784.930
Oconee	12.200	NR	12.200
Pickens	2,611,758.000	NR	2,611,758.000
Richland	473,338.480	NR	473,338.480
Spartanburg	13,852.416	NR	13,852.416
Union	316,309.036	NR	316,309.036
York	932,089.000	NR	932,089.000

NR = None Reported

	Surface Water	Groundwater
Source Total:	15,202,999.337	1.181

Total Hydro Power Use (million gallons): 15,203,000.518

Hydroelectric Source Comparison



Average daily flow-through hydroelectric use for any of the 31 reporting facilities averaged 1.34 billion gallons of surface water per day in 2004

Thermoelectric Water Use

Thermoelectric facilities generate electricity by superheating water to steam then passing the steam under pressure to turbines. Boilers are fired by coal, nuclear power or residual fuel oil. Large volumes of cooling water are required to condense the steam to the liquid state. Reported water use for 19 thermoelectric sources accounted for more than 3.232 trillion gallons, approximately 17.56% of reported water use for power production and 17.15% of total reported water use for the year.

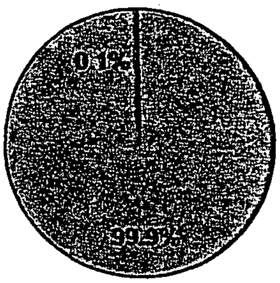
County	Surface Water	Groundwater	County Total
Aiken	46,744.000	NR	46,744.000
Anderson	37,417.276	NR	37,417.276
Berkeley	167,653.708	12.035	167,665.743
Cherokee	NR	1.326	1.326
Colleton	1,616.455	1.828	1,618.283
Darlington	285,140.000	363.509	285,503.509
Fairfield	246,543.778	NR	246,543.778
Georgetown	4,687.310	NR	4,687.310
Greenwood	116.137	NR	116.137
Horry	38,448.870	NR	38,448.870
Lexington	46,310.870	NR	46,310.870
Oconee	2,147,899.000	NR	2,147,899.000
Orangeburg	0.328	1,661.441	1,661.769
Richland	169,724.200	NR	169,724.200
York	37,762.000	NR	37,762.000

NR = None Reported

	Surface Water	Groundwater
Source Total:	3,230,063.932	2,036.985

Total Thermoelectric Use (million gallons):	**3,232,104.071**

Thermoelectric Source Comparison



Surface Water
Groundwater

Average daily use for any thermoelectric facility (19 total) equaled 4.66 billion gallons of surface water per day

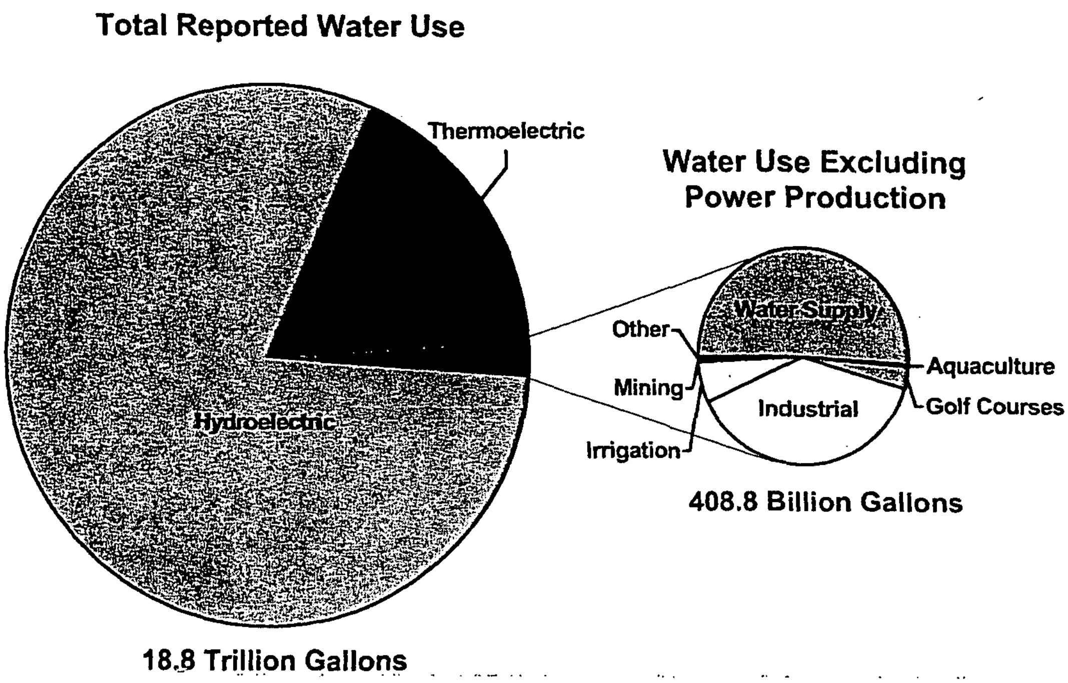


Figure 6: Reported Water Use by Category in South Carolina, 2004

Reported Water Use Excluding Power Production

During 2004, reported water use (excluding power production) totaled more than 408.8 billion gallons with surface water withdrawal accounting for 336.7 billion gallons or approximately 82.3%, and groundwater withdrawal accounting for 72.0 billion gallons or approximately 17.7%. Non-power production-oriented water use accounted for 2.2% of all reported water use in 2004.

	Groundwater	Surface Water	Total	Percentage of Total Non-Power Use
Aquaculture	238.249	1,117.38	1,355.63	0.33%
Golf Courses	3,699.10	9,531.36	13,230.46	3.24%
Industrial	11,794.44	145,514.58	157,309.02	38.48%
Irrigation	13,992.56	10,127.31	24,119.87	5.90%
Mining	2,456.62	785.00	3,241.62	0.79%
Other	85.505	NR	85.505	0.02%
Water Supply	39,764.83	169,699.47	209,464.30	51.24%

Total Non-Power Water Use **408,806.42** million gallons

NR = None Reported

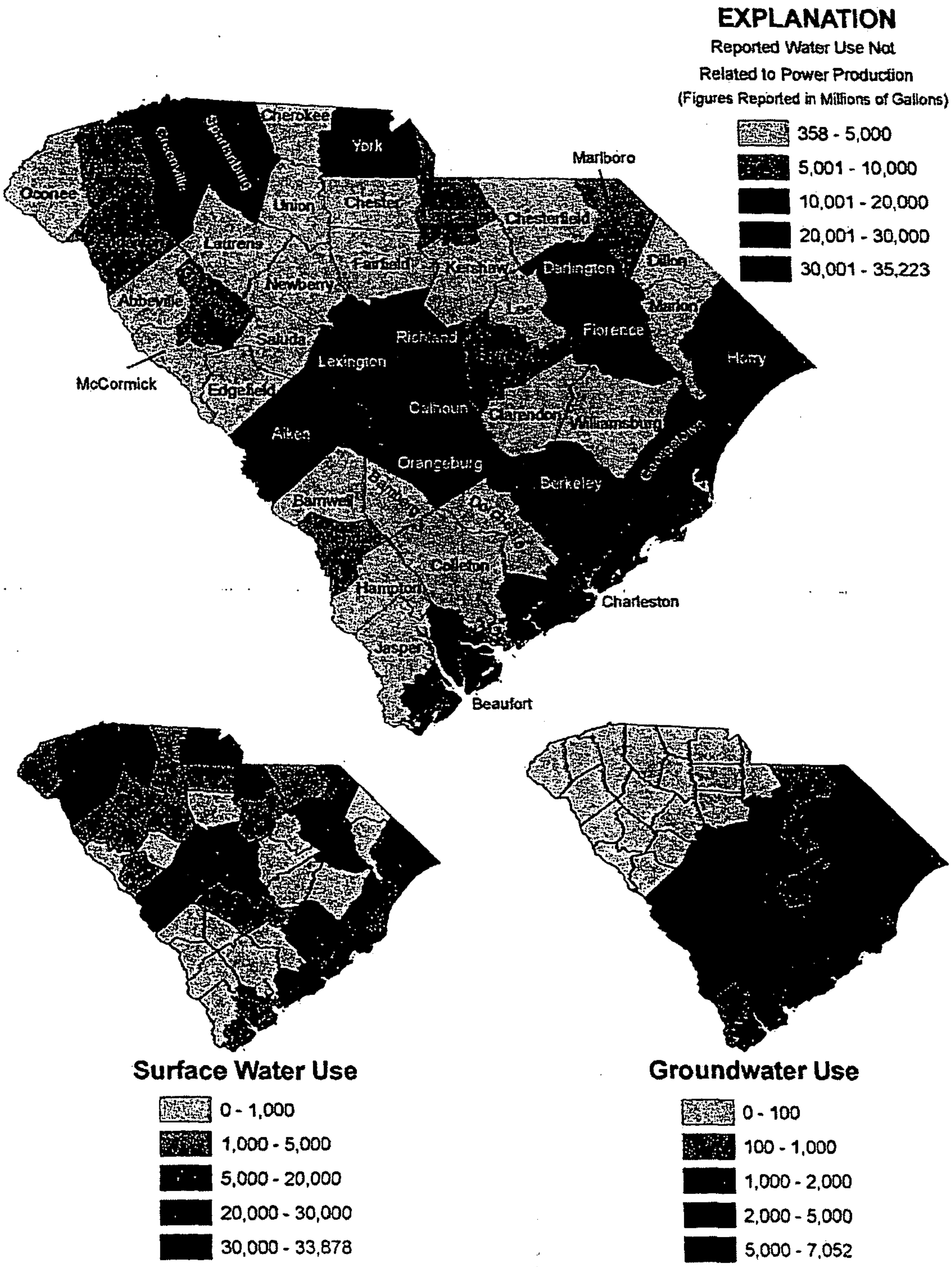


Figure 7: Distribution of Reported Water Usage Unrelated to Power Production, 2004. Figures in millions of gallons per year.

Water Supply

South Carolina has federally 1,551 defined public water systems, of which 685 are community water systems. The public water systems provide water to 3,450,928 citizens. Water withdrawal for public water supply from 223 reporting suppliers totaled 209.464 billion gallons, with 82 surface water sources accounting for 169.699 billion gallons and 745 groundwater sources accounting for 39.764 billion gallons.

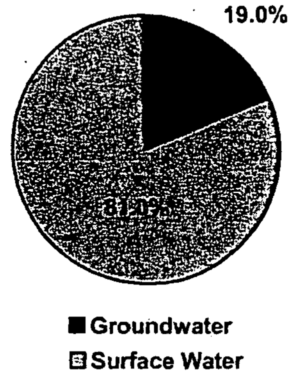
County	Groundwater	Surface Water	County Total
Abbeville	2.798	1,017.236	1,020.034
Aiken	4,878.595	2,081.947	6,960.542
Allendale	408.135	NR	408.135
Anderson	NR	7,579.473	7,579.473
Bamberg	502.982	NR	502.982
Barnwell	1,085.024	NR	1,085.024
Beaufort	4,132.591	7,206.600	11,339.191
Berkeley	174.644	5,107.400	5,282.044
Calhoun	234.662	NR	234.662
Charleston	2,993.134	18,748.790	21,741.924
Cherokee	NR	3,536.200	3,536.200
Chester	NR	1,097.200	1,097.200
Chesterfield	618.460	1,028.890	1,647.350
Clarendon	729.432	NR	729.432
Colleton	809.169	NR	809.169
Darlington	2,505.969	NR	2,505.969
Dillon	1,706.404	NR	1,706.404
Dorchester	607.082	NR	607.082
Edgefield	NR	1,545.994	1,545.994
Fairfield	64.334	795.788	860.122
Florence	3,873.342	1,589.940	5,463.282
Georgetown	908.137	2,220.469	3,128.606
Greenville	38.137	23,801.700	23,839.837
Greenwood	27.127	4,900.928	4,928.055
Hampton	519.409	NR	519.409
Horry	951.496	14,045.400	14,996.896
Jasper	435.596	NR	435.596
Kershaw	674.355	1,818.655	2,493.010
Lancaster	NR	7,752.035	7,752.035
Laurens	NR	1,609.625	1,609.625
Lee	595.968	NR	595.968
Lexington	441.282	5,287.679	5,728.961
Marion	1,356.885	NR	1,356.885
Marlboro	983.436	NR	983.436
McCormick	NR	421.956	421.956
Newberry	30.956	2,270.162	2,301.118
Oconee	58.070	3,580.243	3,638.313
Orangeburg	675.943	3,007.440	3,683.383
Pickens	NR	3,982.405	3,982.405
Richland	334.976	23,259.800	23,594.776
Saluda	2.397	NR	2.397
Spartanburg	25.844	13,626.928	13,652.772
Sumter	5,675.104	NR	5,675.104
Union	NR	1,248.260	1,248.260
Williamsburg	689.090	NR	689.090
York	13.867	5,530.328	5,544.195

NR = None Reported

	Groundwater	Surface Water
Source Total:	39,764.832	169,699.471

Total Water Supply Use (millions of gallons):	209,464.303

Water Supply Use Source Comparison



Average daily use for any reporting water supply facility (223 total) in 2004 equaled 488,541 gallons of groundwater and 2,084,888 gallons of surface water per day.

Distribution of reported water supply water use in South Carolina, 2004. Darker shades indicate the highest use areas.

Industrial Use

Water withdrawal for industrial use from 94 reporting industries totaled 157.309 billion gallons, with 55 surface water sources accounting for 145.514 billion gallons and 209 groundwater sources accounting for 11.794 billion gallons. Water use at industrial facilities is predominantly cooling water (contact and non-contact) with return to surface water systems through permitted NPDES discharges.

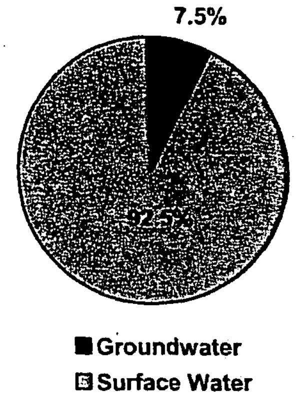
County	Groundwater	Surface Water	County Total
Aiken	1,450.483	19,383.065	20,833.548
Allendale	890.420	NR	890.420
Anderson	NR	57.300	57.300
Beaufort	143.902	NR	143.902
Berkeley	1,100.794	3,774.825	4,875.619
Calhoun	138.448	28,274.894	28,413.342
Charleston	33.722	9,624.900	9,658.622
Cherokee	NR	483.126	483.126
Chester	1.432	91.173	92.605
Darlington	1,896.045	7,768.653	9,664.698
Dorchester	916.381	174.455	1,090.836
Florence	798.964	7,202.600	8,001.564
Georgetown	110.301	11,288.732	11,399.033
Greenville	47.702	NR	47.702
Greenwood	NR	49.850	49.850
Hampton	393.200	NR	393.200
Horry	165.340	2.749	168.089
Kershaw	417.738	923.742	1,341.480
Lancaster	NR	1,010.530	1,010.530
Lexington	414.221	10,197.980	10,612.201
Marlboro	230.453	7,743.082	7,973.535
Oconee	NR	674.440	674.440
Orangeburg	701.127	154.767	855.894
Pickens	NR	3,044.110	3,044.110
Richland	677.192	10,263.504	10,940.696
Spartanburg	15.113	NR	15.113
Sumter	315.873	NR	315.873
Union	2.530	516.200	518.730
Williamsburg	929.368	NR	929.368
York	3.694	22,809.904	22,813.598

NR = None Reported

	Groundwater	Surface Water
Source Total:	11,794.443	145,514.581

Total Industrial Use (millions of gallons):	157,309.024

Industrial Use Source Comparison



Average use for any reporting industrial facility (94 total) in 2004 equaled 343,761 gallons of groundwater and 4,241,171 gallons of surface water per day.

Distribution of reported industrial water use in South Carolina, 2004. Darker shades indicate the highest use areas.

Irrigation Use

Water withdrawal for irrigation use from 210 reporting entities totaled 24.119 billion gallons, with 226 surface water sources accounting for 10.127 billion gallons and 413 groundwater sources accounting for 13.992 billion gallons.

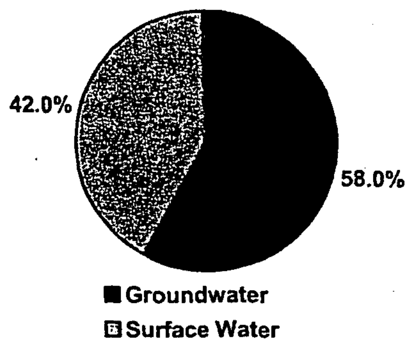
County	Groundwater	Surface Water	County Total
Aiken	484.652	1,020.000	1,504.652
Allendale	3,325.401	432.680	3,758.081
Bamberg	512.490	645.928	1,158.418
Barnwell	134.763	77.915	212.678
Beaufort	720.401	20.700	741.101
Berkeley	0.240	1093.194	1,093.434
Calhoun	853.542	141.543	995.085
Charleston	12.852	35.491	48.343
Chesterfield	238.797	NR	238.797
Clarendon	182.026	152.086	334.112
Colleton	929.700	265.000	1,194.700
Darlington	0.995	158.163	159.158
Dillon	34.900	NR	34.900
Edgefield	21.000	506.840	527.840
Florence	105.208	12.000	117.208
Georgetown	19.743	1,670.289	1,690.032
Greenville	NR	24.750	24.750
Greenwood	1.200	NR	1.200
Hampton	876.001	16.000	892.001
Horry	179.111	283.847	462.958
Jasper	270.970	NR	270.970
Lee	98.439	8.000	106.439
Lexington	1622.548	496.570	2,119.118
Marion	28.400	22.000	50.400
Marlboro	191.894	88.190	280.084
McCormick	NR	NR	NR
Newberry	60.700	125.700	186.400
Oconee	NR	282.850	282.850
Orangeburg	2,282.848	1,497.681	3,780.529
Pickens	NR	NR	NR
Richland	7.088	0.300	7.388
Saluda	NR	355.870	355.870
Spartanburg	NR	100.124	100.124
Sumter	796.649	586.850	1,383.499
Williamsburg	NR	4.300	4.300
York	NR	2.450	2.450

NR = None Reported

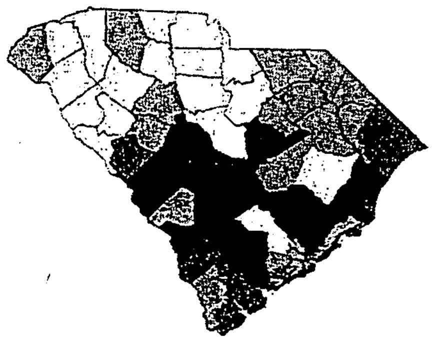
	Groundwater	Surface Water
Source Total:	13,992.558	10,127.311

Total Irrigation Use (millions of gallons):	**24,119.869**

Irrigation Use Source Comparison



Average use for any reporting irrigator (210 total) in 2004 equaled 190,717 gallons of groundwater and 138,035 gallons of surface water per day.



Distribution of reported irrigation water use in South Carolina, 2004. Darker shades indicate the highest use areas.

Golf Course Use

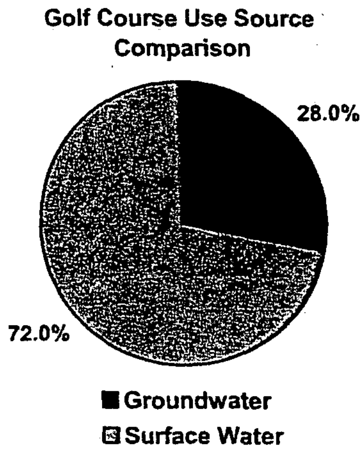
Water withdrawal from 254 reporting courses for golf course irrigation totaled 13.230 billion gallons, with 284 surface water sources accounting for 9.531 billion gallons and 291 groundwater sources accounting for 3.699 billion gallons.

County	Groundwater	Surface Water	County Total
Aiken	29.900	179.523	209.423
Anderson	NR	107.177	107.177
Barnwell	NR	59.178	59.178
Beaufort	1571.158	2150.114	3721.272
Berkeley	11.648	12.555	24.203
Calhoun	38.200	48.800	87.000
Charleston	766.056	226.615	992.671
Chester	18.000	14.000	32.000
Chesterfield	NR	222.230	222.230
Clarendon	24.950	30.820	55.770
Colleton	54.803	1.085	55.888
Darlington	10.600	95.849	106.449
Dorchester	29.000	NR	29.000
Edgefield	75.850	43.500	119.350
Florence	137.536	32.721	170.257
Georgetown	0.900	915.344	916.244
Greenville	3.674	255.429	259.103
Greenwood	6.980	47.645	54.625
Hampton	30.067	NR	30.067
Horry	607.426	3296.873	3904.299
Kershaw	47.561	57.470	105.031
Lancaster	1.224	2.700	3.924
Laurens	NR	54.612	54.612
Lexington	36.780	204.818	241.598
Marion	7.277	26.158	33.435
McCormick	NR	39.568	39.568
Newberry	NR	10.000	10.000
Oconee	NR	103.235	103.235
Orangeburg	20.105	93.528	113.633
Pickens	NR	406.088	406.088
Richland	22.239	341.138	363.377
Spartanburg	5.686	120.252	125.938
Sumter	82.703	200.493	283.196
Union	NR	8.750	8.750
York	58.780	123.091	181.871

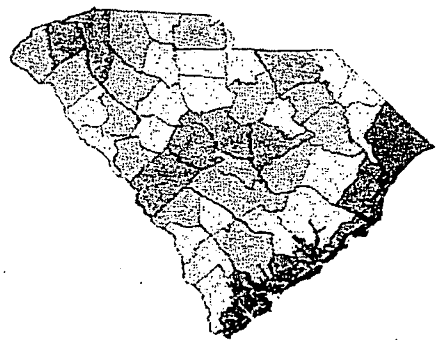
NR = None Reported

	Groundwater	Surface Water
Source Total:	3,699.103	9,531.359

Total Golf Course Use (million gallons):	13,230.462



Average daily use for any reporting golf course (254 total) in 2004 equaled 39,433 gallons of groundwater and 101,604 gallons of surface water per day.



Distribution of reported golf course water use in South Carolina, 2004. Darker shades indicate the highest use areas.

Mining Use

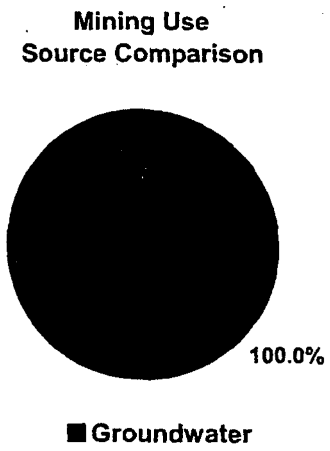
Water withdrawal associated with mining activities at 13 reporting facilities totaled 2.456 billion gallons, with groundwater accounting for all reported use.

County	Groundwater	Surface Water	County Total
Aiken	29.160	NR	29.160
Berkeley	2.654	NR	2.654
Lexington	464.850	NR	464.850
Orangeburg	1711.087	NR	1711.087
Richland	235.872	NR	235.872
York	13.000	NR	13.000

NR = None Reported

	Groundwater	Surface Water
Source Total:	2456.623	NR

Total Irrigation Use (million gallons):	2456.623



Aquaculture Use

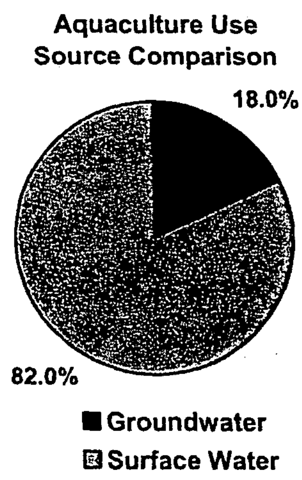
Water withdrawal from 10 reporting aquaculture-farming facilities totaled 1.320 billion gallons, with 12 surface water sources accounting for 1.312 billion gallons and 8 groundwater sources accounting for 238.249 million gallons.

County	Groundwater	Surface Water	County Totals
Beaufort	5.984	78.234	84.218
Berkeley	2.961	94.492	97.453
Charleston	NR	895.620	895.620
Dillon	33.700	NR	33.700
Hampton	128.304	NR	128.304
Richland	67.300	13.900	81.200
Spartanburg	NR	35.136	35.136

NR = None Reported

	Groundwater	Surface Water
Source Total:	238.249	1082.246

Total Aquaculture Use (million gallons):	1320.495



Other Use

Water withdrawal for other, non-specific use from 2 reporting facilities totaled 85.505 million gallons, with groundwater accounting for all reported use.

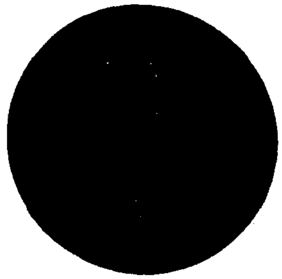
County	Groundwater	Surface Water	County Total
Beaufort	41.430	NR	41.430
Horry	44.075	NR	44.075

NR = None Reported

	Groundwater	Surface Water
Source Total:	85.505	NR

Total Other Use (million gallons):	85.505

Other Use
Source Comparison



Appendix A: Surface and Groundwater Use Summary Tables

Surface Water Use Summary Table (Figures in Millions of Gallons)

County	County Total	Hydroelectric	Thermoelectric	Aquaculture	Golf Course	Industry	Irrigation	Mining	Water Supply
Abbeville	29,636.236	28,619.000	NR	NR	NR	NR	NR	NR	1,017.236
Aiken	69,408.535	NR	46,744.000	NR	179.523	19,383.065	1,020.000	NR	2,081.947
Allendale	432.680	NR	NR	NR	NR	NR	432.680	NR	NR
Anderson	45,435.419	274.193	37,417.276	NR	107.177	57.300	NR	NR	7,579.473
Bamberg	645.928	NR	NR	NR	NR	NR	645.928	NR	NR
Barnwell	137.093	NR	NR	NR	59.178	NR	77.915	NR	NR
Beaufort	9,455.648	NR	NR	78.234	2,150.114	NR	20.700	NR	7,206.600
Berkeley	1,391,572.486	1,213,836.312	167,653.708	94.492	12.555	3,774.825	1,093.194	NR	5,107.400
Calhoun	28,465.237	NR	NR	NR	48.800	28,274.894	141.543	NR	NR
Charleston	29,531.416	NR	NR	895.620	226.615	9,624.900	35.491	NR	18,748.790
Cherokee	459,132.326	455,113.000	NR	NR	NR	483.126	NR	NR	3,536.200
Chester	2,172,431.373	2,171,229.000	NR	NR	14.000	91.173	NR	NR	1,097.200
Chesterfield	1,251.120	NR	NR	NR	222.230	NR	NR	NR	1,028.890
Clarendon	182.906	NR	NR	NR	30.820	NR	152.086	NR	NR
Colleton	1,884.225	NR	1,616.455	NR	1.085	NR	265.000	1.685	NR
Darlington	293,162.665	NR	285,140.000	NR	95.849	7,768.653	158.163	NR	NR
Dorchester	174.455	NR	NR	NR	NR	174.455	NR	NR	NR
Edgefield	1,001,905.644	999,809.310	NR	NR	43.500	NR	506.840	NR	1,545.994
Fairfield	3,273,235.626	3,025,896.060	246,543.778	NR	NR	NR	NR	NR	795.788
Florence	8,837.261	NR	NR	NR	32.721	7,202.600	12.000	NR	1,589.940
Georgetown	20,782.144	NR	4,687.310	NR	915.344	11,288.732	1,670.289	NR	2,220.469
Greenville	164,932.879	140,851.000	NR	NR	255.429	NR	24.750	NR	23,801.700
Greenwood	322,131.560	317,017.000	116.137	NR	47.645	49.850	NR	NR	4,900.928
Hampton	16.000	NR	NR	NR	NR	NR	16.000	NR	NR
Horry	56,297.099	NR	38,448.870	NR	3,296.873	2.749	283.847	219.360	14,045.400
Jasper	0.000	NR	NR	NR	NR	NR	NR	NR	NR
Kershaw	1,210,066.867	1,207,267.000	NR	NR	57.470	923.742	NR	NR	1,818.655
Lancaster	1,102,559.265	1,093,794.000	NR	NR	2.700	1,010.530	NR	NR	7,752.035
Laurens	1,813.637	149.400	NR	NR	54.612	NR	NR	NR	1,609.625
Lee	8.000	NR	NR	NR	NR	NR	8.000	NR	NR
Lexington	264,846.802	201,784.930	46,310.870	NR	204.818	10,197.980	496.570	563.955	5,287.679
Marion	48.158	NR	NR	NR	26.158	NR	22.000	NR	NR
Marlboro	7,831.272	NR	NR	NR	NR	7,743.082	88.190	NR	NR
McCormick	461.524	NR	NR	NR	39.568	NR	NR	NR	421.956
Newberry	2,405.862	NR	NR	NR	10.000	NR	125.700	NR	2,270.162
Oconee	2,152,551.968	12.200	2,147,899.000	NR	103.235	674.440	282.850	NR	3,580.243
Orangeburg	4,753.744	NR	0.328	NR	93.528	154.767	1,497.681	NR	3,007.440
Pickens	2,619,190.603	2,611,758.000	NR	NR	406.088	3,044.110	NR	NR	3,982.405
Richland	676,941.322	473,338.480	169,724.200	13.900	341.138	10,263.504	0.300	NR	23,259.800
Saluda	355.870	NR	NR	NR	NR	NR	355.870	NR	NR
Spartanburg	27,734.856	13,852.416	NR	35.136	120.252	NR	100.124	NR	13,626.928
Sumter	787.343	NR	NR	NR	200.493	NR	586.850	NR	NR
Union	318,082.246	316,309.036	NR	NR	8.750	516.200	NR	NR	1,248.260
Williamsburg	4.300	NR	NR	NR	NR	NR	4.300	NR	NR
York	998,316.773	932,089.000	37,762.000	NR	123.091	22,809.904	2.450	NR	5,530.328
Grand Total:	**18,769,838.373**	**15,202,999.337**	**3,230,063.932**	**1,117.382**	**9,531.359**	**145,514.581**	**10,127.311**	**785.000**	**169,699.471**

NR = None Reported

Groundwater Use Summary Table (Figures in Millions of Gallons)

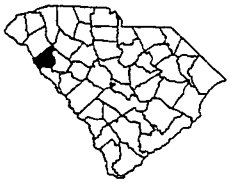
County	County Total	Hydroelectric	Thermoelectric	Aquaculture	Golf Course	Industry	Irrigation	Mining	Other	Water Supply
Abbeville	2.798	NR	NR	NR	NR	NR	NR	NR	NR	2.798
Aiken	6,872.790	NR	NR	NR	29.900	1,450.483	484.652	29.160	NR	4,878.595
Allendale	4,623.956	NR	NR	NR	NR	890.420	3,325.401	NR	NR	408.135
Bamberg	1,015.472	NR	NR	NR	NR	NR	512.490	NR	NR	502.982
Barnwell	1,219.787	NR	NR	NR	NR	NR	134.763	NR	NR	1,085.024
Beaufort	6,615.466	NR	NR	5.984	1,571.158	143.902	720.401	NR	41.430	4,132.591
Berkeley	1,306.157	1.181	12.035	2.961	11.648	1,100.794	0.240	2.654	NR	174.644
Calhoun	1,264.852	NR	NR	NR	38.200	138.448	853.542	NR	NR	234.662
Charleston	3,805.764	NR	NR	NR	766.056	33.722	12.852	NR	NR	2,993.134
Cherokee	1.326	NR	NR	NR	NR	NR	NR	NR	NR	NR
Chester	19.432	NR	NR	NR	18.000	1.432	NR	NR	NR	NR
Chesterfield	857.257	NR	NR	NR	NR	NR	238.797	NR	NR	618.460
Clarendon	936.408	NR	NR	NR	24.950	NR	182.026	NR	NR	729.432
Colleton	1,795.500	NR	1.828	NR	54.803	NR	929.700	NR	NR	809.169
Darlington	4,777.118	NR	363.509	NR	10.600	1,896.045	0.995	NR	NR	2,505.969
Dillon	1,775.004	NR	NR	33.700	NR	NR	34.900	NR	NR	1,706.404
Dorchester	1,552.463	NR	NR	NR	29.000	916.381	NR	NR	NR	607.082
Edgefield	96.850	NR	NR	NR	75.850	NR	21.000	NR	NR	NR
Fairfield	64.334	NR	NR	NR	NR	NR	NR	NR	NR	64.334
Florence	4,915.050	NR	NR	NR	137.536	798.964	105.208	NR	NR	3,873.342
Georgetown	1,039.081	NR	NR	NR	0.900	110.301	19.743	NR	NR	908.137
Greenville	89.513	NR	NR	NR	3.674	47.702	NR	NR	NR	38.137
Greenwood	35.307	NR	NR	NR	6.980	NR	1.200	NR	NR	27.127
Hampton	1,946.981	NR	NR	128.304	30.067	393.200	876.001	NR	NR	519.409
Horry	1,947.448	NR	NR	NR	607.426	165.340	179.111	NR	44.075	951.496
Jasper	706.566	NR	NR	NR	NR	NR	270.970	NR	NR	435.596
Kershaw	1,139.654	NR	NR	NR	47.561	417.738	NR	NR	NR	674.355
Lancaster	1.224	NR	NR	NR	1.224	NR	NR	NR	NR	NR
Lee	694.407	NR	NR	NR	NR	NR	98.439	NR	NR	595.968
Lexington	2,979.681	NR	NR	NR	36.780	414.221	1,622.548	464.850	NR	441.282
Marion	1,392.562	NR	NR	NR	7.277	NR	28.400	NR	NR	1,356.885
Marlboro	1,405.783	NR	NR	NR	NR	230.453	191.894	NR	NR	983.436
Newberry	91.656	NR	NR	NR	NR	NR	60.700	NR	NR	30.956
Oconee	58.070	NR	NR	NR	NR	NR	NR	NR	NR	58.070
Orangeburg	7,052.551	NR	1,661.441	NR	20.105	701.127	2,282.848	1,711.087	NR	675.943
Richland	1,344.667	NR	NR	67.300	22.239	677.192	7.088	235.872	NR	334.976
Saluda	2.397	NR	NR	NR	NR	NR	NR	NR	NR	2.397
Spartanburg	46.643	NR	NR	NR	5.686	15.113	NR	NR	NR	25.844
Sumter	6,870.329	NR	NR	NR	82.703	315.873	796.649	NR	NR	5,675.104
Union	2.530	NR	NR	NR	NR	2.530	NR	NR	NR	NR
Williamsburg	1,618.458	NR	NR	NR	NR	929.368	NR	NR	NR	689.090
York	89.341	NR	NR	NR	58.780	3.694	NR	13.000	NR	13.867
Grand Total:	**74,072.633**	**1.181**	**2,038.813**	**238.249**	**3,699.103**	**11,794.443**	**13,992.558**	**2,456.623**	**85.505**	**39,764.832**

NR = None Reported

Appendix B: Surface and Groundwater Use Summary by County in South Carolina, 2004

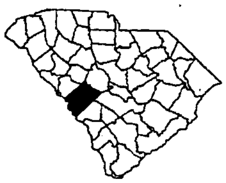
The following tables list reported surface water and groundwater withdrawals for the 2004 calendar year by county. Water usage data are shown by water use category and, in the case of power generation, includes surface water use that is typically considered non-consumptive. As presented throughout this report, all water use figures presented are in millions of gallons.

Abbeville County



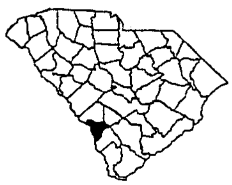
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	28619.000
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	NR
Water Supply:	2.798	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**2.798**	Water Supply:	1017.236
		Total:	**29636.236**

Aiken County



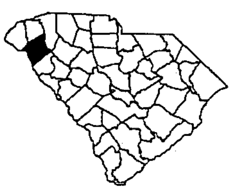
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	29.900	Golf Course:	179.523
Industrial:	1450.483	Hydroelectric:	NR
Irrigation:	484.652	Industrial:	19383.065
Mining:	29.160	Irrigation:	1020.000
Water Supply:	4878.595	Mining:	NR
Other:	NR	Thermal Power:	46744.000
Total:	**6872.790**	Water Supply:	2081.947
		Total:	**69408.535**

Allendale County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	890.420	Hydroelectric:	NR
Irrigation:	3325.401	Industrial:	NR
Mining:	NR	Irrigation:	432.68
Water Supply:	408.135	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**4623.956**	Water Supply:	NR
		Total:	**432.68**

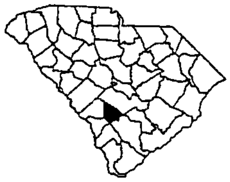
Anderson County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	107.177
Industrial:	NR	Hydroelectric:	274.193
Irrigation:	NR	Industrial:	57.300
Mining:	NR	Irrigation:	NR
Water Supply:	NR	Mining:	NR
Other:	NR	Thermal Power:	37417.276
Total:	**NR**	Water Supply:	7579.473
		Total:	**45435.419**

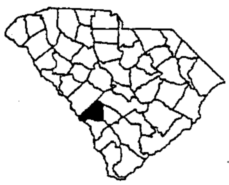
NR = None Reported

Bamberg County



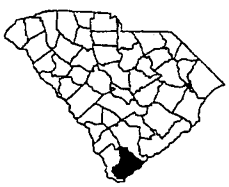
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	NR
Irrigation:	512.490	Industrial:	NR
Mining:	NR	Irrigation:	645.928
Water Supply:	502.982	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1015.472**	Water Supply:	NR
		Total:	**645.928**

Barnwell County



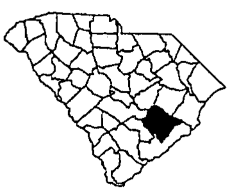
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	NR
Irrigation:	134.763	Industrial:	59.178
Mining:	NR	Irrigation:	77.915
Water Supply:	1085.024	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1219.787**	Water Supply:	NR
		Total:	**137.093**

Beaufort County



Groundwater Use		Surface Water Use	
Aquaculture:	5.984	Aquaculture:	78.234
Golf Course:	1571.158	Golf Course:	2150.114
Industrial:	143.902	Hydroelectric:	NR
Irrigation:	702.401	Industrial:	NR
Mining:	NR	Irrigation:	20.700
Water Supply:	4132.591	Mining:	NR
Other:	41.430	Thermal Power:	NR
Total:	**6615.166**	Water Supply:	7206.600
		Total:	**9455.648**

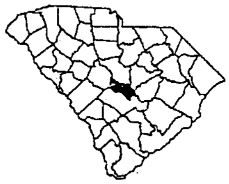
Berkeley County



Groundwater Use		Surface Water Use	
Aquaculture:	2.916	Aquaculture:	94.492
Golf Course:	11.648	Golf Course:	12.555
Industrial:	1100.794	Hydroelectric:	1213836.312
Irrigation:	0.240	Industrial:	3774.825
Mining:	02.654	Irrigation:	1093.194
Water Supply:	174.644	Mining:	NR
Hydroelectric:	1.181	Thermal Power:	167653.708
Thermal Power:	12.035	Water Supply:	5107.400
Total:	**1306.157**	**Total:**	**1391572.486**

NR = None Reported

Calhoun County

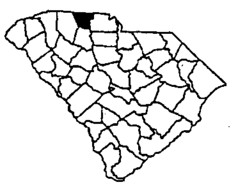


Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	38.200	Golf Course:	48.800
Industrial:	138.448	Hydroelectric:	NR
Irrigation:	853.542	Industrial:	28274.894
Mining:	NR	Irrigation:	141.543
Water Supply:	234.662	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1264.852**	Water Supply:	NR
		Total:	**28465.237**

Charleston County

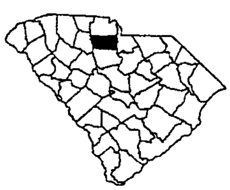
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	895.620
Golf Course:	766.056	Golf Course:	226.615
Industrial:	33.722	Hydroelectric:	NR
Irrigation:	12.852	Industrial:	9624.900
Mining:	NR	Irrigation:	35.491
Water Supply:	2993.134	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**3805.764**	Water Supply:	18748.790
		Total:	**29531.416**

Cherokee County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	455113.000
Irrigation:	NR	Industrial:	483.126
Mining:	NR	Irrigation:	NR
Water Supply:	NR	Mining:	NR
Thermal Power	1.326	Thermal Power:	NR
Total:	**1.326**	Water Supply:	3536.200
		Total:	**459132.326**

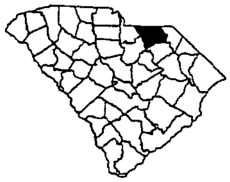
Chester County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	18.000	Golf Course:	14.000
Industrial:	1.432	Hydroelectric:	2171229.000
Irrigation:	NR	Industrial:	91.173
Mining:	NR	Irrigation:	NR
Water Supply:	NR	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	19.432	Water Supply:	1097.200
		Total:	**2172461.373**

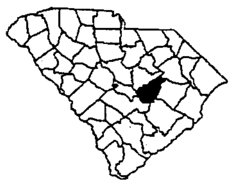
NR = None Reported

Chesterfield County



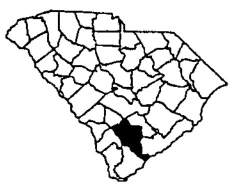
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	222.230
Industrial:	NR	Hydroelectric:	NR
Irrigation:	238.797	Industrial:	NR
Mining:	NR	Irrigation:	NR
Water Supply:	618..460	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	857.257	Water Supply:	1028.890
		Total:	**1251.120**

Clarendon County



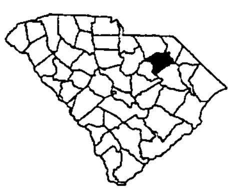
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	24.950	Golf Course:	30.820
Industrial:	NR	Hydroelectric:	NR
Irrigation:	182.026	Industrial:	NR
Mining:	NR	Irrigation:	152.086
Water Supply:	729.432	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	936.408	Water Supply:	NR
		Total:	182.906

Colleton County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	54.803	Golf Course:	1.085
Industrial:	NR	Hydroelectric:	NR
Irrigation:	929.700	Industrial:	NR
Mining:	NR	Irrigation:	265.000
Water Supply:	809.169	Mining:	1.685
Thermal Power	1.828	Thermal Power:	1616.455
Other:	NR	Water Supply:	NR
Total:	1795.500	**Total:**	**1884.225**

Darlington County



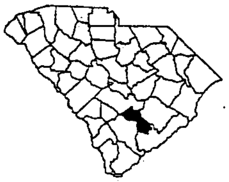
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	10.600	Golf Course:	95.849
Industrial:	1896.045	Hydroelectric:	NR
Irrigation:	0.995	Industrial:	7768.653
Mining:	NR	Irrigation:	158.163
Nuclear Power:	363.509	Mining:	NR
Water Supply:	2505.969	Nuclear Power:	285140.000
Other:	0	Water Supply:	NR
Total:	**4777.118**	**Total:**	**293162.665**

NR = None Reported

Dillon County

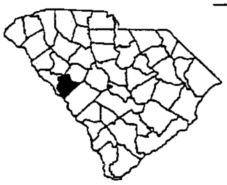
Groundwater Use		Surface Water Use	
Aquaculture:	33.700	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	NR
Irrigation:	34.900	Industrial:	NR
Mining:	NR	Irrigation:	NR
Water Supply:	1706.404	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1775.004**	Water Supply:	NR
		Total:	**NR**

Dorchester County



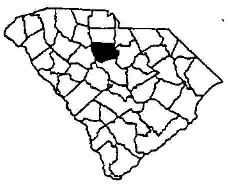
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	29.000	Golf Course:	NR
Industrial:	916.381	Hydroelectric:	NR
Irrigation:	NR	Industrial:	174.455
Mining:	NR	Irrigation:	NR
Water Supply:	607.082	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1552.463**	Water Supply:	NR
		Total:	**174.455**

Edgefield County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	75.850	Golf Course:	43.500
Industrial:	NR	Hydroelectric:	999809.310
Irrigation:	21.000	Industrial:	NR
Mining:	NR	Irrigation:	506.840
Water Supply:	NR	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**96.850**	Water Supply:	1545.994
		Total:	**1001905.644**

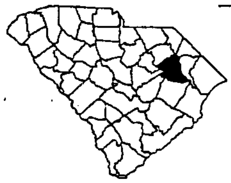
Fairfield County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	3025896.060
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	NR
Water Supply:	64.334	Mining:	NR
Other:	NR	Nuclear Power:	246543.778
Total:	64.334	Water Supply:	795.788
		Total:	**3273235.626**

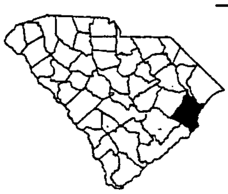
NR = None Reported

Florence County



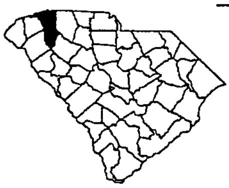
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	137.536	Golf Course:	32.721
Industrial:	798.964	Hydroelectric:	NR
Irrigation:	105.208	Industrial:	7202.600
Mining:	NR	Irrigation:	12.00
Water Supply:	3873.342	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**4915.050**	Water Supply:	1589.940
		Total:	**8837.261**

Georgetown County



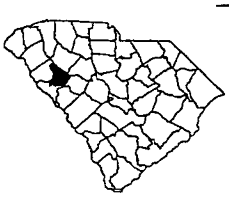
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	0.900	Golf Course:	915.344
Industrial:	110.301	Hydroelectric:	NR
Irrigation:	19.743	Industrial:	11288.732
Mining:	NR	Irrigation:	1670.289
Water Supply:	908.137	Mining:	NR
Other:	NR	Thermal Power:	4687.31
Total:	**1039.081**	Water Supply:	2220.469
		Total:	**20782.144**

Greenville County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	3.674	Golf Course:	255.429
Industrial:	47.702	Hydroelectric:	140851.000
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	24.750
Water Supply:	38.137	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**89.513**	Water Supply:	23801.700
		Total:	**164932.879**

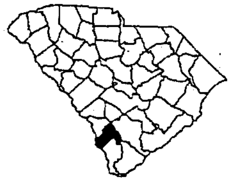
Greenwood County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	6.980	Golf Course:	47.645
Industrial:	NR	Hydroelectric:	317017.000
Irrigation:	1.200	Industrial:	49.850
Mining:	NR	Irrigation:	NR
Water Supply:	27.127	Mining:	NR
Other:	NR	Thermal Power:	116.137
Total:	**35.307**	Water Supply:	4900.928
		Total:	**3221131.560**

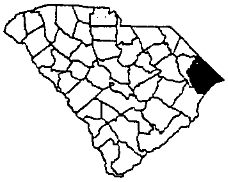
NR = None Reported

Hampton County



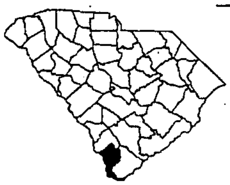
Groundwater Use		Surface Water Use	
Aquaculture:	128.304	Aquaculture:	NR
Golf Course:	30.067	Golf Course:	NR
Industrial:	383.200	Hydroelectric:	NR
Irrigation:	876.001	Industrial:	NR
Mining:	NR	Irrigation:	16.000
Water Supply:	519.409	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1946.981**	Water Supply:	NR
		Total:	**16.000**

Horry County



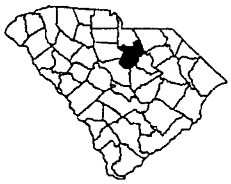
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	607.426	Golf Course:	3296.873
Industrial:	165.340	Hydroelectric:	NR
Irrigation:	179.111	Industrial:	2.749
Mining:	NR	Irrigation:	283.847
Water Supply:	951.496	Mining:	219.360
Other:	44.075	Thermal Power:	38448.870
Total:	**1947.448**	Water Supply:	14045.400
		Total:	**56297.009**

Jasper County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	NR
Irrigation:	270.970	Industrial:	NR
Mining:	NR	Irrigation:	NR
Water Supply:	435.596	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**706.566**	Water Supply:	NR
		Total:	**NR**

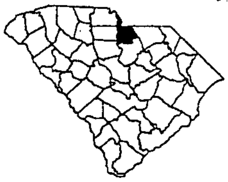
Kershaw County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	47.561	Golf Course:	57.470
Industrial:	417.738	Hydroelectric:	1207267.000
Irrigation:	NR	Industrial:	923.742
Mining:	NR	Irrigation:	NR
Water Supply:	674.355	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1139.654**	Water Supply:	1818.655
		Total:	**1210066.867**

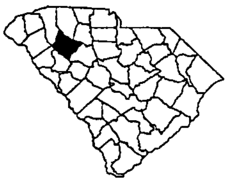
NR = None Reported

Lancaster County



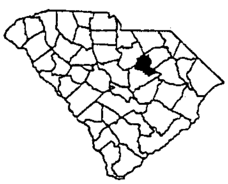
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	1.244	Golf Course:	54.612
Industrial:	NR	Hydroelectric:	1093794.000
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	NR
Water Supply:	NR	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1.244**	Water Supply:	1609.625
		Total:	**1102559.265**

Laurens County



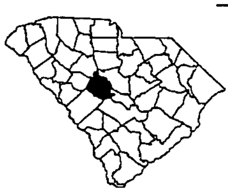
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	54.612
Industrial:	NR	Hydroelectric:	149.400
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	NR
Water Supply:	NR	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**NR**	Water Supply:	1609.625
		Total:	**1813.637**

Lee County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	NR
Irrigation:	98.439	Industrial:	NR
Mining:	NR	Irrigation:	8.000
Water Supply:	595.968	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**694.407**	Water Supply:	NR
		Total:	**8.000**

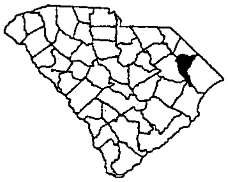
Lexington County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	36.780	Golf Course:	204.818
Industrial:	414.221	Hydroelectric:	201784.930
Irrigation:	1622.548	Industrial:	10197.980
Mining:	464.850	Irrigation:	496.570
Water Supply:	441.282	Mining:	563.955
Other:	NR	Thermal Power:	46310.870
Total:	**2979.681**	Water Supply:	5287.679
		Total:	**264846.802**

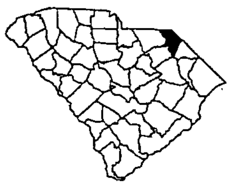
NR = None Reported

Marion County



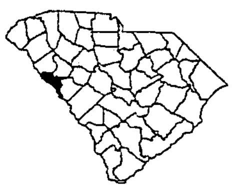
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	7.277	Golf Course:	26.158
Industrial:	NR	Hydroelectric:	NR
Irrigation:	28.400	Industrial:	NR
Mining:	NR	Irrigation:	22.000
Water Supply:	1356.885	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1392.562**	Water Supply:	NR
		Total:	**48.158**

Marlboro County



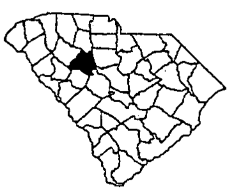
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	230.453	Hydroelectric:	NR
Irrigation:	191.894	Industrial:	7743.082
Mining:	NR	Irrigation:	88.190
Water Supply:	983.436	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**1405.783**	Water Supply:	NR
		Total::	**7831.272**

McCormick County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	39.568
Industrial:	NR	Hydroelectric:	NR
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	NR
Water Supply:	NR	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**NR**	Water Supply:	421.956
		Total:	**461.524**

Newberry County



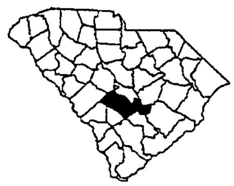
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	10.000
Industrial:	NR	Hydroelectric:	NR
Irrigation:	60.700	Industrial:	NR
Mining:	NR	Irrigation:	125.700
Water Supply:	30.956	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**91.656**	Water Supply:	2270.162
		Total:	**2405.862**

NR = None Reported

Oconee County

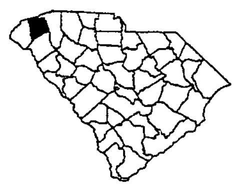
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	103.235
Industrial:	NR	Hydroelectric:	12.200
Irrigation:	NR	Industrial:	674.440
Mining:	NR	Irrigation:	282.85
Water Supply:	58.070	Mining:	NR
Other:	NR	Nuclear Power:	2147899.000
Total:	**58.070**	Water Supply:	3580.243
		Total:	**2152551.968**

Orangeburg County



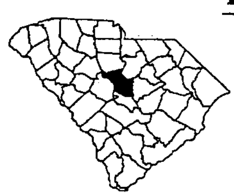
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	20.105	Golf Course:	93.528
Industrial:	701.127	Hydroelectric:	NR
Irrigation:	2282.848	Industrial:	154.767
Mining:	1711.087	Irrigation:	1497.681
Thermal Power:	1661.441	Mining:	NR
Water Supply:	675.943	Thermal Power:	0.328
Other:	NR	Water Supply:	3007.440
Total:	**7052.551**	**Total:**	**4753.744**

Pickens County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	406.088
Industrial:	NR	Hydroelectric:	2611758.000
Irrigation:	NR	Industrial:	3044.110
Mining:	NR	Irrigation:	NR
Water Supply:	NR	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**NR**	Water Supply:	3982.405
		Total:	**2619190.603**

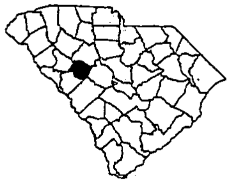
Richland County



Groundwater Use		Surface Water Use	
Aquaculture:	67.300	Aquaculture:	13.900
Golf Course:	22.239	Golf Course:	341.138
Industrial:	677.192	Hydroelectric:	473338.480
Irrigation:	7.088	Industrial:	10263.504
Mining:	235.872	Irrigation:	0.300
Water Supply:	334.976	Mining:	NR
Other:	NR	Thermal Power:	169724.200
Total:	**1344.667**	Water Supply:	23259.800
		Total:	**676941.322**

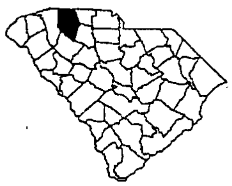
NR = None Reported

Saluda County



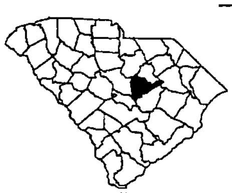
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	NR	Hydroelectric:	NR
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	355.870
Water Supply:	2.397	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**2.397**	Water Supply:	NR
		Total:	355.870

Spartanburg County



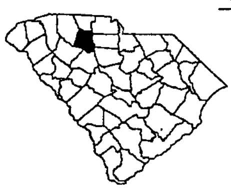
Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	35.136
Golf Course:	5.686	Golf Course:	120.252
Industrial:	15.113	Hydroelectric:	13852.416
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	100.124
Water Supply:	25.844	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**46.643**	Water Supply:	13626.928
		Other:	**27734.856**

Sumter County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	82.703	Golf Course:	200.496
Industrial:	315.873	Hydroelectric:	NR
Irrigation:	796.649	Industrial:	NR
Mining:	NR	Irrigation:	586.850
Water Supply:	5675.104	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**6870.329**	Water Supply:	NR
		Total:	**787.343**

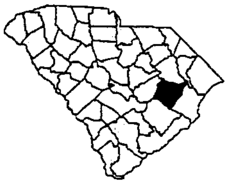
Union County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	8.750
Industrial:	2.530	Hydroelectric:	316309.036
Irrigation:	NR	Industrial:	516.200
Mining:	NR	Irrigation:	NR
Water Supply:	NR	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	**NR**	Water Supply:	1248.260
		Total:	**318082.246**

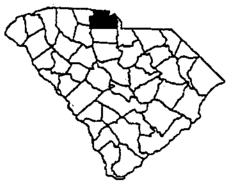
NR = None Reported

Williamsburg County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	NR	Golf Course:	NR
Industrial:	929.368	Hydroelectric:	NR
Irrigation:	NR	Industrial:	NR
Mining:	NR	Irrigation:	4.300
Water Supply:	689.090	Mining:	NR
Other:	NR	Thermal Power:	NR
Total:	1618.458	Water Supply:	NR
		Total:	**4.300**

York County



Groundwater Use		Surface Water Use	
Aquaculture:	NR	Aquaculture:	NR
Golf Course:	58.780	Golf Course:	123.091
Industrial:	3.694	Hydroelectric:	932089.000
Irrigation:	NR	Industrial:	22809.904
Mining:	13.00	Irrigation:	2.450
Water Supply:	13.867	Mining:	NR
Other:	NR	Nuclear Power:	37762.000
Total:	**89.341**	Water Supply:	5530.328
		Total:	**998316.773**

NR = None Reported

Appendix C: Population by County

Population and Projections by County

County	2000	2005	2010	2015	2020	2025
Abbeville	26,167	26,740	27,610	28,480	29,350	30,210
Aiken	142,552	153,900	163,950	174,000	184,060	194,110
Allendale	11,211	11,820	11,960	12,110	12,260	12,400
Anderson	165,740	172,120	180,280	188,440	196,590	204,750
Bamberg	16,658	16,130	15,740	15,340	14,950	14,560
Barnwell	23,478	24,350	25,390	26,440	27,490	28,540
Beaufort	120,937	132,760	146,440	160,110	173,790	187,460
Berkeley	142,651	156,610	167,520	178,420	189,330	200,230
Calhoun	15,185	15,570	16,350	17,130	17,910	18,690
Charleston	309,969	320,080	328,570	337,070	345,560	354,060
Cherokee	52,537	54,770	57,860	60,960	64,050	67,140
Chester	34,068	34,630	35,500	36,370	37,240	38,110
Chesterfield	42,768	43,100	44,310	45,520	46,730	47,940
Clarendon	32,502	33,300	34,650	35,990	37,330	38,680
Colleton	38,264	39,910	41,590	43,260	44,940	46,610
Darlington	67,394	67,910	69,260	70,610	71,960	73,310
Dillon	30,722	30,220	30,280	30,340	30,400	30,460
Dorchester	96,413	106,590	115,430	124,280	133,130	141,980
Edgefield	24,595	25,490	27,400	29,320	31,230	33,150
Fairfield	23,454	24,260	25,010	25,770	26,520	27,280
Florence	125,761	130,140	134,510	138,870	143,230	147,590
Georgetown	55,797	58,300	61,770	65,240	68,710	72,190
Greenville	379,616	397,580	421,210	444,840	468,470	492,100
Greenwood	66,271	68,590	71,170	73,750	76,330	78,910
Hampton	21,386	21,810	22,690	23,570	24,450	25,330
Horry	196,629	215,850	239,020	262,190	285,360	308,530
Jasper	20,678	21,390	23,000	24,610	26,220	27,830
Kershaw	52,647	55,300	58,880	62,460	66,040	69,620
Lancaster	61,351	61,940	63,940	65,950	67,950	69,950
Laurens	69,567	72,800	77,190	81,580	85,960	90,350
Lee	20,119	20,540	21,010	21,480	21,960	22,430
Lexington	216,014	233,060	252,580	272,090	291,600	311,120
McCormick	9,958	10,670	11,290	11,910	12,530	13,150
Marion	35,466	35,930	36,390	36,840	37,300	37,760
Marlboro	28,818	28,100	27,460	26,820	26,170	25,530
Newberry	36,108	37,270	38,530	39,790	41,050	42,320
Oconee	66,215	70,910	75,470	80,040	84,600	89,160
Orangeburg	91,582	94,260	96,890	99,510	102,140	104,770
Pickens	110,757	119,040	127,110	135,190	143,260	151,330
Richland	320,677	331,810	345,660	359,520	373,370	387,220
Saluda	19,181	19,400	20,090	20,790	21,480	22,180
Spartanburg	253,791	267,390	280,590	293,790	306,990	320,190
Sumter	104,646	112,030	116,100	120,180	124,260	128,330
Union	29,881	29,720	29,480	29,240	29,010	28,770
Williamsburg	37,217	36,960	36,820	36,680	36,540	36,400
York	164,614	177,420	192,290	207,160	222,030	236,900
South Carolina:	4,012,012	4,218,460	4,446,240	4,674,050	4,901,810	5,129,630

Appendix D: Glossary

Aquifer – A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquaculture water use (water use category) – Water used for raising, farming and/or harvesting of organisms that live in water, such as fish, shrimp and other shellfish and vegetal matter (seaweed).

Consumptive water use – The amount of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.

Effluent (wastewater) – Water conveyed out of a wastewater treatment facility or other works used for the purpose of treating, stabilizing, or holding wastewater.

Evapotranspiration – Collective term, including water discharged to the atmosphere as a result of evaporation from the soil and surface-water bodies and plant transpiration.

Fall Line –

Farm – Any operation from which $1000.00 or more of agricultural products were sold or normally would be sold during the year.

Golf course irrigation (water use category) – Water applied to maintain golf course turf, including tee boxes, fairways, putting greens, associated practice areas and periphery aesthetic landscaping.

Groundwater – Generally, all subsurface water as distinct from surface water; specifically, that part of the subsurface water in the saturated zone.

Hydroelectric water use (water use category) – Water used in generating electricity where turbine generators are driven by falling water.

Industrial water use (water use category) – Water used for commercial and industrial purposes, including fabrication, processing, washing, in-plant conveyance and cooling.

Irrigated acreage – Acreage capable of being irrigated, with regard to availability of water, suitable soils and topography of land.

Irrigation water use (water use category) – Water that is used for agricultural and landscaping purposes including turf farming and livestock management.

Mining water use (water use category) – Water that is used for in conjunction with surface or subsurface mining of minerals or natural materials

Other use (water use category) – Any use of surface water or groundwater not specifically identified in any of the other categories.

Reclaimed water – Wastewater treatment plant effluent that has been diverted, intercepted, or otherwise conveyed for use before it reaches a natural waterway or aquifer.

Surface water – Water flowing or stored on the earth's surface such as a stream, lake, or reservoir.

Thermoelectric water use (water use category) – Water used in generating electricity from fossil fuel (coal, oil, natural gas), geothermal, biomass, solid waste, or nuclear energy.

Water supply (water use category) – Water withdrawn by public and private water suppliers and conveyed to users or groups of users. Water suppliers provide water for a variety of uses including domestic, commercial, industrial and public water use.

Water usage rates – As utilized in this report, measurements to quantitatively represent withdrawal over time; as in gallons per minute (gpm), gallons per day (gpd) and gallons per year (gpy).

Water use – Generally, water that is used for a specific purpose (i.e., domestic use, industrial, etc.). Broadly, human interaction with and influence on the hydrologic cycle, and includes water withdrawal, distribution, consumptive use, wastewater collection and return flow.

Withdrawal – The removal of surface water or groundwater from the natural hydrological system for use, including, but not limited to, water supply, industrial use, commercial use, domestic use, irrigation, livestock, power generation

Sec. 2.3 Ref 29

State of South Carolina

Integrated Report for 2006

Part II: *Section 305(b) Assessment and Reporting*

March 29, 2006

DHEC

PROMOTE PROTECT PROSPER

South Carolina Department of Health and Environmental Control

PREFACE

The South Carolina Department of Health and Environmental Control (SCDHEC) prepared this report as a requirement of Section 305(b) of Public Law 100-4, last reauthorized and commonly known as The Clean Water Act (CWA) of 1987, and as a public information document. The report presents a general assessment of water quality conditions and water pollution control programs in South Carolina. SCDHEC has published Watershed Water Quality Management Assessments (WWQA), that contain information pertaining to the specific watersheds and give a more complete picture of the waters referenced in this document. While the title page states that this is an integrated report, Section 303(d) of the CWA requirements are submitted separately as a companion document.

The determinations of surface water quality were based on data collected by SCDHEC at ambient water quality monitoring stations, point source permit required monitoring and evaluation of nonpoint source (NPS) data. Other information in this report was obtained from SCDHEC programs associated with water quality monitoring and water pollution control.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Clean Water Act (CWA) states "it is the national goal that wherever attainable, an interim goal of water quality that provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water shall be achieved by July 1, 1983."

The State of South Carolina has promulgated S.C. Regulation 61-68, *Water Classifications and Standards* and S.C. Regulation 61-69, *Classified Waters* that establish specific standards and general rules to protect and maintain these uses and designate classified uses for each waterbody. It is the intent and purpose of the regulations that waters that meet standards shall be maintained and waters that do not meet standards shall be improved.

The statewide Probability-Based, or random sampling, component of the ambient monitoring program is designed to make statewide estimates of water quality. The data derived from those monitoring activities is used to develop the stream, lake/reservoir, and estuarine summary information presented in this report. A probability-based monitoring design is a type of a survey design in that the population of interest is sampled in a fashion that allows statements to be made about the whole population based on a subsample. The advantage of the probability-based sampling design is that statistically valid statements about water quality can be made about large areas based on a relatively small subsample.

Based on the modified USEPA National Hydrography Dataset (NHD) and the results of probability site selection validation, South Carolina has an estimated 20,954 miles of freshwater rivers and streams representing the stream sampling design frame, and 308,765 acres of lake and reservoir representing the lake/reservoir sampling design frame. Based on a hydrographic GIS cover developed jointly by SCDHEC and the South Carolina Department of Natural Resources and the results of probability site selection validation, South Carolina has an estimated 277 combined square miles of tide creek and open water habitat representing the estuarine sampling design frame.

Quality assured water quality data collected as part of the probability network from 2001 through 2004 provided the database for this assessment. Evaluation of these data determines if water quality in rivers, lakes, and estuaries is suitable to support State classified uses. The tables on the following page include the level of use support for the waters of South Carolina and the cause of nonattainment affecting the largest size in each waterbody type for aquatic life and primary contact recreation uses.

Aquatic Life Use Support

Waterbody Type	Fully Supported	Partially Supported	Not Supported	Predominant Cause
Rivers	65%	18%	17%	Macroinvertebrate Community
Lakes	84%	4%	11%	pH
Estuaries	78%	3%	19%	Turbidity

Recreational Use Support

Waterbody Type	Fully Supported	Partially Supported	Not Supported	Predominant Cause
Rivers	47%	22%	31%	Fecal Coliform
Lakes	99%	<1%	0%	Fecal Coliform
Estuaries	99%	0%	<1%	Fecal Coliform

BACKGROUND

1. Resource Overview

The following table gives a representation of state population and geographical information.

Table 1. Atlas

Topic	Value
State Population	3,602,900
State Surface Area (square miles)	30,203
Total miles of rivers and streams	29,794
- Border Miles	408
- Border Rivers: Chattooga, Tugaloo, Savannah, Catawba	
- Border Lakes: Hartwell, Thurmond, Russell, Wylie	
Number of lakes/reservoirs/ponds	
- 10 - 1000 acres (total acreage of 60,335)	1,598
- >1000 acres (total acreage of 461,402)	19
Estuarine waters (square miles)	401
Total miles of Ocean Coast	190
Freshwater wetlands (acreage)	4,146,510
Tidal wetlands (acreage)	512,490

2. Total Waters

The United States Environmental Protection Agency (USEPA) has developed a system to determine estimates of total river miles and total lake acres for the states to use in reporting for §305(b) reports. This system is based on the Digital Line Graph (DLG) database and the USEPA National Hydrography Dataset (NHD), that are in turn based on the United States Geological Survey (USGS) 1:100,000 scale topographic maps. The original DLG database was missing several lakes of relatively recent construction as well as a significant number of streams. Many of these missing features have been added by SCDHEC, with the cooperation and oversight of the USEPA. This revised system was utilized in this §305(b) report to estimate the sizes of the different use support categories and cause sizes for the Rivers and Streams, and Lakes summary statistics. Other base maps were used to estimate sizes for the Clean Lakes Program, Estuaries, and Shellfish Restrictions/Closures. These alternative databases are identified in the appropriate sections.

3. Water Pollution Control Program

A. Watershed Approach

SCDHEC conducts water quality assessment and protection on a watershed basis in order to promote a coordinated approach to river basin development and water quality maintenance or improvement, to better address congressional and legislative mandates, to better utilize current resources, and to better inform the public and regulated community of existing and future water quality issues. Watershed water quality management recognizes the interdependence of water quality and all the activities that occur in the associated drainage basin including: monitoring, assessment, problem identification and prioritization, water quality modeling, planning, permitting, and other activities. In the Watershed Water Quality Assessments (WWQA), these activities are integrated by basin leading to watershed management plans and implementation strategies and serve to appropriately refocus water quality protection efforts.

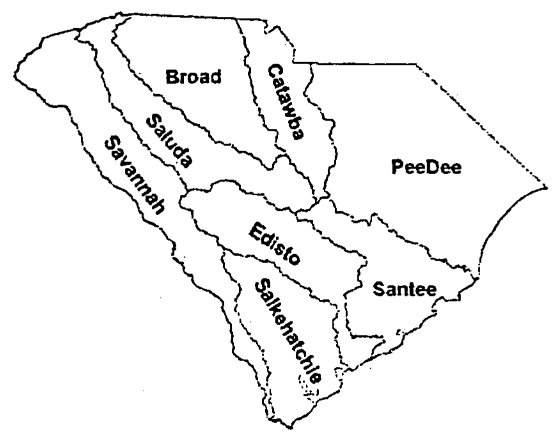


Figure 1. South Carolina Watershed Water Quality Management Basins

Watershed water quality management planning and strategy development provides SCDHEC with the tools and information necessary for program implementation. The planning process and the resulting strategy provide a structured and predictable schedule for carrying out program elements to ensure the protection of the State's water resources. While an important aspect of the program is water quality problem identification and problem solving, the emphasis of the program is on problem prevention.

SCDHEC has divided the state into eight major drainage basins along USGS hydrologic units (Figure 1), encompassing approximately 280 Natural Resources Conservation Service (NRCS) watersheds. These watersheds serve as the hydrologic boundaries that guide SCDHEC water quality activities. The majority of water quality activities in these watersheds are based on a five-year rotation.

For most activities the Savannah and Salkehatchie basins are addressed in the same year, as are the Saluda and Edisto basins, and the Catawba and Santee basins. Five years are required to assess all basins in the State, and National Pollutant Discharge Elimination System (NPDES) permits have a five-year lifespan. Each year SCDHEC revises the assessment for the targeted basin(s). Planning on a watershed basis is consistent with basic ecological principles of watershed management. It allows the coordination of implementation activities so that all actual and potential impacts on water quality can be evaluated. Both point source and nonpoint source impacts can be evaluated when making water quality protection decisions. Problem areas in a particular drainage basin can be identified and existing and potential contributors can be examined. Subsequently, waste assimilative capacities can be determined and allocated in a more equitable fashion.

Proposed permit issuances within a watershed are consolidated and presented to the public in groups rather than one at a time. By issuing all the NPDES permits during the same period, SCDHEC will be able to realize a resource savings and the public will realize an information advantage since all of the permitting activity for a specific area will occur in a specified period of time when public notices and public meetings and hearings will be conducted.

The watershed management process also focuses resources. Limited resources require targeting work efforts in order to maximize useful results. Focusing on specific basins each year allows SCDHEC to coordinate staff activities to make efficient use of available resources. While the statewide ambient monitoring network is maintained, the monitoring strategy has been revised so the district monitoring staff concentrate on the targeted basin(s). The monitoring activities support the development of wasteload allocations and total maximum daily loads (TMDLs). Developing wasteload allocations and TMDLs on a watershed basis allows for an equitable assessment of all actual and potential impacts on the water quality from both point sources and nonpoint sources. Focusing decision making efforts in a single watershed will highlight the need to examine water quality standards and use designation for the appropriate waterbodies. An examination of the water quality and use designations may point to the need for site specific standards or stream classification changes.

In preparing the eight watershed assessments and in updating and revising each one on a five-year rotation, SCDHEC will be able to respond more efficiently, and in a timely manner, to federal requirements. More importantly, SCDHEC will be better able to utilize available resources, coordinate water quality improvement efforts, and protect water quality in South Carolina. These watershed assessments serve as a starting point to fulfill a number of EPA reporting requirements. EPA requires various reporting activities under §303(d), §305(b), §314, and §319 of the Clean Water Act (CWA).

B. Water Quality Standards and Classifications

S.C. Regulations 61-68, *Water Classifications and Standards* and S.C. Regulation 61-69, *Classified Waters* were promulgated by SCDHEC pursuant to the South Carolina Pollution Control Act (48-1-10, *et seq*, S.C. Code of Laws, 1976).

The water quality standards regulation contains provisions that provide for the protection and maintenance of the existing and classified uses of the waters of the State. The water quality standards include general rules and specific water quality criteria, both narrative and numeric, to protect those classified and existing uses as well as antidegradation rules to protect the public health and welfare and maintain and enhance water quality.

The water quality standards also serve as the basis for decisions in the other water quality program areas. NPDES permit limitations for waste discharges are determined according to the classification and standards of the receiving water. The standards and classifications also affect the control of toxic substances, thermal discharges, stormwater discharges, dredge and fill activities, and other water related activities. SCDHEC implements the antidegradation rules through its regulatory programs.

S.C. Regulation 61-69 alphabetically lists the waterbodies in South Carolina that have been specifically classified by name, gives the classification, describes the boundaries of the use classification, the county of location, and any applicable site-specific standards.

Revisions to water quality standards and any reclassification of waters of the State require a public hearing process, approval by the Board of SCDHEC, approval by the General Assembly, and publication in the State Register. S.C. Regulation 61-68 was last amended on June 25, 2004 and R. 61-69 was last amended May 28, 2004.

Surface Water Classes - Freshwaters

Table 2. Freshwater Classifications and Descriptions

Freshwaters	**Description**
Outstanding National Resource Waters	Exceptional national recreational and/or ecological resource.
Outstanding Resource Waters	Exceptional recreational and/or ecological resource and suitable for drinking water source with minimal treatment.
Trout Waters - (3 types) Natural Put, Grow and Take	Suitable for supporting reproducing and/or stocked trout populations and cold water indigenous aquatic community and the survival and propagation of aquatic life. Primary and secondary recreational contact including fishing and as drinking water source. Suitable for industrial and agricultural uses.
Put and Take	(See Freshwater Description)
Freshwater	Suitable for the survival and propagation of aquatic life; fishing and primary and secondary recreational contact and as drinking water source. Suitable also for industrial and agricultural uses.

Surface Water Classes - Saltwaters

Table 3. Saltwater Classifications and Descriptions

Saltwaters	**Description**
Outstanding National Resource Waters	Exceptional national recreational and/or ecological resource.
Outstanding Resource Waters	Exceptional recreational and/or ecological resource.
Shellfish Harvesting Waters	Suitable for survival and propagation of aquatic life; primary and secondary contact recreation. Suitable for harvesting of shellfish, crabbing, and fishing for market purposes and/or for human consumption.
Class SA	Suitable for survival and propagation of aquatic life; primary and secondary contact recreation; crabbing and fishing for market purposes and/or human consumption.
Class SB	Suitable for survival and propagation of aquatic life; primary and secondary contact recreation; crabbing and fishing for market purposes and/or human consumption.

Groundwater Classes

Table 4. Groundwater Classifications and Descriptions

Groundwater Type	**Description**
Class GA	Vulnerable to contamination due to hydrological characteristics.
Class GB	Suitable as an underground source of drinking water. All groundwaters of the State unless otherwise classified.
Class GC	Not suitable for underground drinking water source.

The following table summarizes the uses of each of the surface water classifications. No degradation of existing uses is permitted regardless of classification and no degradation of natural conditions is allowed in Outstanding Resource Waters or Outstanding National Resource Waters.

Table 5. Summary of Supported Classified Uses for South Carolina

Uses	Description
Fish and wildlife	All classes
Domestic water supply	All freshwater classes
Primary contact recreation	All classes
Secondary contact recreation	All classes
Industrial	All freshwater classes
Agriculture	All freshwater classes
Navigation	All classes

Reclassifications and Site-Specific Criteria

SCDHEC is presently reclassifying several waterbodies to recognize their best and/or existing uses. Most reclassifications are initiated after receiving a written request from an individual, special interest group, or organization. SCDHEC also proposes waters for reclassification where existing water quality is better than required to protect the classified uses or if there is an existing use not recognized by the present classification. Also added to the classification system is the designation of No Discharge Zones (NDZs). NDZs relate specifically to the discharge of treated waste from Marine Sanitation Devices (MSDs) and are authorized pursuant to §312 of the Federal Clean Water Act. Waters of the State designated as NDZ prohibit any discharge from MSDs into these waters and require that the MSDs be pumped out at an appropriate facility. SCDHEC has designated seven waterbodies as NDZs and is currently considering designating other coastal waters as NDZs. SCDHEC is in the process of reclassfying several waterbodies within the boundary of the Congaree National Park to Outstanding Resource Waters (ORWs) and a portion of Cedar Creek which is contained within the boundary of the park to an Outstanding National Resource Water (ONRW). Cedar Creek will be the State's first ONRW.

Site-specific criteria applicable to a single waterbody is also incorporated into R.61-69. SCDHEC has adopted a dissolved oxygen (DO) standard for the lower Saluda River which is classed as a Trout- Put, Grow, and Take waterbody. The revised DO standard better protects the trout resources of this waterbody.

Water reclassifications, NDZ designations, and site-specific criteria are amendments to state regulation and, as such, are not effective until approved by the South Carolina General Assembly and published in the State Register.

C. Point Source Program - Municipal Facilities

The EPA has delegated the authority to SCDHEC for administering the National Pollutant Discharge Elimination System (NPDES) Program within the State. As a functional part of this NPDES program, all municipal and private domestic wastewater treatment works that discharge to surface water in South Carolina are monitored by the Bureau of Water (BOW). Permit effluent limits of each surface water discharge are derived using water quality models and other tools.

Loan Program

Beginning with fiscal year 1989, the state established a State Revolving Loan Fund (SRF) program, with EPA providing annual capitalization grants to seed the SRF program. This program is a low-interest, revolving loan program established pursuant to Public Law (P.L. 100-4), Water Quality Act of 1987. The State, in accordance with EPA requirements, has established a project priority rating system. The State's priority list ranks each wastewater treatment project need as well as other projects based on water quality and sludge disposal needs.

Projects receiving SRF loans since fiscal year 1989 have totaled over $425,753,822 million through June 30, 2003.

The result of the newly constructed or upgraded treatment works using these funding sources has been improved wastewater treatment resulting in favorable water quality benefits. This construction has eliminated poorly treated effluent from many streams and provided improvements to facility capacity. The improvement of water quality has been seen by routine monthly discharge monitoring reports (DMRs) submitted by each treatment plant owner to SCDHEC. As an overall result, the SRF helps to improve and maintain water quality.

Pretreatment and Toxicity Program

The implementation of SCDHEC pretreatment program continues. The State approves implementation pretreatment programs for Publicly Owned Treatment Works (POTWs). The pretreatment programs are typically updated upon permit renewal or when the facility expands the discharge. An assessment of program requirements is conducted to insure that the latest pretreatment regulation requirements are in place. There has been a direct benefit to in-stream water quality demonstrated from many, if not all, of the implemented pretreatment programs. With the implementation of approved programs many industries previously discharging untreated wastewater to a POTW must pretreat their discharges. This has resulted in a significant reduction in the amounts of materials (contaminants) that POTWs are now receiving from the industries. This allows the POTW to adequately treat all wastewater prior to discharging to a State stream, resulting in the ability to better maintain the existing stream water quality standards.

Since FY 89 appropriate majors, significant minors (minors with pretreatment programs) and selected other permits have been issued or reissued with effluent toxicity monitoring requirements to be performed as appropriate based on the information related to the discharge characteristics. Depending on the in-stream waste concentration and presence or absence of a diffuser, there can be either an acute test, chronic test, or both required. The toxicity testing typically will be multi concentration tests that will allow an assessment of the potential toxicity of the effluent at varying concentrations.

Stormwater Controls

South Carolina has no known combined stormwater/sanitary sewer discharges associated with POTWs. Combined sewers are usually prohibited by local ordinance to preclude overloading treatment systems with stormwater. Stormwater runoff control on POTW sites is mandatory in some areas of the State.

SCDHEC is implementing a state stormwater permitting program policy in support of EPA guidelines of requirements required by the 1987 amendments to the Clean Water Act. See the Section on Stormwater Permits under "D. Point Source Program - Industrial and Agricultural Facilities."

Land Application of Treated Waste

SCDHEC issues State discharge permits to facilities that discharge directly to land as spray irrigation. This involves the application of, at least, secondary-treated wastewater to land surfaces with the applied effluent being further treated as it percolates through the plant-soil matrix. A portion of the applied effluent percolates to groundwater, some is absorbed by vegetation, and some evaporates to the atmosphere.

The primary objectives of this program are:

(a) Treatment and disposal of applied wastewater without exceeding ground-water quality standards as specified in S.C. Regulation 61-68 *Water Classifications and Standards*.

(b) Economic return from use of treated effluent, water and nutrients, to produce marketable crops.

(c) Water conservation by replacing potable water with treated effluent.

(d) Preservation of open space through vegetation.

As a permit requirement, a program for monitoring the quality of groundwater is typically established and implemented. Proper placement of ground-water monitoring wells will provide a check on the effectiveness of the wastewater renovation and will serve as an early warning system for ground-water quality protection for nearby ground-water users. The direction of groundwater flow determines the placement of ground-water monitoring wells.

Strategies to Improve the Municipal Permitting Program

SCDHEC district personnel inspect the operation and maintenance programs of POTWs on a routine basis. Deficiencies noted during inspections are conveyed to the POTW and may require SCDHEC to take formal enforcement action. Operational advice is provided on a limited basis by SCDHEC staff. The South Carolina Environmental Training Center at Sumter Area Technical College also provides training for treatment plant operators.

SCDHEC has developed sludge management regulations and guidance for permittees. All NPDES permits issued or reissued have sludge disposal requirements. The permit typically requires the sludge generator to monitor the content of its sludge and to dispose of it in an environmentally acceptable manner. The permit authorizes specific methods (e.g., land application, land filling, etc.) and procedures to be fully implemented.

D. Point Source Program - Industrial and Agricultural Facilities

Industrial Facilities

SCDHEC reviews NPDES permit applications for new and existing facilities and determines whether treatment must be technology-based or based on water quality standards. The more stringent of these derived numbers are used as the applicable permit limits. Effluent guidelines, where promulgated by EPA, are used to determine technology-based limits. If EPA effluent guidelines have not been developed, best professional judgment of technology-based limits is used. Water quality limits are developed using computerized water quality modeling procedures, which result in wasteload allocations for constituents affecting in-stream oxygen levels. South Carolina water quality standards and/or biological monitoring are used to determine limits for potentially toxic constituents. Where appropriate, permit limits are developed using a combination of water quality limitations for specific constituents, whole effluent toxicity limits, and in-stream biological monitoring to insure no adverse impacts from industrial point source dischargers.

Agricultural Facilities

Unregulated wastewater discharges from agricultural animal facilities or fruit and vegetable processing facilities may affect water quality. Additionally, South Carolina does not allow surface water discharges from these facilities under any circumstances. To ensure these wastes do not enter the waters of the State, SCDHEC requires that both solid and liquid agricultural wastes from these facilities be collected, treated, and disposed in an environmentally acceptable manner. This is accomplished through a State permitting and inspection program requiring recycling or land application of agricultural wastes. Land application of wastes to viable crops at agronomic rates eliminates direct surface water discharges of agricultural wastes and is effective in insuring water quality. South Carolina's state agricultural program is and will continue to be more stringent than the federal NPDES program for animal facilities.

Toxics Controls

Toxic pollutants are generally defined as substances which by themselves or in combination with other chemicals are harmful to animal life or human health. They include some of the metals, pesticides, and other synthetic organic pollutants that have the potential to contaminate water, fish tissue, and bottom sediments. Each NPDES permit application is reviewed for potential toxic pollutants. These pollutants are evaluated for aquatic life and human health concerns. If determined to be potentially toxic, a limitation is placed in the NPDES permit for that specific pollutant using South Carolina water quality standards. SCDHEC has EPA-approved standards for specific pollutants. Whole effluent toxicity testing is placed in many NPDES permits; those tests being for acute and/or chronic monitoring as appropriate. In-stream biological assessments are also being utilized in some cases (i.e., to evaluate stormwater runoff).

Land Application of Treated Wastewater

The process utilized for industrial and agricultural facilities is the same as that for municipal facilities. However, limitations for the spray effluent are not permitted as secondary limits, but are based on site-specific requirements.

Stormwater Permits- Industrial

SCDHEC regulates storm water discharges associated with industrial activities. The State has issued two general NPDES permits for activities associated with industry. These permits are the Construction Activity NPDES Permit and the Associated with Industrial Activity, except construction, NPDES Permit.

The general permits require permittee's to develop and implement Storm Water Pollution Prevention Plans (SWPPPs) that will minimize pollutants in their storm water discharges. Some industrial activities, except construction, must monitor on either an annual or semiannual basis while all industrial activities, except construction, are required to update their SWPPP's on an annual basis. Industrial construction activities are required to conduct inspections weekly and after every rainfall event of 1 inch or greater.

Where appropriate, individual NPDES permits will be issued in accordance with EPA's tiered permitting strategy. Water quality monitoring will help identify the industrial activities that must receive individual permits instead of general permits. In the watershed approach, the individual permits will be tailored to address the water quality concerns of the storm water discharges from industrial activity.

Stormwater Permits – Construction

In addition to regulating storm water discharges associated with industrial activities, SCDHEC is charged with regulation storm water discharges originating from construction sites. This is done through the NPDES General Permit for Storm Water Discharges from Large and Small Construction Sites (SCR100000).
The newest version of the General Permit was issued in February of 2006 and is anticipated to become effective in the spring of 2006. The new permit includes additional inspection and reporting requirements. Storm Water Pollution Prevention Plans (SWPPPs) are to be prepared and submitted to the Department for review. Plans are to be updated and must reflect the activities, from initial clearing to final stabilization, that are to take place on the construction site. Plans must also reflect any controls necessary to keep the site in compliance with existing TMDLs or other water quality concerns.

Stormwater Permits- MS4

SCDHEC also regulates Municipal Separate Storm Sewer Systems (MS4s) in the overall storm water program. There are four Phase I MS4's in South Carolina, one large and three medium. The large one is SCDOT and is scheduled to be issued on June 1, 2006. Two of the three medium MS4's, Greenville County and Richland County, are already permitted and are in the preliminary draft stage of re-issuance. The remaining medium MS4 is the City of Columbia and the application is currently under review by EPA. The Phase Two NPDES Permit is now effective and 64 automatically regulated SMS4's will be phase in for coverage during the permit term. These permits help insure water quality protection within the boundaries of the affected local governments.

E. Permit Compliance and Enforcement

Compliance tracking is a complex activity that involves various program elements and activities within the Bureau of Water. Regulatory functions require ongoing monitoring of all permits, inspection activities, and investigatory work. A computer based tracking system, the WPC Network, is maintained for the storage, retrieval, and management of permit compliance information for individual permits, including all effluent limits and compliance schedule data, facility operation and maintenance and pretreatment status. The availability of this information and ability to manage the data electronically enhances the Bureau information base providing greater program management capabilities.

All data necessary for issuing permits and tracking the compliance of those individual permits is maintained on the Bureau's network. Staff have access to information on permitting status, compliance monitoring, enforcement status, etc.

The WPC Network is designed to interface with EPA's Permit Compliance System (PCS). Updated compliance data is batched to PCS weekly. The Bureau is continuing its efforts to improve its utilization of the computer generated EPA Quarterly Noncompliance Report (QNCR).

Enforcement activities are performed in order to identify and appropriately respond to facilities in permit noncompliance and other entities found to be in violation of state statutes and regulations. Data accessibility through the Bureau's networking system, as well as organizational changes, have greatly enhanced enforcement staff capabilities for efficient case development and management. Improvements in entry of limits and data will further improve tracking and enforcement efficiency.

An emphasis on enforcement activity will continue in accordance with implementation of the Bureau's Watershed Water Quality Management Program. Appropriate and timely enforcement responses in conjunction with the activities of other program areas are expected to contribute significantly to accomplishment of this program's goals through the development of TMDLs.

Enforcement staff will become more involved in the referral of cases for criminal investigation and providing assistance to criminal investigators. A greater emphasis has been placed upon pursuing prosecution of violators under the criminal statutes and the support and assistance of enforcement staff in this process will continue to be invaluable; however, criminal and administrative investigations must be conducted separately.

It is recognized that aggressive enforcement activity encourages compliance. In this regard, enforcement staff are committed to secure for South Carolina the benefits from these activities to protect our water resources through implementation of appropriate enforcement strategies. The development and continued improvement of automated tools and methodology to accomplish this is considered to be vital to this function and will be given priority.

F. Nonpoint Source Program

Nonpoint Source (NPS) water pollution generally comes from diffuse, numerous sources. Runoff occurring after a rain event may transport sediment from plowed fields, construction sites, or logging operations, pesticides and fertilizers from farms and lawns, motor oil and grease deposited on roads and parking lots, or bacteria containing waste from agricultural animal facilities or malfunctioning septic systems. The rain moves the pollutants across the land to the nearest water body or storm drain where they may impact the water quality in creeks, rivers, lakes, estuaries and wetlands. Nonpoint source pollution may also impact groundwaters when it is allowed to seep or percolate into aquifers. The adverse effects of NPS pollution include physical destruction of aquatic habitat, fish die-offs, interference with or elimination of recreational uses of a water body (particularly lakes), closure of shellfish beds, reduced water supply or taste and odor problems in drinking water, potential human health problems due to bacteria and toxic chemicals in NPS runoff, and increased potential for flooding because water bodies become choked with sediment.

The *South Carolina Nonpoint Source Management Program, 1999 Update* outlines the state's strategic plan for addressing statewide water quality impairments attributable to nonpoint source pollution discharges. To accomplish this strategy, 17 long-term goals for reducing or preventing NPS pollution are enumerated. Throughout the document, five-year action strategies are described that lead to attainment of the long-term goals, and annual milestones leading to attainment of the action strategies are further described. The Program is two-pronged; focusing on reducing NPS impacts in priority watersheds, and implementing activities statewide in order to prevent NPS pollution. Components include both regulatory and voluntary approaches.

To facilitate success in achieving water quality improvements, South Carolina's NPS program focuses federal Clean Water Act Section 319 funding and state resources on impaired 303(d) listed waterbodies in priority watersheds through the implementation of approved NPS Total Maximum Daily Loads (TMDLs). The state's Coastal Nonpoint Pollution Control Program under federal Coastal Zone Management legislation is also implemented.

Nine categories of NPS pollution that impact South Carolina's waters are identified and described: agriculture, forestry, urban areas, marinas and recreational boating, mining, hydrologic modification, wetlands disturbance, land disposal/groundwater impacts, and atmospheric deposition. Technology based controls, or management measures, are employed to address these categorical impacts. The Program describes specific management measures for each category as well as implementation schedules. South Carolina has the legal authority to implement all of the necessary management measures.

SCDHEC is responsible for Program implementation, but is dependent upon the cooperation of all levels of government, private sector stakeholders, and especially the citizens of the State in order to realize positive results. Many organizations have expertise that can be beneficial to the NPS pollution management program. For example, trade and environmental organizations have program delivery mechanisms that reach persons capable of implementing NPS controls, e.g., farmers, contractors, mine operators, and homeowners. These partnership roles are described in the program.

A system of evaluation/monitoring techniques is a necessary component of the NPS Management Program, in order to evaluate its progress and success. Evaluation will show whether the Program is attaining the state's overall water quality vision, stated long-term goals, and five-year action strategies. In South Carolina, several monitoring and tracking efforts are described that address available information on improvements in water quality, implementation milestones, and available information on reductions in NPS pollution. Evaluation techniques include water quality monitoring, level of participation in management measure implementation, and stakeholder feedback.

This *South Carolina NPS Management Program Update* fulfills the requirements of both Section 319 of the Clean Water Act Amendments of 1987, and Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990. It comprehensively describes a framework for agency coordination and cooperation and serves to implement a strategy for employing effective management measures and programs to control NPS pollution statewide for the next five years.

It incorporates nine key elements that are iterated in Environmental Protection Agency NPS guidance. Through the use of a framework that addresses these key elements, South Carolina will continue to have an effective NPS program that is designed to achieve and maintain beneficial uses of water.

South Carolina receives funding in excess of $3 million annually for implementation of projects to reduce or eliminate NPS pollution through section 319 of the Clean Water Act. Some of these projects are statewide or regional in scope and include activities such as water quality monitoring, NPS outreach and education, and best management practice (BMP) compliance. Other projects are watershed based, aimed at remediating NPS related problems from the state's 303(d) list. A relatively new focus for section 319 funding is the development and implementation of total maximum daily loads (TMDLs). Since FY 2003, one-half of the State's allocation has been used for this purpose.

G. Wasteload Allocations and Total Maximum Daily Loads

A total maximum daily load (TMDL) is the maximum load of a pollutant that can be assimilated by a waterbody without contravening water quality standards. Section 303(d) of the Clean Water Act requires that TMDLs be developed for waters that are determined to be impaired, that is, not meeting applicable water quality standards. A TMDL is made up of a wasteload allocation (WLA) which is the portion of the assimilative capacity allocated to point sources, a load allocation (LA) which is the portion of the assimilative capacity allocated to nonpoint sources, plus a margin of safety. A TMDL can be developed for an individual pollutant, such as bacteria, or for a category of pollutants, such as oxygen demanding substances. In addition to developing WLAs in conjunction with TMDLs for waters on the State's 303(d) list of impaired waters, SCDHEC also develops WLAs as part of the routine review required for new discharges or for permit reissuance for existing discharges.

Various techniques, ranging from simple mathematical models to complex computer based models, are used by SCDHEC to determine the ability of a waterbody to assimilate various pollutants. TMDLs and WLAs developed using these techniques allow use of the assimilative capacity of a waterbody while protecting water quality and maintaining existing and classified uses. WLAs are developed as part of the basin review process as well as in response to proposals for new and expanded projects throughout the State. WLAs for oxygen demanding substances (carbonaceous and nitrogenous oxygen demand) and ammonia toxicity are determined by the Water Quality Modeling Section. WLAs for metals, total residual chlorine, organic pollutants and most toxicants are determined by the individual permitting sections.

Wasteload allocations fall into one of two categories, effluent limited or water quality limited. In instances when the assimilative capacity of a waterbody exceeds the existing or proposed pollutant loading, the waterbody is said to be effluent limited and a TMDL is not required. Effluent limitations for discharges to such waters are determined by the minimum standards required for the type of discharge involved. In instances where the permitted loading is equal to or a proposed loading is greater than the assimilative capacity, the stream is said to be water quality limited. The limits on the discharges to such waters are determined by the water quality of the receiving stream, rather than the minimum standards. TMDLs are not required for water quality limited streams that meet applicable standards. In cases where the water body is meeting standards but a previously permitted or proposed loading would cause the waterbody to be impaired, the new wasteload allocation is a maximum allowable loading. In multiple discharge situations, the load must be divided or allocated among the discharges.

To date, TMDLs have been developed for fecal coliform bacteria, phosphorus, pH, and oxygen demanding substances for many waterbodies. Development of additional TMDLs is currently underway. Wasteload allocations have been developed for numerous waterbodies for ammonia and oxygen demanding substances. While not TMDLs, these WLAs in many cases constitute the maximum allowable loading to the waterbody. WLAs for phosphorus have been developed for several waterbodies including Eighteen Mile Creek, Reedy River, Bush River and Catawba River, with efforts underway or planned for development of nutrient TMDLs for the Reedy River and Catawba River. Development of new TMDLs is expected to play an increasingly important part in the overall wasteload allocation process as SCDHEC continues implementation of the basin planning and permitting strategy with emphasis on restoring the State's impaired waters.

H. Special State Concerns and Recommendations

The Bureau of Water continues to implement the operational plan initiated in 2001. These efforts implement portions of the Agency's and Environmental Quality Control's strategic plans. Elements of the operational plan embrace the Bureau's mission and the Agency's values, and visions.

Bureau of Water Mission

The water people drink in South Carolina is safe, and that there is plenty of it. Water resources of South Carolina are of such quality that they are suitable for use by all citizens and that all surface waters are of a quality suitable to support and maintain aquatic flora and fauna.

DHEC Values

Customer service
Teamwork
Use of applied scientific knowledge

DHEC Visions

Cultural competence
Excellence in government
Local solutions

Bureau of Water Goals

The eight goals of the Bureau of Water will ensure that our mission is accomplished while embracing the DHEC values and visions.

The primary way to accomplish this is reflected in **Goal 1**: Protect Surface and Ground Water Quality. **Goal 2**: Adequately Assess Water Quality allows us to track the progress of achieving the first goal. **Goal 3**: Reduce and Eliminate Water Pollution offers ways to improve upon the activities supporting Goal 1.
Water quality protection includes protecting the habitat necessary for aquatic organisms, indicators of water quality. This is reflected in **Goal 4**: Protect and Restore Aquatic Habitat.

Citizens of the State are the ultimate consumers requiring clean water. Safe, clean drinking water is essential for life and is accomplished through the activities in **Goal 5**: Provide Safe Drinking Water.

Many Bureau of Water Programs provide protection of health and safety for activities undertaken in or on waters. **Goal 6**: Protect Public Health and Safety accomplishes this.

It is important for citizens to understand their role in water quality protection as presented in **Goal 7**: Expand the Public's Knowledge about Water Issues.

Finally, if we implement **Goal 8**: Plan Effectively for Growth, water pollution impacts can be further minimized and the ability to achieve all other goals will be enhanced.

The Bureau of Water continues to implement the operational plan initiated in 2001. These efforts implement portions of the Agency's and Environmental Quality Control's strategic plans. Elements of the operational plan embrace the Bureau's mission and the Agency's values, and visions.

Program funding continues to be a central concern and overall limiting factor to the development of new programs or enhancement of existing water quality programs. While we suffered significant reductions in State funds in previous fiscal years, State reductions in FY 04 and FY 05 were not significant. However Federal rescissions and reductions are causing us to take a close look at program priorities.

Since 1992, SCDHEC's Bureau of Water has successfully implemented a Watershed Water Quality Management Program designed to maximize the use of resources, equalize workloads on an annual basis, and develop strategies for water quality maintenance or improvement on a priority basis. Last year we had a low backlog for major NPDES permits. The Watershed Water Quality Management Program also has allowed us to better utilize water quality monitoring resources to evaluate water quality in the State as well as wasteload modeling resources for permit limits development.

Our current or future activities will be focused on implementing the following recommendations and strategies. They are presented according to the goal they will help us attain.

Protect Surface and Ground Water Quality

* In May 2004, we received Legislative approval for the triennial review completed in December 2003. Major revisions are adoption of current federal criteria, revision of the bacterial indicator for coastal recreational waters, and inclusion of a variance from standards for NPDES permit holders.

* The SCDHEC continues an assertive process to evaluate and to properly classify surface waters. In February 2006, our Board approved the reclassification of waters within Congaree National Park, South Carolina's first National Park, to Outstanding Resource Waters. They also approved reclassification of a portion of Cedar Creek within the Park to National Outstanding Resource Waters. This amendment regulation is presently pending Legislative approval
* The SCDHEC continues its point source permitting policy of issuing water quality based NPDES permits.

Adequately Assess Water Quality

* Water quality monitoring efforts must be continually revised and expanded to address

the additional potential impacts of increasing population and development. We have completed our fifth year of monitoring waters at statistically selected stations for lakes and rivers and use these data for our overall statements about water quality in this report. There remains the need for increased analytical capabilities to measure the presence of chemicals at very low concentrations. A greater emphasis on biological integrity is also a recognized need. We participated in the national wadeable streams monitoring effort and are assisting in data evaluation. The SCDHEC must continue to seek resources to develop and implement more extensive biological monitoring and assessment. Supplemental monitoring funds in the Section 106 grant has not yet been used to fund staff since there is some uncertainty as to the continuation of this supplement. Recognizing that EPA may be moving away from STORET, we are exploring other ways to house our monitoring data.

Reduce and Eliminate Water Pollution

* Improving water quality of impaired waters continues to be a SCDHEC priority. The SCDHEC must develop Total Maximum Daily Loads (TMDLs) for all waters listed on the 303(d) list of impaired waters. The SCDHEC has used Federal Section 319 funds to assist with TMDL development and are now focusing 319 funds on TMDL implementation. South Carolina has 312 approved TMDLs and local partners are implementing 34 TMDLs where nonpoint sources must be controlled. In addition, SCDHEC is implementing several more TMDLs through stringent NPDES permits.

* Regulations dealing with Phase II of the National Pollutant Discharge Elimination System (NPDES) storm water permit program have been finalized. The SCDHEC has issued a General Permit for small MS4s and has reissued General Prmits for industrial storm water and construction activities. We have added staff for storm water permitting but additional inspectors would make this program more effective.

Protect and Restore Aquatic Habitat

* The SCDHEC will more aggressively integrate the Shellfish Sanitation Program into its ongoing efforts to maintain and enhance water quality by focusing corrective actions on impaired shellfish harvesting waters.

* The SCDHEC will continue to protect wetlands as waters of the State through its water programs including 401 water quality certification, NPDES permitting, and State stormwater permitting. The SCDHEC is using storm water permitting programs in conjunction with the SC Pollution Control Act to protect isolated wetlands since a Supreme Court decision removed them from regulatory jurisdiction of the Corps of Engineers. We have not been successful in amending water quality certification regulations to provide for protection of isolated wetlands; however, a new statute to protect isolated wetlands was introduced by the Legislature in 2006.

Provide Safe Drinking Water

* Source Water Protection and Wellhead Protection Programs will receive priority to insure drinking water uses of surface and ground waters are given the highest levels of

protection. The SCDHEC completed all source water protection reports ahead of schedule and has provided them to the water systems for implementation. We have recently added staff with Source Water set-aside funding to work with water systems on implementation.

Protect Public Health and Safety

* The fish tissue monitoring program was previously expanded, but State budget cuts have affected this program greatly. We have maintained the capability to monitor a limited number of fish samples for mercury in order to keep our advisories current. In 2005, we made significant improvements to our advisory booklets and our on-line advisory information.

* Ocean water quality monitoring with appropriate advisories to the public continues with federal funding under the BEACH Act. In Horry County, the SCDHEC is collecting rainfall data along with surf samples in order to use rainfall levels to predict bacterial levels thereby reducing the amount of monitoring needed.

Expand the Public's Knowledge about Water Issues

* The SCDHEC publishes environmental quality data in its annual report, *Healthy People Living in Healthy Communities*, to inform and educate the general public, State legislature, and State congressional delegation as to the status of our progress to date and important issues. This effort to increase the general awareness of the citizens of the State to the mission, programs, and achievements of the SCDHEC and to help them better understand environmental issues should be expanded through other activities that facilitate interaction between citizens and SCDHEC representatives.

* The Bureau of Water has a stable program to provide education in connection with nonpoint source pollution and drinking water issues. We also have a well-established partnership program, Champions of the Environment, for youth. With staff changes and diminished 319 funding, we are evaluating the continuation of our Water Watch Program.

* The Bureau of Water has an excellent Internet web site to facilitate information exchange and to provide public participation in the regulatory process. We continue to provide speakers to address issues of interest to the public and have participated in developing an education curriculum for primary and secondary schools.

* In addition to public education on water quality issues, we also recognize the need to provide public forums for participation in water quality management planning and TMDL development.

* The SCDHEC continues to expand and upgrade its computer and electronic capabilities, including implementation of the new STORET database system. We are also using a LIMS (Laboratory Information Management System) to input data from the lab into STORET. There are numerous areas where electronic management and processing of

data and tracking systems would relieve valuable manpower for other activities and allow a more effective use of available resources. EPA support for better utility of STORET is essential and we are concerned about EPA's moving away from STORET. We also see a need for modernizing the Permit Compliance data system.

Plan Effectively for Growth

* The Governors of South Carolina and Georgia, through Executive Orders, established committees specifically for the purpose of protecting shared water resources. They are currently engaged in discussions on two issues that could significantly affect growth in both states: saltwater intrusion into the upper Floridan aquifer and development and implementation of a Total Maximum Daily Load for the Savannah River.

* Legislation in both South Carolina and North Carolina established joint river basin advisory commissions for the Catawba/Wateree River and the Yadkin/Pee Dee River. Members have been named for the Catawba/Wateree Commission and they have met several times. Issues of concern are ensuring adequate quantity for downstream uses and increased pollutant loadings into the Catawba River.

* Legislation to allow the SCDHEC to regulate water withdrawals has been introduced this year. The Governor's Water Law Review Committee recommended in it's 2004 Report that this legislation is needed for South Carolina to be able to negotiate with neighboring states on water quantity issues.

SURFACE WATER ASSESSMENT

1. Surface Water Monitoring Program

A. Purpose and Design

State administrators need to assess the quality of the aquatic environment so that they can make decisions concerning water program priorities and provide reports to the public on the state of the environment, important trends over time, and accomplishments. They also need to evaluate the effectiveness of control measures. Water quality monitoring data provide information necessary to meet these needs.

The SCDHEC operates and collects data from a statewide network of ambient monitoring sites. The ambient monitoring network is directed toward determining long-term water quality trends, assessing attainment of water quality standards, identifying locations in need of additional attention, and providing background data for planning and evaluating stream classifications and standards. The ambient monitoring network, as a program, involves sampling a wide range of physical and chemical parameters and analyzing them for the presence or effects of contaminants and comparing them to criteria to determine use support.

There are several major components to SCDHEC's ambient water quality monitoring activities, including ongoing fixed-location monitoring, cyclic watershed monitoring, and statewide probability-based monitoring, each designed to provide data for water quality assessment of major water resource types at different spatial and temporal scales. For a detailed discussion of each of these components, please see the most recent version of the State of South Carolina Monitoring Strategy at http://www.scdhec.gov/water/html/monitoring.html.

B. Networks and Programs

The statewide Probability-Based, or random sampling, component of the ambient monitoring program is designed to make statewide estimates of water quality. The data derived from those monitoring activities is used to develop the stream, lake/reservoir, and estuarine summary information presented in this report. A probability-based monitoring design is a type of a survey design in that the population of interest is sampled in a fashion that allows statements to be made about the whole population based on a subsample, and produces an estimate of the accuracy of the assessment results. The advantage of the probability-based sampling design is that statistically valid statements about water quality can be made about large areas based on a relatively small subsample.

Separate monitoring schemes have been developed for stream, lake/reservoir, and estuarine resources. Site selection is done in association with the U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory (NHEERL), Corvallis, Oregon. Random Sites are sampled once a month for one year, and a new statewide set of probability-based random sites is selected for each waterbody type every year. Please refer to the State of South Carolina Monitoring Strategy at http://www.scdhec.gov/water/html/monitoring.html for details of parameters sampled.

Although statements about resource conditions can theoretically be made based on data from a single year, the compilation of data from multiple years increases the confidence and accuracy of statements about water quality. An additional advantage of the probability-based approach is that it presents the opportunity for previously unsampled locations to be selected for data collection.

C. Laboratory Analytical Support

The Analytical and Radiological Environmental Services Division (ARESD) provides laboratory services to the Bureaus of Water and Land and Waste Management. The analytical services offered include bacteriological, chemical, and physical analyses. The types of samples analyzed include water, wastewater, leachate, soil, sediment, chemical waste, fish, and shellfish.

The organizational structure encompasses five sections and seven regional laboratories. The Central Laboratory Sections include Sample Characterization/ Automated Analysis/ Data Management, Metals Analysis, Organic Analysis, and Environmental Microbiology located in the Hayne Building in Columbia. The Radiological Environmental Monitoring Section is located in the Sims/Aycock Building in Columbia. The seven regional laboratories are located in Aiken, Beaufort, North Charleston, Florence, Greenville, Lancaster, and Myrtle Beach.

The Regional Laboratories, except for Beaufort and Myrtle Beach, initiate all stream and wastewater analysis. The Central Laboratories provide support analyses, i.e., metal, nutrient, toxic extraction procedures, and organic analyses. The Beaufort and Myrtle Beach Regional Laboratories analyze microbiological samples only. The Central Laboratory also acts as the Regional Laboratory for the Central Midlands District, performing the same functions as the other Regional Laboratories. Drinking Water Chemical Analysis is essentially a Central Laboratory program with support from the Regional Laboratories. All Regional Laboratories perform microbiological analyses for the Drinking Water Program.

D. Quality Assurance

SCDHEC's Quality System is the means by which the Department implements the quality management process. The Quality System encompasses a variety of technical and administrative elements which are outlined in the SCDHEC Quality Assurance Management Plan, 2003. This plan describes how programs within Environmental Quality Control (EQC) will plan, implement, and assess the quality of environmental work to be performed as part of the various programs' functions within the Agency.

The Deputy Commissioner for Environmental Quality Control has the overall responsibility for the development, implementation, and continued operation of EQC's QA Program. To insure that EQC's QA policy is uniformly applied to the generating and processing of all environmental data, a State Quality Assurance Management Office (SQAMO) has been established.

This office is responsible for the Quality Assurance Program. Environmentally-related measurement activities conducted by or for EQC shall be done only with the approval of the State Quality Assurance Management Office (SQAMO) after assuring that adequate quality assurance guidelines and procedures have been incorporated. This includes study-planning, sample collection, preservation and analysis, data handling, and use of physical, chemical, biological, and other data related to the effects, sources, transport and control of pollution, as well as personnel review and training.

To accomplish these goals the Water Quality Monitoring Section, Aquatic Biology Section, and Pollution Source Compliance Section have developed and instituted SQAMO approved field study procedures and documentation, data review, and routine EPA operating overview. These procedures are documented in SCDHEC's Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (SOP) (2001). This document describes in detail the field sampling procedures, meter calibration and maintenance procedures, sample chain-of-custody documentation, sample preservation, holding times and recommended sample containers specifications, data sheet examples, and data submission requirements.

At least once yearly all field personnel are accompanied on sample collection activities by the appropriate program quality assurance officer for evaluation of adherence to standard operating procedures (SOP) for QA/QC. These evaluations each year are for water quality monitoring SOP review and for facility compliance sampling SOP review. Approximately every other year the EPA conducts on-site routine overviews of SCDHEC's QA/QC procedures.

The Division Director and the Quality Assurance Officer for EQC Laboratories coordinate the internal quality assurance program. The laboratory quality assurance program encompasses every aspect of the laboratory analysis from container preparation through the actual data release from the Analytical Services Laboratory to the Environmental Quality Control (EQC) Programs.

Analytical Services has developed two quality control manuals that detail the day-to-day operation of the quality assurance program: (1) Procedures and Quality Control Manual for Chemistry Laboratories--Analytical Services; and (2) Laboratory Procedures Manual for Environmental Microbiology-- Analytical Services. The elements of quality control addressed in the manuals include organization and sample chain of custody; personnel training; quality control of laboratory services, scope and application, equipment and supplies, reagents, standards, methodology, preservation and storage, calibration, performance criteria and quality assurance, and waste management.

The overall laboratory quality assurance program, which includes the previously discussed elements, requires a minimum of 25% of allocated resources. The frequency for analysis of replicates and spike recovery samples is noted in the manuals and is in compliance with U.S. EPA guidelines. Acceptance criteria for each QC check is stated. Performance samples are also analyzed as noted in the manuals. The Environmental Microbiology Laboratories perform replicate analyses, positive test controls, media control tests, equipment control tests, etc., as required by EPA Laboratory Certification and Evaluation guidelines. In addition, Analytical Services and the seven regional laboratories participate in annual Water Supply and Water Pollution Proficiency Testing Programs. All district personnel who collect samples that require field testing participate in either the yearly Water Supply or Water Pollution Proficiency Testing Program, whatever is appropriate.

The laboratory analyses are conducted according to the List of Approved Test Procedures in the Federal Register, Volume 49, No. 209, October 26, 1984; Federal Register, Volume 59, No. 20, January 31, 1994; and Federal Register, Volume 67, No. 205, October 23, 2002. The Analytical Services quality control manuals include a section on methodology designed to reduce variations in applied techniques among the State laboratories where methods permit analyst interpretation, and thus provide a more uniform approach that will increase the reproducibility of results reported from the laboratory system. Analytical SOPs are identified by number and date of revision. Each SOP includes the approved method reference.

SOPs includes instrument calibration and maintenance procedures as well as corrective actions for any deficiencies or problems encountered.

E. Data Storage, Management and Interpretation

Routine ambient stream and sediment samples are collected by Regional Office personnel while special study and biological samples are genereally collected by Water Quality Monitoring Section or Aquatic Biology Section personnel Some sample analyses are conducted in the Regional Laboratories and others by the Central Laboratory. Data for samples that are analyzed in the Regional Laboratories are reported on the appropriate data sheets and released by the sample custodian for the region. These data sheets are sent to the Analytical and Radiological Environmental Services Division in Columbia where they, along with data sheets generated in the Central Laboratory, are sent to the appropriate program areas. All Ambient Surface Water Physical & Chemical Monitoring data are distributed by the Compliance Assurance Division to the Water Quality Monitoring Section. The data are reviewed by the Water Quality Monitoring Section and are sent to the Information Services Section for data entry. The data are edited and stored on at least an annual basis in the EPA's STORET distributed water quality database. Data sheets are kept on file in the Water Quality Monitoring Section.

After biological samples are collected, data sheets are kept on file in the Aquatic Biology Section until sample analysis is completed. Macro invertebrate and habitat data are entered into an in-house relational database program. Phytoplankton data are stored in a separate in-house database. Fish tissue results are entered into an Excel database and hard copies are filed and kept on site. Data sheets describing biological data are kept on file in the Aquatic Biology Section.

2. Assessment Methodology

A. Probability-Based §305(b) Assessment Approach

The initial selection of prospective probability-based, or random, monitoring site locations is conducted by the U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory (NHEERL), Corvallis, Oregon. Independently for each waterbody type, rivers and streams, lakes and reservoirs, and estuarine habitat, a statewide grid system and computer selection program is used to randomly select a particular grid to achieve a statewide spatial distribution of sites, and then a specific location within a selected grid is chosen according to the specifics of each waterbody design as described below.

The basic starting dataset for stream and lake site selection is the USEPA National Hydrography Dataset (NHD) coverage at a scale of 1:100,000, which is based on the U.S. Geological Survey (USGS) Digital Line Graph map base. Because of stream density inconsistencies in NHD some missing stream reaches in part of the state were added by digitization for a more consistent statewide representation. Similarly some important reservoirs that are missing in NHD were also added.

Estuarine sites selection uses a hydrographic GIS cover developed jointly by SCDHEC and the South Carolina Department of Natural Resources from the National Wetlands Inventory (NWI) digital files at a scale of 1:24,000.

Rivers and Streams

Streams of different sizes may be more or less sensitive to different types of environmental perturbations. Because of this, three stream sizes have been specifically targeted to ensure they are represented in the selected random sites. Approximately 30 total randomly selected stream sites are sampled each year. Each site is sampled monthly for one year.

1. First Order streams, or headwater streams, are targeted because these represent streams with the least dilution capacity and therefore are most immediately impacted by adjacent land use activities and associated runoff. These streams may also serve as spawning areas for fish and refuge areas for young from larger aquatic predators.

2. Second Order streams, are also streams with relatively small dilution capacity and represent important habitat for reproduction and survival of aquatic life. They may also reflect the direct impacts of major land use activities.

3. Third Order and larger streams, that include the major rivers of the State. In general these streams have greater dilution capacity and are less affected by small scale land use perturbations and may be heavily utilized for contact recreation.

These different sizes do not occur in equal proportions in the state, therefore an unequal weighting procedure is used in the site selection process to guarantee inclusion of approximately equal numbers of sites in all three stream sizes. These differential weights are based on the relative proportions of these three size classes in the streams of the state and are used in the assessment to adjust the contribution of each stream site to the statewide resource size.

Lakes and Reservoirs

Eligible lakes/reservoirs are restricted to "significant lakes," defined as those freshwater lakes/reservoirs with at least 40 acres surface area that offer public access. The size of significant lakes/reservoirs varies immensely; therefore two size classes of lakes/reservoirs have been specifically targeted to ensure that the smaller lakes/reservoirs are represented in the selected random sites. Approximately 30 total randomly selected lake and reservoir sites are sampled each year. Each site is sampled monthly for one year.

1. Major Lakes/Reservoirs greater than 850 acres surface area.

2. Minor Lakes/Reservoirs greater than 40 acres surface area, but less than or equal to 850 acres.

These different sizes do not occur in equal proportions in the state, therefore an unequal weighting procedure is used in the site selection process to guarantee inclusion of approximately equal numbers of sites in both sizes. These differential weights are based on the relative proportions of these two size classes in the lakes and reservoirs of the state and are used in the assessment to adjust the contribution of each lake site to the statewide resource size.

Estuaries

The coastal estuarine probability-based monitoring scheme has been developed jointly by SCDHEC, Bureau of Water, and the South Carolina Department of Natural Resources (SCDNR), Marine Resources Research Institute (MRRI). This effort has been dubbed the South Carolina Estuarine and Coastal Assessment Program (SCECAP) and sampling of the probability-based coastal estuarine sites is a cooperative venture between SCDHEC and SCDNR-MRRI. To ensure inclusion of a variety of estuarine ecosystems and habitats, the coastal estuaries have been divided into two discrete categories (strata) based on a common GIS cover developed and utilized by both agencies.

1. Tidal Creeks, identified as less than 100 meters wide on the GIS cover, serve as nursery areas for important marine species and are most immediately affected by upland land use activities and associated runoff.

2. Open Water areas, identified as greater than 100 meters wide on the GIS cover, represent larger estuarine rivers and sounds.

Within these waterbody types there are two distinct types of monitoring sites based on sampling frequency, Core Sites and Supplemental Sites. Core Sites are sampled monthly for one year by SCDHEC for water column physical and chemical parameters and are used for §305(b) reporting purposes.

The Supplemental Sites are sampled one time by SCDNR-MRRI and SCDHEC and are used in conjunction with one time samples collected at the Core Sites in the SCECAP reports and USEPA National Coastal Assessment.

Each year there will be approximately 15 Core Tidal Creek sites and 15 Core Open Water sites. Differential weights are based on the relative proportions of these two size classes in the estuarine areas of the state and are used in the assessment to adjust the contribution of each estuary site to the statewide resource size.

B. Determination of Attainment of Classified Uses

General Considerations

Physical, chemical and biological data were evaluated, as described below, to determine if water quality met the water quality criteria established to protect the State classified uses defined in S.C. Regulation 61-68, *Water Classifications and Standards*. Some waters may exhibit characteristics outside the appropriate criteria due to natural conditions. Such natural conditions do not constitute a violation of the water quality criteria. To determine the appropriate classified uses and water quality criteria for specific waterbodies and locations, refer to S.C. Regulation 61-69, *Classified Waters*, in conjunction with S.C. Regulation 61-68.

Water samples for analysis are collected as surface grab samples once per month, quarter, or year, depending on the parameter. Grab samples collected at a depth of 0.3 meters are considered to be a surface measurement. At most stations sampled by boat, dissolved oxygen and temperature are sampled as a water column profile, with measurements being made at either a depth of 0.3 meters below the water surface and at one-meter intervals to the bottom or at 0.3 meters, bottom and mid-depth. At stations sampled from bridges, these parameters are measured only at a depth of 0.3 meters. For the purpose of assessment, only surface samples are used in standards comparisons. Because of the inability to target individual high or low flow events on a statewide basis these data are considered to represent typical physical conditions and chemical concentrations in the waterbodies sampled. All samples are collected and analyzed according to standard procedures (SCDHEC 2001).

Results from water quality samples can be compared to State and USEPA criteria, with some restrictions due to time of collection and sampling frequency. For certain parameters, the monthly sampling frequency employed is insufficient for strict interpretation of the standards. The grab sample method is considered to be representative for the purpose of indicating excursions relative to criteria, within certain considerations. A single grab sample is more representative of a one-hour average than a four-day average, more representative of a one-day average than a one-month average, and so on; thus, when inferences are drawn from grab samples relative to criteria, sampling frequency and the intent of the criteria must be weighed. When the sampling method or frequency does not agree with the intent of the particular standard, any conclusion about water quality should be considered as only an indication of conditions, not as a proven circumstance.

Macroinvertebrate community structure is analyzed routinely at selected stream stations as a means of detecting adverse biological impacts on the aquatic fauna of the state's waters due to water quality conditions that may not be readily detectable in the water column chemistry.

The following statewide assessment information is based on the available quality assured physical, chemical and biological water quality data collected through the probability-based monitoring design from 2001-2004.

Aquatic Life Use Support - One important goal of the Clean Water Act, the South Carolina Pollution Control Act, and the State Water Quality Classifications and Standards is to maintain the quality of surface waters to provide for the survival and propagation of a balanced indigenous aquatic community of fauna and flora. The degree that aquatic life is protected (Aquatic Life Use Support) is assessed by comparing important water quality characteristics and the concentrations of potentially toxic pollutants with numeric criteria.

Support of aquatic life uses is determined based on the percentage of numeric criteria excursions and, where data are available, the composition and functional integrity of the biological community. The term excursion is used to describe a measured pollutant concentration that is outside of the acceptable range as defined by the appropriate criterion. Some waters may exhibit characteristics outside the appropriate criteria due to natural conditions. Such natural conditions do not constitute a violation of the water quality criteria. A number of waterbodies have been given waterbody-specific criteria for pH and dissolved oxygen, to reflect natural conditions. To determine the appropriate numeric criteria and classified uses for specific waterbodies and locations, please refer to S.C. Regulation 61-68, *Water Classifications and Standards* and S.C. Regulation 61-69, *Classified Waters.*

If the appropriate criterion for dissolved oxygen and pH are contravened in 10 percent or less of the samples, the criterion is said to be fully supported. If the percentage of criterion excursions is greater than 10 percent, but less than or equal to 25 percent, the criterion is partially supported, unless excursions are due to natural conditions. If there are more than 25 percent excursions, the criterion is not supported, unless excursions are due to natural conditions. The decision that criteria excursions are due to natural conditions is determined by consensus and/or the professional judgment of SCDHEC staff with specific local knowledge.

If the appropriate acute or chronic aquatic life criterion for any individual toxicant (heavy metals, priority pollutants, ammonia) is exceeded more than once, representing more than 10 percent of the samples collected, the criterion is not supported. If the acute or chronic aquatic life criterion is exceeded more than once, but in less than or equal to 10 percent of the samples, the criterion is partially supported.

The total recoverable metals criteria for heavy metals are adjusted to account for solids partitioning following the approach set forth in the Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria, October 1, 1993, by Martha G. Prothro, Acting Assistant Administrator for Water, available from the Water Resource center, USEPA, 401 M St., SW, mail code RC4100, Washington, DC 20460; and 40CFR131.36(b)(1). Under this approach, a default TSS value of 1 mg/L is used. Where the metals criteria are hardness based, a default value of 25 mg/L is used for waters where hardness is 25 mg/l or less.

For ammonia, the calculation of the appropriate criterion value requires the values of several associated field parameters measured concurrent with the ammonia sample collection. Where direct measurements of any of the parameters are lacking the ammonia value will not be used to determine compliance with the standards.

For turbidity in all waters, and for waters with numeric total phosphorus, total nitrogen, and chlorophyll-a criteria, if the appropriate criterion is exceeded in more than 25 percent of the samples, the criterion is not supported. If the criterion is exceeded in more than 10 but less than 25 percent, sites are evaluated on a case-by-case basis to determine if local conditions indicate that classified uses are impaired. Among the characteristics considered are: hydrology and morphometry of the waterbody, existing and projected trophic state, characteristics of pollutant loadings and ongoing pollutant control mechanisms. If the criterion is exceeded in less than 10 percent of the samples, then the criterion is fully supported.

If the conclusion for any single parameter is that the criterion is "not supported", then it is concluded that aquatic life uses are not supported in the waterbody, at that monitoring location. If there are no criteria that are "not supported", but the conclusion for at least one parameter criterion is "partially supported", then it is concluded that aquatic life uses are partially supported. Regardless of the number of samples, no monitoring site will be listed as partially or not supporting for any pollutant based a single water chemistry sample result because of the possibility of an anomalous event.

For aquatic life uses, the goal of the standards is the protection of a balanced indigenous aquatic community. Therefore, biological data are the ultimate deciding factor, regardless of chemical conditions. If biological data shows a healthy, balanced community, the use is considered supported even if chemical parameters do not meet the applicable criteria.

Macroinvertebrate Data Interpretation - Macroinvertebrate community assessment data are used to directly determine Aquatic Life Use Support and to support determinations based on water chemistry data. Macroinvertebrate community data may also be used to evaluate potential impacts from the presence of sediment contaminants. Aquatic and semi-aquatic macroinvertebrates are identified to the lowest practical taxonomic level depending on the condition and maturity of specimens collected.

The EPT Index and the North Carolina Biotic Index (BI) are the main indices used in analyzing macroinvertebrate data. To a lesser extent, taxa richness and sometimes total abundances may be used to help interpret data. The EPT Index or the Ephemeroptera (mayflies) - Plecoptera (stoneflies) - Trichoptera (caddisflies) Index is the total taxa richness of these three generally pollution-sensitive orders. EPT values are compared with least impacted regional sites. The Biotic Index for a sample is the average pollution tolerance of all organisms collected, based on assigned taxonomic tolerance values.

Taxa richness is the number of distinct taxa collected and is the simplest measure of diversity. High taxa richness is generally associated with high water quality. Increasing levels of pollution progressively eliminate the more sensitive taxa, resulting in lower taxa richness. Total abundance is the enumeration of all macroinvertebrates collected at a sampling location. When gross differences in abundance occur between stations, this metric may be considered as a potential indicator.

Recreational Use Support - The degree to that the swimmable goal of the Clean Water Act is attained (Recreational Use Support) is based on the frequency of fecal coliform bacteria excursions.

For fecal coliform bacteria, an excursion is an occurrence of a bacteria concentration greater than 400/100 ml for all surface water classes. Comparisons to the bacteria geometric mean standard are not considered appropriate based on sampling frequency and the intent of the standard.

If 10 percent or less of the samples are greater than 400/100 ml then recreational uses are said to be fully supported. A percentage of criteria excursions greater than 10 and less than or equal to 25 is considered partial support of recreational uses, and greater than 25 percent is considered to represent nonsupport of recreational uses.

3. Rivers and Streams Water Quality Assessment

The U.S. Environmental Protection Agency has developed a system to determine estimates of total river miles and total lake acres for the states to use in reporting for §305(b) reports. The estimates are based on the Digital Line Graph (DLG) database and the National Hydrography Dataset (NHD), that are in turn based on the U.S. Geological Survey 1:100,000 scale hydrologic maps. The original DLG database was missing a significant number of South Carolina streams. Many of these missing features have been added by SCDHEC, with the cooperation and oversight of the USEPA.

A. Summary Statistics

Based on the modified USEPA National Hydrography Dataset (NHD) and the results of probability site selection validation, South Carolina has an estimated 20,954 miles of freshwater rivers and streams representing the stream sampling design frame previously described.

A summary of classified use support statewide based on 118 probability-based monitoring sites sampled from 2001-2004, along with causes for partial or nonattainment, is presented below. The Lower and Upper 95 Percent Confidence Intervals for the probability-based estimates signify that it is 95% certain that the true mileage is between the upper and lower confidence limits.

Table 6. Rivers and Streams Use Support Summary (Miles)

Indicator	Category	Probability-Based Estimated Percent of Total Resource	Probability-Based Estimated Miles of Total Resource	Lower 95 Percent Confidence Interval (Miles)	Upper 95 Percent Confidence Interval (Miles)
Aquatic Life Use	Fully Supporting	65.1%	13,647	11,610	15,683

	Partially Supporting	18.2%	3,816	2,076	5,555
	Not Supporting	16.7%	3,492	2,103	4,880
Recreational Use	Fully Supporting	46.8%	9,807	7,846	11,768
	Partially Supporting	21.9%	4,580	2,891	6,270
	Not Supporting	31.3%	6,567	4,675	8,458

Table 7. Summary of Fully Supporting and Impaired Rivers and Streams (Not including Fish Consumption Use)

Category	Probability-Based Estimated Percent of Total Resource	Probability-Based Estimated Miles of Total Resource	Lower 95 Percent Confidence Interval (Miles)	Upper 95 Percent Confidence Interval (Miles)
Fully Supporting All Assessed Uses	33.3%	6,970	5,205	8,735
Impaired for One or More Use	66.7%	13,984	12,219	15,748

Table 8. Total Sizes of Rivers and Streams Impaired by Various Cause Categories (Miles)

Cause Category	Probability-Based Estimated Miles of Total Resource	Lower 95 Percent Confidence Interval (Miles)	Upper 95 Percent Confidence Interval (Miles)
Macroinvertebrate Community*	3,075	1,905	4,246
Turbidity	407	72	742
Dissolved Oxygen	1,747	768	2,726
pH	809	23	1594
Metals (Combined)	2,183	1,038	3,328
Chromium	106	0	289
Copper	1,375	383	2,366
Nickel	106	0	289
Zinc	809	202	1,415
Fecal Coliform Bacteria	11,147	9,186	13,108

*Macroinvertebrates could not be collected at all sites, so the total resource size represented by macroinvertebrate results is 5,667 miles.

The following table summarizes the use of macroinvertebrate data in the preparation of this report. Although macroinvertebrate data are available for other locations in South Carolina, no estimates of the mileage represented by these sites were available.

Table 9. Categories of Data Used in Aquatic Life Use Support (ALUS) Assessments for All Rivers and Streams

Degree of ALUS	Miles Assessed Based on Physical/ Chemical Data Only	Miles Assessed Based on Physical/Chemical and Biological/Habitat Data	Total Miles Assessed for ALUS
Fully Supporting	9,741	3,906	13,647
Partially Supporting	0	3,816	3,816
Not Supporting	2,497	995	3,492

4. Lakes Water Quality Assessment

A. Summary Statistics

Based on the modified USEPA National Hydrography Dataset (NHD) and the results of probability site selection validation, South Carolina has an estimated 308,765 acres of lake and reservoir representing the lake/reservoir sampling design frame previously described. A significant amount of data associated with the 2004 probability-based lake and reservoir monitoring sites is still awaiting final QA/QC verification. Therefore the assessment of the probability-based results is based only on the 2001-2003 data. A summary of classified use support statewide based on 91 probability-based monitoring sites sampled from 2001-2003, along with causes for partial or nonattainment, is presented below. The Lower and Upper 95 Percent Confidence Intervals for the probability-based estimates signify that it is 95% certain that the true acreage is between the upper and lower confidence limits.

Table 10. Lake Use Support Summary (Acres)

Indicator	Category	Probability-Based Estimated Percent of Total Resource	Probability-Based Estimated Acres of Total Resource	Lower 95 Percent Confidence Interval (Acres)	Upper 95 Percent Confidence Interval (Acres)
Aquatic Life Use	Fully Supporting	84.4%	260,767	235,640	285,894
	Partially Supporting	4.4%	13,432	0	28,209
	Not Supporting	11.2%	34,566	13,504	55,629
Recreational Use	Fully Supporting	99.9%	308,436	308,039	308,765
	Partially Supporting	0.1%	329	0	726

Table 11. Summary of Fully Supporting and Impaired Lakes (Not including Fish Consumption Use)

Category	Probability-Based Estimated Percent of Total	Probability-Based Estimated Acres of Total	Lower 95 Percent Confidence Interval (Acres)	Upper 95 Percent Confidence Interval (Acres)

	Resource	Resource		
Fully Supporting All Assessed Uses	84.4%	260,438	235,312	285,565
Impaired for One or More Use	15.6%	48,327	23,201	73,454

Table 12. Total Sizes of Lakes Impaired by Various Cause Categories (Acres)

Cause Category	Probability-Based Estimated Acres of Total Resource	Lower 95 Percent Confidence Interval (Acres)	Upper 95 Percent Confidence Interval (Acres)
Turbidity	658	161	1,155
Dissolved Oxygen	494	40	947
pH	32,921	11,934	53,909
Total Phosphorus	20,970	5,017	36,924
Total Nitrogen	329	0	733
Chlorophyll-*a*	7,209	0	17,859
Metals (Combined)	494	60	927
Copper	164	0	464
Zinc	329	22	636
Fecal Coliform Bacteria	329	0	726

B. Section 314 Reporting

Section 314(a) of the Clean Water Act of 1987 directs each State to prepare or establish: (1) an identification and classification according to trophic condition of publicly-owned freshwater lakes within such State; (2) procedures, processes, and methods to control sources of pollution of such lakes; (3) methods and procedures, in conjunction with appropriate Federal agencies, to restore the quality of such lakes; (4) a list and description of lakes for that uses are known to be impaired; and (5) an assessment of the status and trends of water quality in lakes. Further, States are required to submit a biennial assessment of lake trophic condition as part of their §305(b) report.

Background

Monthly sampling is conducted each year in lakes throughout the state as part of SCDHEC's ambient water quality monitoring activites, including ongoing fixed-location monitoring, cyclic watershed monitoring, and statewide probability-based monitoring.

Trophic Status

In 2001, South Carolina adopted numeric nutrient criteria for lakes by ecoregion and beginning FY 2002, trophic condition assessment was based upon the criteria for Total Phosphorus (TP), Total Nitrogen (TN) and Chlorophyll *a* (CHL-A). Table 13 lists those lake sites that were identified as not meeting one or more of these numeric criteria as part of the current §303(d) assessment reported in *Part I: Listing of Impaired Waters* of this Integrated Report. The second part of the same table lists all other sites that were assessed and found to meet the numeric criteria.

Table 13. Condition of Significant South Carolina Lakes

Lake Sites Not Attaining Numeric Nutrient Criteria		
PIEDMONT		
STATION ID(S)	**Location**	**Parameters**
S-308 / CL-052	LAKE GREENWOOD, REEDY RVR ARM, 150 YDS US RABON CK	TP
SV-268	LAKE HARTWELL - EIGHTEEN MILE CK ARM AT S-04-1098	TP
CL-035	LAKE JOHNSON AT SPILLWAY AT S-42-359	TP, CHL-A
S-222	LAKE MURRAY, LITTLE SALUDA ARM AT SC 391	TP
S-309 / CL-081	LAKE MURRAY, BUSH RVR ARM, 4.6 KM US SC 391	TP, CHL-A
CL-021	LAKE OLIPHANT, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CHL-A
CW-207	LK WATEREE AT END OF S-20-291	TP
CW-208	LK WATEREE AT S-20-101 11 MI ENE WINNSBORO	TP, CHL-A
CW-209	LK WATEREE AT SMALL ISLAND 2.3 MI N OF DAM	TP
CW-231	LK WATEREE HEADWATERS APPROX 50 YDS DS CONFL CEDAR CK	TP
RL-02314	LAKE WATEREE 1.0 MI SW FROM MOUTH OF BEAVER CK	TP
RL-03336	LAKE WATEREE NEARSHORE ALONG S-28-802 OPP COLONEL CK CONFL	TP
RL-01029	LAKE WELCHEL 2.7 M N OF GAFFNEY	CHL-A
S-311 / CL-013	BOYD MILL POND .6 KM W DAM	TN, TP
CW-033	CEDAR CK RESERVOIR 100 M N OF DAM	TP
CW-174	CEDAR CK RESERVOIR AT UNIMP RD AB JCT WITH ROCKY CK	TN, TP
CW-175	CEDAR CK RESERVOIR/ROCKY CK AT S-12-141 SE OF GREAT FALLS	TP
RL-01007	CEDAR CK RES 2.15 M SE OF GREAT FALLS	CHL-A
RL-02319	CEDAR CK RES FROM W OF BIG ISL 7 MI BELOW ROCKY CK CONFL	TP
RL-02452	CEDAR CK RES 0.15 MI SE OF S TIP PICKETT ISLAND	TP
RL-03351	CEDAR CREEK RESERVOIR 0.3 MI NE OF DAM AND W OF BIG ISLAND	TP
RL-03353	CEDAR CREEK RESERVOIR 1.9 MI SE OF GREAT FALLS AND E OF BIG ISLAND	TP
RL-03458	GREAT FALLS RSVR 1 MI NE OF GREAT FALLS	TP
RL-04375	CEDAR CREEK RESERVOIR 2.2 MI SE OF GREAT FALLS SE OF BOWDEN ISLAND	TP
RL-04379	CEDAR CREEK RESERVOIR 1.25 MI ESE OF GREAT FALLS NW OF HILL ISLAND	TP
CW-016F	FISHING CK RES 2 MI BL CANE CREEK	TP
CW-057	FISHING CK RES 75 FT AB DAM NR GREAT FALLS	TP
RL-01012	FISHING CK RES 3.8 M S OF FORT LAWN OFF W SHORE OF THE TOWN OF LAKE VIEW	CHL-A
RL-03332	GREAT FALLS RESERVOIR 0.9 MI NE OF GREAT FALLS	TN, TP
B-346 / CL-075	PARR RESERVOIR 4.8 KM N OF DAM, UPSTREAM MONTICELLO RESERVOIR	TP
SOUTHEASTERN PLAINS		
STATION ID(S)	**Location**	Parameters
CL-077	LAKE ASHWOOD, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	TN, CHL-A
C-058	LK INSPIRATION - ST MATTHEWS (FRONT OF HEALTH DEPT)	TN, TP
RL-04388 / SC-044	LAKE MARION 0.5 MI NE OF CALHOUN LANDING (USE SC-044)	TP
SC-005	UPPER LAKE MARION NEAR PACK'S LANDING	TP
SC-010	UPPER LAKE MARION AT CHANNEL MARKER 150	TP
SC-014	UPPER LAKE MARION @ HEADWATERS OF CHAPEL BRANCH CREEK	TP, CHL-A
SC-038	UPPER LAKE MARION @ THE MOUTH OF HALFWAY SWAMP CREEK	TP
SC-039	UPPER LAKE MARION 2.0 KM BELOW RIMINI RAILROAD TRESTLE	TP
ST-034 / RL-01002 / SC-008	LAKE MARION AT RR TRESTLE AT LONE STAR (SC-008)	TP
MIDDLE ATLANTIC COASTAL PLAIN		
STATION ID(S)	**Location**	Parameters
RL-03331	LAKE GEORGE WARREN 0.2 MI W OF SPILLWAY NE CORNER OF LAKE CLOSER TO LAKE WARREN ST PARK SHORELINE	TN, TP, CHL-A

Lake Sites Not Attaining Numeric Nutrient Criteria		
RL-03340	GOOSE CREEK RESERVOIR 1.0 MI NW OF SPILLWAY NEAR W SHORELINE	TP, CHL-A
RL-04390	GOOSE CREEK RESERVOIR 2.8 MI NW OF SPILLWAY NEAR OTRANTO	TP
ST-032 / CL-049	GOOSE CREEK RESERVOIR 100 M US OF DAM	TP, CHL-A
ST-033 / CL-050	GOOSE CK RESERVOIR AT 2ND POWERLINES US OF BOAT RAMP	TP, CHL-A

Lake Sites Attaining Numeric Nutrient Criteria	
BLUE RIDGE	
STATION ID(S)	**Location**
CL-019	LK JOCASSEE IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
SV-334	LK JOCASSEE, MAIN BODY
SV-335	LK JOCASSEE AT TOXAWAY, HORSE PASTURE, & LAUREL FORK CONFLUENCE
SV-336	LK JOCASSEE AT CONFLUENCE OF THOMPSON AND WHITEWATER RVRS
SV-337	LK JOCASSEE OUTSIDE COFFER DAM AT BAD CK PROJECT
RL-04380	LAKE KEOWEE, EASTATOE CREEK ARM 0.5 MI N OF KEOWEE/TOXAWAY STATE PARK
RL-01030	YONAH LAKE 0.8 M UPLAKE FROM YONAH DAM WHERE IT EMPTIES INTO TUGALOO RIVER
RL-04376	LAKE YONAH 0.65 MI NNE OF SPILLWAY
SV-358 / CL-014	LAKE YONAH, 50% BETWEEN CENTER OF SPILLWAY AND OPPOSITE SHORE
S-292	NORTH SALUDA RESERVOIR AT WATER INTAKE
S-291	TABLE ROCK RESERVOIR AT WATER INTAKE
SV-359 / RL-02320	TUGALOO LAKE, FOREBAY EQUIDISTANT FROM SPILLWAY AND SHORELINES
PIEDMONT	
STATION ID(S)	**Location**
B-347	LAKE BLALOCK IN FOREBAY NEAR DAM
RL-01019	LAKE BLALOCK 4 M SSW OF CHESNEE AND 0.3 M NE OF BUCK CREEK CHURCH
RL-02323	LAKE BLALOCK AT S-42-43
RL-03345	LAKE BLALOCK 0.1 MI SE BUCK CREEK CHURCH/S-42-189
RL-04363	LAKE BLALOCK 0.3 MI UPLAKE OF US 221
RL-04367	LAKE BLALOCK 0.9 MI UPLAKE OF US 221
RL-04389	LAKE BLALOCK 0.6 MI UPLAKE OF US 221
RL-04461	LAKE BLALOCK AT US 221
B-339 / CL-006	LAKE BOWEN 0.3 MI W OF SC 9
B-340 / CL-007	LAKE BOWEN NEAR HEADWATERS, 0.4 KM W OF S-42-37
RL-02455	LAKE BROADWAY 0.2 MI NW OF ALLEN PARK
B-343 / CL-028	LAKE CHEROKEE IN FOREBAY NEAR DAM
B-348 / RL-02325	LAKE COOLEY IN FOREBAY NEAR DAM
CL-033 / RL-04383	LAKE CRAIG 45 M NORTHWEST OF DAM
RL-01005	LAKE CRAIG IS IN CROFT STATE PARK 7.5 M SE OF SPARTANBURG
RL-01035	LAKE CRAIG IS IN CROFT STATE PARK 7.95 M SE OF SPARTENBURG
B-341 / CL-009 / RL-03347	LAKE CUNNINGHAM IN FOREBAY NEAR DAM
RL-02311	LAKE GREENWOOD 1.0 MI NW OF SEABOARD RR CROSSING
RL-04387	LAKE GREENWOOD 2.2 MI NW OF LAKE GREENWOOD STATE PARK
S-022	REEDY FORK OF LK GREENWOOD AT S-30-29
S-024	LAKE GREENWOOD, HEADWATERS, JUST US S-30-33
S-097	LAKE GREENWOOD - CANE CK ARM AT SC 72 3.1 MI SW CROSS HILL
S-131	LK GREENWOOD AT US 221 7.6 MI NNW 96
S-303	LAKE GREENWOOD 200 FT US OF DAM
S-307 / CL-051	LAKE GREENWOOD, RABON CK ARM, .8 KM N RD S-30-307
RL-01018	LAKE HARTWELL, 12 M WSW OF ANDERSON AND 3.5 M W OF ROBERTS CHURCH
RL-01020	LAKE HARTWELL 6 M NNW OF ANDERSON
RL-02315	LK HARTWELL 12.0 NW OF ANDERSON 2.0 MI N OF SADLERS CK ST PK
RL-02330	LK HARTWELL 0.4 MI SE OF OCONEE/ANDERSON CO LINE 5.0 M W OF SANDY SPRINGS
RL-03333	LAKE HARTWELL 3.9 MI NW OF SADLERS CREEK ST PARK
RL-03352	LK HARTWELL 0.9 MI NE ANDERSON/OCONEE/HART CO, GA JUNCTION
RL-03459	LK HARTWELL TUGALOO RVR ARM APPROXIMATELY 1.2 MI S OF JCT S-04-890 & S-04-23

Lake Sites Attaining Numeric Nutrient Criteria	
RL-04371	LAKE HARTWELL COVE 0.75 MI SE OF SADLERS CREEK STATE PARK
RL-04378	LAKE HARTWELL, SENECA RVR ARM 0.8 MI WNW OF CLEMSON LOOKOUT TOWER
SV-106	MARTIN CK ARM OF LAKE HARTWELL AT S-37-65 N OF CLEMSON
SV-107	LAKE HARTWELL - TWELVE MI CK ARM AT SC 133
SV-200	TUGALOO RVR ARM OF LAKE HARTWELL AT US 123
SV-236	LAKE HARTWELL AT S-37-184 6.5 MI SSE OF SENECA
SV-249	LAKE HARTWELL HEADWATERS, SENECA RVR ARM AT SC 183 3.8 MI WSW SIX MILE
SV-288	LK HARTWELL, SENECA RVR ARM AT USACE BUOY BTWN MRKRS S-28A & S-29
SV-339	LK HARTWELL, SENECA RVR ARM AT USACE BUOY BTWN S-14 AND S-15
SV-340	LK HARTWELL, MAIN BODY AT USACE WQ BUOY BTWN MRKRS 11 & 12
SV-363	LAKE HARTWELL OFF GLENN FORD LANDING US BEAVERDAM CK COVE
SV-360	LAKE ISSAQUEENA, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
RL-02304	LAKE KEOWEE 7.0 MI E OF WALHALLA
RL-03354	LAKE KEOWEE 1.6 MI NW OF SC 188 & 0.7 MI SE OF S-37-175
SV-311	LK KEOWEE AT SC 188 - CANE CK ARM 3.5 MI NW SENECA
SV-312	LK KEOWEE AT SC 188 - CROOKED CK ARM 4.5 MI N SENECA
SV-338	LK KEOWEE ABOVE SC ROUTE 130 AND DAM
SV-361	LK KEOWEE IN FOREBAY OF LITTLE RIVER DAM
B-099A	ON # 1 INLET LK LANIER IN GREENVILLE CO
B-099B	AT DAM LK LANIER IN GREENVILLE CO
B-344 / CL-038	LAKE JOHN D. LONG IN FOREBAY NEAR DAM
RL-01010	LAKE LONG 7.75 MI NE OF UNION AND 3.5 M W OF SUMTER NATIONAL FOREST
CL-083	LK MURRAY IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
RL-01023	LAKE MURRAY 9.3 M N OF GILBERT AND 0.75 M NNE FROM THE END OF S-32-443
RL-02316	LAKE MURRAY SW OF JAKES MARINA
RL-03334	LAKE MURRAY COVE 1.3 MI W OF BALLENTINE
RL-03338	LAKE MURRAY 0.8 MI S OF COUNTS ISLAND & 0.75 MI NW OF LUNCH ISLAND
RL-04372	LAKE MURRAY HOLLOW/HORSE CREEKS ARM 1.75 MI NNE OF US 378 CROSSING
S-204	LK MURRAY AT DAM AT SPILLWAY (MARKER 1)
S-211	HOLLANDS LANDING LK MURRAY OFF S-36-26 AT END OF S-36-3
S-212	MACEDONIA LANDING LK MURRAY AT END OF S-36-26 MACEDONIA
S-213	LAKE MURRAY AT S-36-15
S-223	BLACKS BR, LK MURRAY AT SC 391
S-273 / RL-04460	LK MURRAY AT MARKER 166
S-274	LK MURRAY AT MARKER 143
S-279 / RL-02318	LK MURRAY AT MARKER 63
S-280	LK MURRAY AT MARKER 102
S-310 / CL-080	LAKE MURRAY, SALUDA RVR ARM, US BUSH RVR, 3.8 KM US SC 391
RL-02307	LAKE OOLENOY SAMPLED FROM S SIDE OF SC 11 BRIDGE
S-798	LAKE OOLENOY AT DRAIN NEAR SPILLWAY AT SC 11
RL-01014	LAKE RABON 7.6 M W OF THE TOWN OF LAURENS
RL-02303	LAKE RABON NEAR NE SHORE AND BELOW US 76
RL-02305	LAKE RABON NEAR BOAT LANDING ON UNN CNTY RD OFF S-30-54
RL-03359	LAKE RABON 0.6 MI SE S-30-312
S-296 / CL-102 / RL-04381	LAKE RABON 300 FT US OF DAM
S-312 / CL-101	LAKE RABON, S RABON CK ARM, JUST DS S-30-312
S-313 / CL-103	LAKE RABON, N RABON CK ARM, 2.5 MI US DAM
CL-100	LAKE ROBINSON, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
RL-01025	LAKE ROBINSON 5.9 M NNW OF GREER (PREVIOUSLY THE SOUTH TYGER RIVER)
RL-02321	LAKE ROBINSON 6.3 MI NNW OF GREER
RL-02327	LAKE ROBINSON 0.4 MI S OF S-23-113
RL-02453	LAKE ROBINSON 0.7 MI S OF S-23-113
RL-03343	LAKE J ROBINSON IN COVE 0.5 MI SW OF S-23-113 CROSSING
RL-04361	LAKE ROBINSON 2.3 MI NNW OF DAM
RL-04365	LAKE ROBINSON 1 MI NNW OF DAM
SV-098 / RL-03337	LAKE RUSSELL AT SC 72 3.1 MI SW CALHOUN FALLS
SV-100	LAKE RUSSELL AT SC 181 6.5 MI SW STARR

Lake Sites Attaining Numeric Nutrient Criteria	
SV-357 / CL-098	LAKE RUSSELL, ROCKY RVR ARM BETWEEN MARKERS 48 & 49, DS FELKEL
SV-331 / CL-004	LK SECESSION, 1 1/4 MI BELOW SC ROUTE 28
SV-332 / CL-005	LK SECESSION APPROX 400 YDS ABOVE DAM
B-342 / CL-032 / RL-03457	LAKE THICKETTY IN FOREBAY NEAR DAM
RL-02301	LAKE THICKETTY NEAR SE SHORE APPROX 1.0 MI FROM MACEDONIA
CL-089	LK WATEREE IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
RL-01003	LAKE WATEREE 11.25 NW OF CAMDEN ON WESTERN SHORE OF LAKE
RL-01033	LAKE WATEREE 9.7 M NW OF CAMDEN, TOWARD THE SOUTHERN END OF THE LAKE
RL-03341	LAKE WELCHEL 2.7 MI NE OF GAFFNEY LAUNCH FROM GAFFNEY PUBLIC WORKS BOAT LANDING
CW-197	LAKE WYLIE AB MILL CK ARM AT END OF S-46-557
CW-198	LAKE WYLIE OUTSIDE MOUTH OF CROWDERS CK ARM
CW-200	LK WYLIE AT SC 274 9 MI NE OF YORK
CW-201	LK WYLIE N LAKEWOODS S/D AT EBENEZER ACCESS
CW-230	LAKE WYLIE AT DAM, UNDER POWERLINES
CW-245 / CW-665	LAKE WYLIE, CROWDERS CK ARM AT FIRST POWERLINES US OF MAIN POOL
RL-03339	LAKE WYLIE 0.1 MI W OF TEGA CAY SAMPLE CLOSER TO TEGA CAY SIDE
B-737	LAKE YORK IN KINGS MOUNTAIN STATE PARK
RL-03355	BROADWAY LAKE 0.5 NW OF SPILLWAY NEARSHORE OPPOSITE END OF S-04-152
SV-258	BROADWAY LAKE, NEALS CK ARM 50% BETWEEN BANKS AT GOLF COURSE
SV-319	BROADWAY LAKE, BROADWAY CK ARM UPSTREAM OF PUBLIC ACCESS
SV-321	BROADWAY LAKE FOREBAY, 50% BETWEEN SPILLWAY AND OPPOSITE LAND
RL-01017	CEDAR CK RES 2.5 M SE OF GREAT FALLS
CL-023	CHESTER STATE PARK LAKE 100 M EAST OF SPILLWAY
CL-039	LITTLE RIVER ARM OF CLARKS HILL RESERVOIR
CL-040	THURMOND (CLARKS HILL) RESERVOIR HEADWATERS (SAVANNAH RVR)
CL-041	THURMOND (CLARKS HILL) RESERVOIR IN FOREBAY NEAR DAM
RL-04385	THURMOND (CLARKS HILL) RESERVOIR COVE 0.5 MI SW OF HAMILTON BRANCH STATE PARK
SV-291	THURMOND (CLARKS HILL) RESERVOIR AT US 378 7 MI SW MCCORMICK
RL-01004	THURMOND (CLARKS HILL) RESERVOIR 0.65 M SW OF SC-81 LAKE BRIDGE ON SHORE NEAREST DELA HOWE SCHOOL
RL-01024	THURMOND (CLARKS HILL) RESERVOIR 1.5 M SE (ALONG SHORELINE) FROM US-378 BRIDGE BETWEEN GA AND SC
RL-01028	THURMOND (CLARKS HILL) RESERVOIR 0.4 M N OF THE DAM SEPERATING THE LAKE AND THE SAVANNAH RIVER
RL-01034	THURMOND (CLARKS HILL) RESERVOIR 4.9 M NE F MCCORMICK, NEAR BAKER CREEK STATE PARK
RL-02309	THURMOND (CLARKS HILL) RESERVOIR NEAR HAMILTON BRANCH ST PK
B-735	DUNCAN CREEK RESERVOIR 6B IN FOREBAY NEAR DAM
B-110	ELIZABETH LAKE AT SPILLWAY ON US 21
B-327	MONTICELLO LK-LOWER IMPOUNDMENT BETWEEN LARGE ISLANDS
B-328	MONTICELLO LK-UPPER IMPOUNDMENT AT BUOY IN MIDDLE OF LAKE
RL-04370	MONTICELLO LAKE 1.7 MI NW OF MONTICELLO
RL-04374	MONTICELLO LAKE 3.5 MI N OF JENKINSVILLE
B-345 / CL-074	PARR RESERVOIR IN FOREBAY NEAR DAM
RL-01015	SALUDA LAKE IS 5 M W OF GREENVILLE AND .8 M NE OF WESTWOOD CHURCH
RL-03349	SALUDA LAKE 0.9 MI SE SC 183 IN SMALL ARM
S-250	SALUDA LAKE AT FARRS BRDG ON SC 183 7 MI NE EASLEY
S-314 / CL-010	SALUDA LAKE, .5 MI US OF LANDING
B-113	SPARTANBURG RESERVOIR #1 ON S-42-213 NE OF INMAN
SV-294	STEVENS CK RESERVOIR HEADWATERS AT CLARKS HILL DAM BOAT RAMP
SOUTHEASTERN PLAINS	
STATION ID(S)	**Location**
C-025	LK CAROLINE SPILLWAY AT PLATT SPRINGS RD
CL-064	LAKE EDGAR BROWN IN FOREBAY NEAR DAM
CL-042 / SC-022	LAKE MARION FOREBAY, SPILLWAY MARKER 44 (SC-022)
RL-01001	LAKE MARION 2.5 M DIRECTLY SW OF I-95 BRIDGE (MIDDLE) OVER LAKE

Lake Sites Attaining Numeric Nutrient Criteria	
RL-01011 / SC-035	LAKE MARION 1.10 M SSE OF SANTEE NAT. WILDLIFE REFUGE AND 1MI S OF EAGLE POINT (SC-035)
RL-01016	LAKE MARION 1.6 M DIRECTLY SW OF I-95 BRIDGE (MIDDLE) OVER LAKE
RL-01021	LAKE MARION 3 M WSW OF EADYTOWN IN SE CORNER OF THE LAKE MARION
RL-01031	LAKE MARION 3.75 M DIRECTLY SW OF I-95 BRIDGE OVER LAKE MARION
RL-02306 / SC-012	LK MARION @ JACK'S CK EMBAYMENT; USE SANTEE COOPER SC-012
RL-02308 / SC-016	LK MARION @ CHANNEL MARKER 69; USE SANTEE COOPER SC-016
RL-02310	LAKE MARION NEAR SANTEE NATL WILDLIFE REFUGE
RL-03358	LAKE MARION 4.0 MI SE OF I-95
RL-03360	LAKE MARION 0.4 MI W OF DAM
RL-04382	LAKE MARION 1 MI DOWNLAKE OF I-95 BRIDGE IN OLD RIVER CHANNEL
RL-04384	LAKE MARION 3.8 MI W OF EADYTOWN
RL-04386	LAKE MARION EUTAW CREEK ARM NEAR CATHEAD BOAT RAMP
SC-017	MID LAKE MARION @ TAW CAW CREEK EMBAYMENT
SC-019	LOWER LAKE MARION @ POTATO CREEK FLOODED EMBAYMENT
SC-021	LOWER LAKE MARION, 1.5 KM NE OF ROCK'S POND CAMPGROUND
SC-023	LOWER LAKE MARION @ WYBOO CREEK FLOODED EMBAYMENT
SC-036	MID LAKE MARION @ THE MOUTH OF TAW CAW CREEK
SC-040	MID LAKE MARION @ CHANNEL MARKER 79
SC-041	MID LAKE MARION 3.2 KM NORTH OF CHANNEL MARKER 79
SC-042	MID LAKE MARION @ NORTH END OF I-95 / U.S. 301 BRIDGES
ST-024	LK MARION AT END OF S-14-64 AT CAMP BOB COOPER
ST-025 / SC-015	LK MARION AT OLD US 301/15 BRDG AT SANTEE (SC-015)
ST-036 / SC-023A	LK MARION, WYBOO CREEK ARM DS OF CLUBHOUSE BR (SC-023A)
CL-094	LK ROBINSON IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES FROM PRIVATE ACCESS
PD-327 / RL-03342	LK ROBINSON AT S-13-346 5 MI E MCBEE BY BOAT
CL-086	LAKE WALLACE, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
RL-02324	LAKE WALLACE S OF S-35-47
RL-04368	LAKE WALLACE 0.4 MI NNE OF FISHING PIER
CL-078	ADAMS MILLPOND, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
RL-03346	EUREKA LAKE IN CHERAW STATE PARK APPROX MID-LAKE
SV-686	FLAT ROCK POND IN FOREBAY NEAR DAM
C-068	FOREST LAKE AT DAM
SV-722 / RL-05419	GRANITEVILLE POND #2 IN FOREBAY NEAR DAM
CL-088	JUNIPER LAKE, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
CL-069	LANGLEY POND IN FOREBAY NEAR DAM
RL-02317	LANGLEY POND NEAR NW SHORE AND 0.6 MI NE OF SPWY
RL-03335	LANGLEY POND 0.05 MI OFF NW END OF DAM AND SHORELINE
RL-04373	LANGLEY POND 0.85 MI UPLAKE (NE) OF SPILLWAY
PD-081	PRESTWOOD LK AT US 15
PD-268	SONOVISTA CLUB HARTSVILLE OFF DOCK OF PRESTWOOD LK
CL-067	VAUCLUSE POND IN FOREBAY NEAR DAM
C-048	WINDSOR LK SPILLWAY ON WINSDOR LK BLVD
MIDDLE ATLANTIC COASTAL PLAIN	
STATION ID(S)	**Location**
RL-01009	LAKE WARREN IN STATE PARK 3.9 M SW OF HAMPTON
RL-01006	LAKE MOULTRIE 5.5 M N OF MONCKS CORNER AND 1.5 M NW OF CAMP MOULTRIE
RL-01026	LAKE MOULTRIE 4.5 M N OF MONCKS CORNER, 1.5 M NNE OF WHERE S-08-5 ENDS
RL-02322	LAKE MOULTRIE NE 3.0 MI FM BONNEAU BEACH
RL-02328	LAKE MOULTRIE SW NEAR DUCK PD AND APPROX 2.0 E OF CROSS
RL-02454	LAKE MOULTRIE SW IN OPEN WATER
RL-03348	LAKE MOULTRIE 5.25 MI NNW OF PINOPOLIS
RL-04362	LAKE MOULTRIE 2.2 MI SE OF CROSS
RL-04364	LAKE MOULTRIE 3.3 MI NW OF BONNEAU BEACH

Lake Sites Attaining Numeric Nutrient Criteria	
RL-04462	LAKE MOULTRIE 4.2 MI SW OF RUSSELLVILLE
SC-027	SW QUADRANT OF LAKE MOULTRIE 1.2 KM EAST OF SHORELINE
SC-028	NW QUADRANT OF LAKE MOULTRIE NEAR ANGEL'S LANDING COVE
SC-031	NORTH QUADRANT OF LAKE MOULTRIE @ MOUTH OF REDIVERSION CANAL
SC-032	SE QUADRANT OF LAKE MOULTRIE @ CHANNEL MARKER 2
SC-046	SE QUADRANT OF LAKE MOULTRIE AT PINOPOLIS EMBAYMENT
ST-037 / SC-030	LAKE MOULTRIE AT CHANNEL MARKER 17 (SC-030)
CL-062 / RL-02451	LAKE GEORGE WARREN IN FOREBAY NEAR DAM
CSTL-075 / RL-05415	LAKE WARREN, BLACK CK ARM, AT S-25-41 5 MI SW OF HAMPTON
CSTL-124	BACK RIVER RES IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES
RL-01008	GOOSE CK RES 2.3 M S OF GOOSE CREEK TOWN CENTER

Control Methods

NPDES permits and nonpoint source control programs, that were previously described in the Municipal and Industrial permitting sections, are designed to protect lake water quality. South Carolina's water classifications and criteria are applicable to lakes.

Restoration Efforts

Plans to restore and/or protect lake quality are integrated with the watershed water quality management approach and other watershed pollution control plans.

Acid Effects on Lakes

SCDHEC measures pH as part of its routine monitoring program at all lake sites. Acidic conditions, for the purposes of this report, existed in any lake for that pH was less than the appropriate State standard in more than 10% of samples. Five lakes, Windsor Lake in Richland County, the South Rabon Creek arm of Lake Rabon in Laurens County, the headwaters of Lake Wateree near Cedar Creek on the border of Lancaster and Fairfield Counties, Lake Welchel in Cherokee County, and the headwater area of Stephens Creek Reservoir in McCormick County were found to experience acidic conditions.

State water quality criteria specify, with few exceptions, a pH of at least 6.0 SU to protect classified and existing uses. EPA's Eastern Lake Survey reported high acid neutralizing capacity in Southern Blue Ridge region lakes, including those in northwestern South Carolina.

Toxic Effects on Lakes

As part of the State's probability-based monitoring all lake sites are monitored for metals and/or ammonia. In the Summary Statistics for this section, Table 10 lists causes for partial or non-support of lake classified uses, and Table18 lists the total size affected by toxicants. The section on Public Health: Aquatic Life Impacts contains a discussion of fish consumption advisories issued in South Carolina.

5. Estuary and Coastal Assessment

Based on a hydrographic GIS cover developed jointly by SCDHEC and the South Carolina Department of Natural Resources and the results of probability site selection validation, South Carolina has an estimated 277 combined square miles of tide creek and open water habitat representing the estuarine sampling design frame previously described.

A. Summary Statistics

A summary of classified use support statewide based on 120 probability-based monitoring sites sampled from 2001-2004, along with causes for partial or nonattainment, is presented below. The Lower and Upper 95 Percent Confidence Intervals for the probability-based estimates signify that it is 95% certain that the true mileage is between the upper and lower confidence limits.

Table 14. Estuaries Use Support Summary (Square Miles)

Indicator	Category	Probability-Based Estimated Percent of Total Resource	Probability-Based Estimated Square Miles of Total Resource	Lower 95 Percent Confidence Interval (Square Miles)	Upper 95 Percent Confidence Interval (Square Miles)
Aquatic Life Use	Fully Supporting	77.6%	215	194	236
	Partially Supporting	2.9%	8	0	17
	Not Supporting	19.5%	54	33	75
Recreational Use	Fully Supporting	99.8%	277	276	277
	Not Supporting	0.2%	0.7	0	1.7

Table 15. Summary of Fully Supporting and Impaired Estuaries (Not including Fish/Shellfish Consumption Use)

Category	Probability-Based Estimated Percent of Total Resource	Probability-Based Estimated Square Miles of Total Resource	Lower 95 Percent Confidence Interval (Square Miles)	Upper 95 Percent Confidence Interval (Square Miles)
Fully Supporting All Assessed Uses	77.6%	215	194	236
Impaired for One or More Use	22.4%	62	41	83

Table 16. Total Sizes of Estuaries Impaired by Various Cause Categories (Square Miles)

Cause Category	Probability-Based Estimated Square Miles of Total Resource	Lower 95 Percent Confidence Interval (Square Miles)	Upper 95 Percent Confidence Interval (Square Miles)
Turbidity	31.0	16.5	45.5
Dissolved Oxygen	21.1	8.1	34.2

Ammonia	4.0	0.0	10.4
Metals (Combined)	15.2	3.0	27.4
Copper	14.5	2.4	26.7
Zinc	0.7	0.0	1.7
Fecal Coliform Bacteria	0.7	0.0	1.7

6. Wetlands Assessment

A. Summary Statistics

Table 17. Extent of Wetlands, by Type

<table>
<tr><th>Wetland Type</th><th>Historical Extent in Acreage</th><th>1980's Reported Acreage</th><th>1994 Reported Acreage</th><th>Most Recent Acreage</th></tr>
<tr><td>Saturated Bottomland Forest</td><td rowspan="2">6,414,000</td><td rowspan="2">4,659,000</td><td>1,804,884</td><td>1,804,884</td></tr>
<tr><td>Nonforested Wetlands/Marsh</td><td>485,314</td><td>485,314</td></tr>
</table>

SCDHEC maintains a number of GIS land use coverages that include wetland acreages. SCDHEC and S.C. Department of Natural Resources (SCDNR) have derived land use/land cover data from SPOT satellite imagery from December 1988 to March 1990.

The National Land Cover Dataset or NLCD (SCDHEC GIS coverage last edited March 16, 2003) includes 15 classes (2 wetland classes) and was compiled from Landsat 5 Thematic Mapper satellite imagery with a spatial resolution of 30 meters and supplemented by a host of ancillary data. The NLCD was produced as a cooperative effort between the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (US EPA) to produce a consistent, land cover data layer for the coterminous U.S. using early 1990s (1991-1993) Landsat Thematic Mapper data purchased by the Multi-Resolution Land Characteristics (MRLC Consortium. The MRLC Consortium is a partnership of federal agencies that produce or use land cover data. Partners include the USGS (National Mapping, Biological Resources, and Water Resources Divisions), U.S. EPA, the U.S. Forest Service, and the National Oceanic and Atmospheric Administration.

Multi-Resolution Land Characteristics (MRLC) Consortium Home:
http://www.mrlc.gov/index.asp

National Land Cover Dataset Home:
http://landcover.usgs.gov/natllandcoverasp

The SC-GAP project mapped the State's natural and man-made vegetation to two classifications, a general 27-class (8 wetland classes) habitat map that was used in modeling vertebrate distributions, and a more detailed 54-class map (at least 21 wetland classes) in accordance with the National GAP guidelines of mapping to the alliance level where possible. The initial data used in developing the map was remotely sensed satellite data from the Multi-Resolution Land Characteristics (MRLC) Consortium.

Ancillary data included detailed soil surveys, National Wetlands Inventory surveys, and elevation maps to improve this classification and develop the 54-class land cover. This was aggregated into the habitat map for use in producing vertebrate distributions. From: "A Gap Analysis of South Carolina, 2001 Final Report"

A detailed National Wetlands Inventory mapping is current, but not yet complete for the State.

B. Extent of Wetlands Resources

A tracking system called Environmental Facilities Information System or EFIS has been adopted agency-wide. The Water Quality Certification, Standards, and Wetlands Programs Section has developed a module into which all Section 10 and Section 404/401 projects are entered. This module includes information on project location (latitude/longitude, basin, and watershed unit), purpose, types of impacts, acreage of wetland and non-wetland impacts, compensation requirements and location (latitude/longitude, basin, and watershed unit) and remediation requirements. Information regarding projects from the years of 1983 to the present has been entered into this tracking system. We are currently working to get this system operational and the data verified. Once this data has been verified, statistics on the location and types of wetland impacts in South Carolina will be available. Currently, maps of compensatory mitigation sites (1990 to present) are being digitized and entered into GIS for future analyses.

C. Integrity of Wetlands Resources

There is no specific legislation authorizing a statewide wetlands protection program. The primary mechanisms for wetlands protection in the state are federal and state regulatory programs for the discharge of dredged or fill material into waters of the state and for activities in the critical areas of the coastal zone.

Section 404 Permit Program - Section 404 of the Clean Water Act requires a permit for the discharge of dredged or fill material into navigable waters, including wetlands, throughout the United States. Certain activities, such as normal agriculture, silviculture and ranching activities, are exempt from such permit requirements. The United States Army Corps of Engineers (ACE) administers the Section 404 permitting program, but the EPA exercises final authority. The Agency can prohibit the use of a disposal area if the discharge will have an adverse impact on municipal water supplies, shellfish beds, fishing areas, wildlife, or recreational areas. No permit can be issued without a Section 401 Certification from SCDHEC's Division of Water Quality, and in coastal areas, a determination of consistency with the Coastal Zone Management Program (CZM) from SCDHEC's Office of Ocean and Coastal Resource Management (OCRM) is required. Other state and federal natural resource agencies, such as DNR, U. S. Fish and Wildlife Service, and National Marine Fisheries Service, provide input to decisions of the federal permitting agency and the state certifying agencies on proposed activities.

Section 404 permit authority can be delegated to states but South Carolina has elected not to assume that authority. In 1986, SCDHEC completed a study to determine the feasibility of assuming the Section 404 program. The study concluded that although SCDHEC had the legal authority and the technical expertise, it was not advisable to assume that authority because of the limited area of the jurisdiction involved. Perhaps more importantly, there would be no new funding from EPA to support assumption.

Section 401 Water Quality Certification - Section 401 of the Clean Water Act requires any applicant for a federal permit or license involved in an activity that may result in a discharge to navigable waters to receive certification from the state that the discharge will not cause violations of the state's water quality standards. Consequently, 401 Certification is required for all activities requiring a Section 404 permit from the ACE. This mechanism provides a State position on wetlands alterations.

The Division of Water Quality evaluated 605 projects that required a §401 Water Quality Certification in FYs 2000 through 2002. Approximately 23% of these projects involved impacts to wetlands. SCDHEC routinely requires compensation for wetland impacts at greater than a one to one basis. This compensation may be in the form of preservation, lineation, enhancement, or restoration and may not strictly meet the State and Federal "no net loss" goals.

SCDHEC administers certification programs using as guidance the South Carolina Pollution Control Act. S. C. Regulation 61-101, *Water Quality Certification*, guides the administration and technical review for the §401 Certification Program that determines if the standards of S. C. Regulation 61-68 will be met.

The S. C. Pollution Control Act provides authority for regulation of wetlands since it defines waters of the State as:

"lakes, bays, sounds, ponds, impounding reservoirs, springs, wells, rivers, streams, creeks, estuaries, marshes, inlets, canals, the Atlantic Ocean within the territorial limits of the State and all other bodies of surface or underground water, natural or artificial, public or private, inland or coastal, fresh or salt, that are wholly or partially within or bordering the State or within its jurisdiction."

This definition does not specifically list wetlands, but wetlands are included through the generic use of the word "marshes" as well as within the broad inclusion of the phrase "all other bodies of surface or underground water." Therefore, all water pollution control programs administered by SCDHEC apply to activities in wetlands.

During review of applications for §401 Certification, SCDHEC, with authority from S.C. Regulation 61-101, evaluates whether or not there are feasible alternatives to the activity that reduce adverse consequences on water quality and classified water uses, if the activity is water dependent, and the intended purpose of the activity. Certification is denied if the activity will adversely affect existing or designated uses. Certification is granted if water quality standards, that includes protection of existing uses, will not be violated. The federal permit cannot be issued if certification is denied.

Water Quality Certification, Nationwide Permits (NWP) - SCDHEC sent a Notice of Proposed Decision for the 2002 NWPs on February 28, 2002 to the ACE. SCDHEC proposed to deny NWPs: 15, 16, 17, 21, 34, and 35. In regard to NWP 17, SCDHEC currently reviews all applications for FERC licenses. The following NWPs were proposed for issuance with conditions: 3, 7, 12, 13, 14, 18, 19, 20, 22, 23, 27, 29, 30, 31, 32, 33, and 36 through 44. The most shared condition states that proposed impacts will not exceed 0.10 ac or 50 linear ft. of special aquatic sites including wetlands, or if exceeded a mitigation plan will be required; and, depending on the NWP some allowed impacts are capped at 0.25 ac or 100 linear ft. of stream. In March of 2000, the ACE proposed to replace NWP 26 with several "activity specific" NWPs and NWP 26 was placed on reserve. To take advantage of a NWP permit, the applicant must submit a wetlands delineation and, in some cases, a pre-construction notification to the ACE.

Wetlands losses can cause significant adverse, but avoidable, cumulative environmental impacts. Wetlands losses may lead to increased costs to the public for flood control and drinking water treatment. Moreover, wetlands are especially important in providing storm water filtration to maintain surface and ground water quality. Protection of wetlands is imperative if South Carolina is to achieve the goals of the Clean Water Act to restore and maintain the chemical, physical, and biological integrity of its waters.

D. Development of Water Quality Standards for Wetlands

S.C. Regulation 61-68 provides that waters not classified by name assume the classification of the waterbody to that they are adjacent. Wetlands contiguous to a stream or lake assume the classification of the waterbody to that they are contiguous. The standards allow variation from specific numeric standards if those variations are due to natural conditions. SCDHEC is continuing to evaluate the development of water quality classifications and standards specifically applicable to wetlands.

With funding from the EPA, SCDHEC developed classifications and standards for wetlands. The intent was that the system would augment the State's existing water quality classifications and standards to ensure greater protection of the State's wetlands through Clean Water Act programs.

Before proceeding with regulation development for the proposed classifications and standards for wetlands, there is the need to gain general agreement regarding wetlands protection policy and mechanisms in the State. Consensus-building among Federal, State, and local regulators with developers, farmers, forestry industry, and environmental groups would ensure acceptance of a clearly defined South Carolina wetlands protection policy. In 1993, SCDHEC received additional funding from EPA to further determine wetlands protection mechanisms and encourage consensus-building through education.

E. Additional Protection Activities

SCDHEC also uses antidegradation rules in S.C. Regulation 61-68 to evaluate applications for Water Quality Certification. The basic tenet of antidegradation is:

"existing uses and the level of water quality necessary to protect existing uses in all segments of a water body must be maintained"

Strict application of this water quality standard is impossible if there is to be any fill in wetlands. Therefore, the federal government determined that some fill in wetlands may be allowed pursuant to Section 404 of the Clean Water Act. S.C. Regulation 61-68 provided for this by adding a provision that states,

"Discharge of fill into waters of the State is not allowed unless the activity is consistent with Department regulations and will result in enhancement of classified uses with no significant degradation to the aquatic ecosystem or water quality".

Fill may only be allowed if it does not cause or contribute to significant degradation of the aquatic environment that can be determined by whether or not the activity will cause adverse effects on:

1. Human health or welfare;

2. Life stages of aquatic life or wildlife dependent upon the aquatic ecosystem;
3. Ecosystem diversity, productivity, and stability;
4. Recreational, aesthetic, and economic values.

7. Public Health - Aquatic Life Concerns

A. Sizes of Water Affected by Toxicants

Toxic pollutants in South Carolina's surface waters were assessed for this report through the evaluation of data collected through the statewide probability-based ambient monitoring program.

Table 18. Total Size Affected by Toxicants

Waterbody Type	Size Monitored for Toxicants	Probability-Based Estimate of Total Resource	Lower 95 Percent Confidence Interval	Upper 95 Percent Confidence Interval
Rivers (miles)	20,954	2,183	1,038	3,328
Lakes (acres)	308,765	494	60	927
Estuaries (square miles)	277.4	19.2	5.4	32.9

B. Public Health: Aquatic Life Impacts

Pollution Caused Fish Kills/Abnormalities

During 2004 there were 40 fish kills reported to SCDHEC and in 2005, 77 reports. Dissolved oxygen depletion, weather conditions, and other natural causes accounted for approximately 60 % of all fish kills in 2004 and 61% in 2005. In approximately 10% of the fish kills reported in 2004, and 15.5 % in 2005, the cause could not be determined. Approximately 17.5% of the fish kills investigated in 2004 and 22% in 2005 were from unnatural causes. Unnatural causes ranged from fish being caught and dumped back into lakes and streams to runoff of pesticides or oil/chemical spills or releases. One fish kill of an estimation of 4,655 fish occurred in the North Fork Edisto River in 2005 as a result of a sodium hydroxide (NaOH) spill into the river. This spill resulted in a lengthy investigation by both DHEC and DNR and culminated in a fine of $20,472.56 issued to the responsible party. Two minor kills of <1000 fish occurred in 2004 and 2 in 2005 as a result of pesticide or herbicide spraying.

Most investigations were conducted a day or more after the initial occurrence of the fish kill. Late reporting of fish kills to SCDHEC investigators hinders accurate determination of the cause of the fish kills.

The *Pfiesteria* program continues to be an important program in South Carolina with the coastal regional offices maintaining trained personnel to investigate *Pfiesteria* related incidents. For the 2004 and 2005 FY's, no fish kills could be linked directly to *Pfiesteria*. *Pfiesteria piscicida*, the only known form to kill fish, has not been detected in South Carolina waters.

There are no waters in the State that routinely experience fish kills or fish abnormalities due to toxics.

When fish kills do occur that can be attributed to other than natural causes, enforcement action is taken. The action usually takes the form of an administrative order and includes penalties commensurate with the violation. Schedules for corrective actions are included in the order along with appropriate assessment of monetary damage of the fish killed. As of May 31, 2001, SCDHEC required that its entire staff use its Field Manual for Investigation of Fish Kills.

Fish Consumption Advisories

SCDHEC uses a risk-based approach to evaluate contaminant concentrations in fish tissue and to issue consumption advisories in affected waterbodies. This approach contrasts the average daily exposure dose to the reference dose (RfD). Using these relationships, fish tissue data are interpreted by determining the consumption rates that would not be likely to pose a health threat to adult males and nonpregnant adult females. Because an acceptable RfD for developmental neurotoxicity has not been developed and because scientific studies suggest that exposure before birth may have adverse effects the health of infants, pregnant women, infants, and children are advised to avoid consumption of fish from any waterbody where an advisory has been issued.

Fish consumption advisories are updated annually in April. For background information and the most current advisories, please visit the Bureau of Water homepage at http://www.scdhec.gov/fish or call SCDHEC's Division of Health Hazard Evaluation, toll-free, at (888) 849-7241.

Shellfish Restrictions/Closures

The goal of SCDHEC's Shellfish Sanitation Program (SSP) is to ensure that mollusk and shellfish and areas from which they are harvested meet the health and environmental quality standards provided by federal and state regulations, laws, and guidelines. Additionally, SCDHEC promotes and encourages coastal quality management programs consistent with protected uses established through the S.C. Regulation 61-68, *Water Classifications and Standards*. SSP management policy is primarily determined by S.C. Regulation 61-47, *Shellfish*, as well as other State legislation. The National Shellfish Sanitation Program (NSSP) Model Ordinance, developed through participation in the Interstate Shellfish Sanitation Conference (ISSC) and endorsed by all shellfish producing states and the United States Food and Drug Administration (USFDA), is used as primary guidance for shellfish regulation development.

Sanitary surveys are conducted by SCDHEC to assess the quality of the coastal waters. These surveys result in shellfish harvesting classifications described as follows:

Approved: Growing areas shall be classified Approved when the sanitary survey concludes that fecal material, pathogenic microorganisms, and poisonous or deleterious substances are not present in concentrations that would render shellfish unsafe for human consumption. Approved area classification shall be determined upon a sanitary survey that includes water samples collected from stations in the designated area adjacent to actual or potential sources of pollution. For waters sampled under adverse pollution conditions, the median fecal coliform Most Probable Number (MPN) or the geometric mean MPN shall not exceed fourteen per one hundred milliliters, nor shall more than ten percent of the samples exceed a fecal coliform MPN of forty-three per one hundred milliliters (per five tube decimal dilution). For waters sampled under a systematic random sampling plan, the geometric mean fecal coliform Most Probable Number (MPN) shall not exceed fourteen per one hundred milliliters, nor shall the estimated ninetieth percentile exceed an MPN of forty-three (per five tube decimal dilution). Computation of the estimated ninetieth percentile shall be obtained using National Shellfish Sanitation Guidelines.

Conditionally Approved: Growing areas may be classified Conditionally Approved when they are subject to temporary conditions of actual or potential pollution. When such events are predictable as in the malfunction of wastewater treatment facilities, non-point source pollution from rainfall runoff, discharge of a major river, potential discharges from dock or harbor facilities that may affect water quality, a management plan describing conditions under that harvesting will be allowed shall be adopted by the Department, prior to classifying an area as Conditionally Approved. Where appropriate, the management plan for each Conditionally Approved area shall include performance standards for sources of controllable pollution, e.g., wastewater treatment and collection systems, evaluation of each source of pollution, and means of rapidly closing and subsequent reopening areas to shellfish harvesting. Memorandums of agreements shall be a part of these management plans where appropriate.

Restricted: Growing areas shall be classified Restricted when sanitary survey data show a limited degree of pollution or the presence of deleterious or poisonous substances to a degree that may cause the water quality to fluctuate unpredictably or at such a frequency that a Conditionally Approved area classification is not feasible. Shellfish may be harvested from areas classified as Restricted only for the purposes of relaying or depuration and only by special permit issued by the Department and under Department supervision. For Restricted areas to be utilized as a source of shellstock for depuration, or as source water for depuration, the fecal coliform geometric mean MPN of restricted waters sampled under adverse pollution conditions shall not exceed eighty-eight per one hundred milliliters nor shall more than ten percent of the samples exceed a MPN of two hundred and sixty per one hundred milliliters for a five tube decimal dilution test. For waters sampled under a systematic random sampling plan, the fecal coliform geometric mean MPN shall not exceed eighty-eight per one hundred milliliters nor shall the estimated ninetieth percentile exceed an MPN of two hundred and sixty (five tube decimal dilution). Computation of the estimated ninetieth percentile shall be obtained using National Shellfish Sanitation Guidelines.

Prohibited: Growing areas shall be classified Prohibited if there is no current sanitary survey or if the sanitary survey or monitoring data show unsafe levels of fecal material, pathogenic microorganisms, or poisonous or deleterious substances in the growing area or indicate that such substances could potentially reach quantities that could render shellfish unfit or unsafe for human consumption.

As a matter of SCDHEC policy, prohibited areas are established adjacent to all point source and/or marinas as a precaution to protect public health. These prohibited areas are not necessarily an indication of lesser water quality or that standards are not being met; rather, they are areas that have the potential for variable water quality.

South Carolina currently has approximately 571,014 estuarine/riverine surface acres classified for the harvest of molluscan shellfish. Of this total, Approved accounts for 67.5% of total acreage, Conditionally Approved – 1.4%, Restricted –18.7%, and Prohibited – 12.3%

Table 19. Summary of Shellfish Harvesting Status in South Carolina Shellfish Waters

Harvesting Status	Acreage	Percent
Approved	385542	67.5%
Conditionally Approved	8064	1.4%
Restricted	106975	18.7%
Prohibited	70433	12.3%
Total Assessed	571014	100.0%

Restrictions on Bathing Areas

There are currently fifty-eight (58) Natural Public Swimming Areas permitted for operation by SCDHEC. These areas are tested for Fecal Coliform (FC) bacteria prior to obtaining a yearly operating permit and are tested twice per month during the swimming season. The following swimming areas exceeded acceptable fecal coliform levels as specified in S.C. Regulation 61-50, *Natural Public Swimming Area.* Areas exceeding the specified parameters are closed until satisfactory sample results are collected. These are all fresh waters. Saltwater areas are addressed in the Ocean Water Quality Monitoring section.

Table 20. Areas of Bathing Restrictions

Natural Area	Frequency
Langley Pond Park	one time 07/01/02
Gem Lakes	recurrent 06/04/02, 09/03/02
Berkeley County Family YMCA – Swim Area A	recurrent 04/17/02, 04/30/02, 05/02/02, 05/21/02, 07/22/02, 07/24/02, 07/26/02
Berkeley County Family YMCA – Swim Area B	recurrent 05/21/02, 06/04/02, 07/22/02, 07/24/02, 07/25/02, 07/26/02
Somerset Point	one time 06/16/03
Paris Mountain State Park	recurrent 08/06/02, 06/03/03
Pleasant Ridge County Park	one time 05/07/03
Look-Up Lodge	recurrent 06/05/03, 06/06/03
Rocks Pond Campground	recurrent 07/08/02, 08/29/02

Ocean Water Quality Monitoring

Ocean water quality is currently monitored at a total of 125 sample sites along the South Carolina coast. Sampling frequency is based on beach Tier level. Tier 1 beaches are high use, high risk beaches. Tier 2 beaches are lower use and/or lower risk beaches. Tier 1 beaches are sampled weekly May 15 through October 15. Sampling is also conducted at Tier 1 beaches following significant rainfall. Tier 2 beaches are sampled twice per month May 15 through October 15. Advisories are issued based on EPA guidelines of 104 Enterococci per 100 ml or greater from two consecutive samples taken within 24 hours. Advisories are issued following a single sampling event if the Enterococcus level exceeds 500 colonies per 100 ml. Precautionary advisories are issued without sampling data based on historical knowledge of the effects of rainfall on specific areas. Advisories are retracted when Enterococcus counts return to below 104 colonies per 100 ml.

Table 21. Areas Affected by Beach Advisories

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
City of North Myrtle Beach	0.076	3	May/2004
City of North Myrtle Beach	0.076	7	June/2004
City of North Myrtle Beach	0.076	11	June/2004
City of North Myrtle Beach	0.19	2	July/2004

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
City of North Myrtle Beach	038	4	July/2004
City of North Myrtle Beach	0.076	4	July/2004
City of North Myrtle Beach	0.076	3	July/2004
City of North Myrtle Beach	0.076	3	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	0.076	3	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	0.076	3	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	8.5	5	Augustr/2004
City of North Myrtle Beach	0.076	6	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	0.076	11	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	0.076	3	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	8.5	5	August/2004
City of North Myrtle Beach	0.076	4	August/2005
City of North Myrtle Beach	0.076	3	August/2005
City of North Myrtle Beach	0.076	2	August/2005

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
City of North Myrtle Beach	0.076	3	August/2005
City of North Myrtle Beach	0.076	2	July/2005
White Point Swash	0.076	2	September/2004
White Point Swash	0.076	4	June/2004
White Point Swash	0.076	4	June/2004
White Point Swash	0.076	5	July/2004
White Point Swash	0.076	3	August/2004
White Point Swash	0.076	3	August/2004
White Point Swash	0.54	5	August/2004
White Point Swash	0.076	2	August/2004
White Point Swash	0.076	10	August/2004
White Point Swash	0.076	4	June/2003
White Point Swash	0.076	5	September/2004
White Point Swash	0.076	6	June/2005
White Point Swash	0.076	2	June/2005
White Point Swash	0.076	2	June/2005
White Point Swash	0.076	2	July/2005
White Point Swash	0.076	3	July/2005
White Point Swash	0.076	3	August/2005
White Point Swash	0.076	5	August/2005
White Point Swash	0.076	32	September/2005
White Point Swash	0.076	6	October/2005
Town of Briarcliffe Acres	0.076	2	September/2004
Town of Briarcliffe Acres	0.54	5	August/2004
Town of Briarcliffe Acres	0.076	3	August/2004
Town of Briarcliffe Acres	0.076	1	September/2004

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
Town of Briarcliffe Acres	0.076	2	September/2004
Town of Briarcliffe Acres	0.076	3	August/2005
Town of Briarcliffe Acres	0.076	5	October/2005
Arcadia Beach	3.47	5	August/2004
Arcadia Beach	3.47	5	August/2004
Arcadia Beach	0.076	3	August/2004
Arcadia Beach	3.47	5	August/2004
Arcadia Beach	0.076	4	June/2004
Arcadia Beach	0.076	7	June/2004
Arcadia Beach	0.076	4	August/2004
Arcadia Beach	0.076	4	August/2004
Arcadia Beach	3.47	5	August/2004
Arcadia Beach	0.076	10	September/2004
Arcadia Beach	0.076	3	September/2004
Arcadia Beach	0.076	5	September/2004
Arcadia Beach	0.076	6	June/2005
Arcadia Beach	0.076	14	June/2005
Arcadia Beach	0.076	4	July/2005
Arcadia Beach	0.076	5	July/2005
Arcadia Beach	0.076	5	August/2005
Arcadia Beach	0.076	8	August/2005
Arcadia Beach	0.076	4	September/2005
Arcadia Beach	0.076	4	September/2005
Arcadia Beach	0.076	2	September/2005
Arcadia Beach	0.076	9	October/2005
City of Myrtle Beach	9.77	3	June/2004
City of Myrtle Beach	0.076	5	June/2004

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
City of Myrtle Beach	0.076	2	June/2004
City of Myrtle Beach	0.076	8	July/2004
City of Myrtle Beach	0.076	8	July/2004
City of Myrtle Beach	0.076	4	July/2004
City of Myrtle Beach	0..076	2	July/2004
City of Myrtle Beach	9.77	3	July/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	9	August/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	5	August/2004
City of Myrtle Beach	0.076	3	October/2004
City of Myrtle Beach	0.076	4	August/2004
City of Myrtle Beach	0.076	4	August/2004
City of Myrtle Beach	0.076	5	August/2004
City of Myrtle Beach	0.076	4	August/2004
City of Myrtle Beach	0.076	4	August/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	9	August/2004
City of Myrtle Beach	0.076	3	September/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	3	July/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	3	July/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	2	August/2004
City of Myrtle Beach	0.076	2	September/2004

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
City of Myrtle Beach	0.076	2	June/2004
City of Myrtle Beach	0.076	3	June/2004
City of Myrtle Beach	0.076	2	July/2004
City of Myrtle Beach	0076	7	July/2004
City of Myrtle Beach	0076	5	July/2004
City of Myrtle Beach	0.076	7	August/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	3	August/2004
City of Myrtle Beach	0.076	8	August/2004
City of Myrtle Beach	0.076	3	September/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	2	June/2004
City of Myrtle Beach	0.076	2	June/2004
City of Myrtle Beach	0.076	2	June/2004
City of Myrtle Beach	0.076	7	July/2004
City of Myrtle Beach	0.076	5	July/2004
City of Myrtle Beach	9.77	5	August/2004
City of Myrtle Beach	0.076	9	August/2004
City of Myrtle Beach	0.076	3	September/2004
City of Myrtle Beach	0.076	7	May/2005
City of Myrtle Beach	0.076	7	May/2005
City of Myrtle Beach	0.076	6	June/2005
City of Myrtle Beach	0.076	6	June/2005
City of Myrtle Beach	0.076	2	June/2005
City of Myrtle Beach	0.076	5	June/2005
City of Myrtle Beach	0.076	2	June/2005
City of Myrtle Beach	0.076	3	June/2005

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
City of Myrtle Beach	0.076	3	June/2005
City of Myrtle Beach	0.076	3	June/2005
City of Myrtle Beach	0.076	3	July/2005
City of Myrtle Beach	0.076	4	July/2005
City of Myrtle Beach	0.076	4	July/2005
City of Myrtle Beach	0.076	7	July/2005
City of Myrtle Beach	0.076	2	July/2005
City of Myrtle Beach	0.076	4	July/2005
City of Myrtle Beach	0.076	4	July/2005
City of Myrtle Beach	0.076	4	July/2005
City of Myrtle Beach	0.076	4	July/2005
City of Myrtle Beach	0.076	5	August/2005
City of Myrtle Beach	0.076	5	August/2005
City of Myrtle Beach	0.076	5	August/2005
City of Myrtle Beach	0.076	6	August/2005
City of Myrtle Beach	0.076	3	August/2005
City of Myrtle Beach	0.076	5	August/2005
City of Myrtle Beach	0.076	5	August/2005
City of Myrtle Beach	0.076	5	August/2005
City of Myrtle Beach	0.076	5	August/2005
City of Myrtle Beach	0.076	8	August/2005
City of Myrtle Beach	0.076	9	August/2005
City of Myrtle Beach	0.076	9	August/2005
City of Myrtle Beach	0.076	10	August/2005
City of Myrtle Beach	0.076	4	August/2005
City of Myrtle Beach	0.076	4	August/2005
City of Myrtle Beach	0.076	4	August/2005

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
City of Myrtle Beach	0.076	3	August/2005
City of Myrtle Beach	0.076	3	August/2005
City of Myrtle Beach	0.076	3	August/2005
City of Myrtle Beach	0.076	2	August/2005
City of Myrtle Beach	0.076	2	September/2005
City of Myrtle Beach	0.076	4	September/2005
City of Myrtle Beach	0.076	4	September/2005
City of Myrtle Beach	0.076	3	September/2005
City of Myrtle Beach	0.076	4	September/2005
City of Myrtle Beach	0.076	4	September/2005
City of Myrtle Beach	0.076	23	September/2005
City of Myrtle Beach	0.076	2	September/2005
City of Myrtle Beach	0.076	2	September/2005
City of Myrtle Beach	0.076	2	September/2005
City of Myrtle Beach	0.076	5	October/2005
City of Myrtle Beach	0.076	5	October/2005
City of Myrtle Beach	0.076	6	October/2005
City of Myrtle Beach	0.076	9	October/2005
City of Myrtle Beach	0.076	4	October/2005
City of Myrtle Beach	0.076	4	October/2005
City of Myrtle Beach	0.076	4	October/2005
City of Myrtle Beach	0.076	4	October/2005
City of Myrtle Beach	0.076	4	October/2005
City of Myrtle Beach	0.076	2	October/2005
City of Myrtle Beach	0.076	2	October/2005
City of Myrtle Beach	0.076	2	October/2005
City of Myrtle Beach	0.076	2	October/2005

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
City of Myrtle Beach	0.076	3	October/2005
City of Myrtle Beach	0.076	3	October/2005
City of Myrtle Beach	0.076	3	October/2005
City of Myrtle Beach	0.076	3	October/2005
Springmaid Beach	0.33	5	August/2004
Springmaid Beach	0.33	4	August/2005
SC State Park	3.4	5	August/2004
SC State Park	0.076	4	June/2004
SC State Park	0.076	4	July/2004
SC State Park	0.076	5	July/2004
SC State Park	0.076	4	August/2004
SC State Park	3.4	5	August/2004
SC State Park	0.076	2	August/2004
SC State Park	0.076	9	August/2004
SC State Park	0.076	3	September/2004
SC State Park	0.076	3	June/2004
SC State Park	0.076	3	July/2004
SC State Park	3.4	5	August/2004
SC State Park	0.076	2	August/2004
SC State Park	0.076	4	July/2004
SC State Park	0.076	2	August/2004
SC State Park	3.4	5	August/2004
SC State Park	0.076	6	August/2004
SC State Park	0.076	2	September/2004
SC State Park	1.79	5	August/2004
SC State Park	1.79	5	August/2004
SC State Park	0.076	2	September/2004

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
SC State Park	0.076	10	May/2005
SC State Park	0.076	4	June/2005
SC State Park	0.076	2	June/2005
SC State Park	0.076	2	June/2005
SC State Park	0.076	3	July/2005
SC State Park	0.076	3	July/2005
SC State Park	0.076	3	July/2005
SC State Park	0.076	4	July/2005
SC State Park	0.076	7	July/2005
SC State Park	0.076	3	July/2005
SC State Park	0.076	2	July/2005
SC State Park	0.076	5	July/2005
SC State Park	0.076	4	August/2005
SC State Park	0.076	4	August/2005
SC State Park	0.076	4	August/2005
SC State Park	0.076	7	August/2005
SC State Park	0.076	2	August/2005
SC State Park	0.076	4	August/2005
SC State Park	0.076	5	August/2005
SC State Park	0.076	5	August/2005
SC State Park	0.076	5	August/2005
SC State Park	0.076	6	August/2005
SC State Park	0.076	7	August/2005
SC State Park	0.076	7	August/2005
SC State Park	3.4	4	August/2005
SC State Park	0.076	7	September/2005
SC State Park	0.076	7	September/2005

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
SC State Park	0.076	6	October/2005
SC State Park	0.076	4	October/2005
Town of Surfside Beach	0.076	2	May/2005
Town of Surfside Beach	0.076	7	May/2005
Town of Surfside Beach	0.076	7	May/2005
Town of Surfside Beach	0.076	7	May/2005
Town of Surfside Beach	0.076	7	May/2005
Town of Surfside Beach	0.076	6	June/2005
Town of Surfside Beach	0.076	4	June/2005
Town of Surfside Beach	0.076	3	June/2005
Town of Surfside Beach	0.076	3	June/2005
Town of Surfside Beach	0.076	3	June/2005
Town of Surfside Beach	0.076	4	July/2005
Town of Surfside Beach	0.076	2	July/2005
Town of Surfside Beach	0.076	2	July/2005
Town of Surfside Beach	0.076	2	July/2005
Town of Surfside Beach	0.076	5	July/2005
Town of Surfside Beach	0.076	3	July/2005
Town of Surfside Beach	0.076	3	July/2005
Town of Surfside Beach	0.076	3	July/2005
Town of Surfside Beach	0.076	4	August/2005
Town of Surfside Beach	0.076	4	August/2005
Town of Surfside Beach	0.076	4	August/2005
Town of Surfside Beach	0.076	4	August/2005
Town of Surfside Beach	0.076	4	August/2005
Town of Surfside Beach	0.076	2	August/2005
Town of Surfside Beach	0.076	5	August/2005

Area Affected	Miles of Beach Affected	Days Posted	Month/Year
Town of Surfside Beach	0.076	6	August/2005
Town of Surfside Beach	0.076	6	August/2005
Town of Surfside Beach	0.076	6	August/2005
Town of Surfside Beach	0.076	8	August/2005
Town of Surfside Beach	0.076	3	August/2005
Town of Surfside Beach	0.076	3	August/2005
Town of Surfside Beach	0.076	4	September/2005
Town of Surfside Beach	0.076	4	September/2005
Town of Surfside Beach	0.076	4	September/2005
Town of Surfside Beach	0.076	4	September/2005
Town of Surfside Beach	0.076	4	September/2005
Town of Surfside Beach	0.076	4	September/2005
Town of Surfside Beach	0.076	7	September/2005
Town of Surfside Beach	0.076	5	October/2005
Town of Surfside Beach	0.076	5	October/2005
Town of Surfside Beach	0.076	5	October/2005
Town of Surfside Beach	0.076	5	October/2005
Town of Surfside Beach	0.076	8	October/2005
Town of Surfside Beach	0.076	4	October/2005
Garden City Beach	0.076	3	September/2004
Garden City Beach	0.076	2	August/2005
Garden City Beach	0.076	2	August/2005

C. Public Health: Drinking Water

Restrictions in Surface Drinking Water Supplies and Incidents of Waterborne Diseases

There were no Notices of Violation (NOV) issued to systems during the period of July 2003 - June 2004 for Treatment Technique and Monitoring and Reporting violations under the Stage 1 Disinfectants/Disinfection Byproducts and Surface Water Treatment Rules. The State reported two (2) exceedances of the Maximum Contaminant Level (MCL) for one (1) system for Trihalomethanes (THMs) and eleven (11) exceedances of the MCL for five (5) systems for Haloacetic Acids (HAAs). The state reported no incidences of waterborne disease during the same period.

There were eleven (11) Notices of Violation (NOV) issued to seven (7) systems during the period of July 2004 - June 2005 for Treatment Technique and Monitoring and Reporting violations under the Stage 1 Disinfectants/Disinfection Byproducts and Surface Water Treatment Rules. The State reported six (6) exceedances of the Maximum Contaminant Level (MCL) for four (4) systems for Trihalomethanes (THMs) and no exceedances of the MCL for Haloacetic Acids (HAAs). The state reported no incidences of waterborne disease during the same period.

GROUNDWATER ASSESSMENT

Groundwater is the source of drinking water for more than 40 percent of the population of the State. This resource is also used by agricultural, industrial, and commercial interests. The policy of the State of South Carolina, with respect to groundwater protection, is founded on the belief that there is a direct connection between land use and groundwater quality, and that at least some activities of man will always impact groundwater, regardless of the regulatory safeguards employed. Because it is an expensive and technologically complex task to restore contaminated groundwater to its original pristine state within a reasonable time frame, a justifiable goal of any groundwater protection strategy is to protect the present and future uses of the resource.

SCDHEC maintains a primary long term objective for groundwater protection. As expressed in the S.C. Regulation 61-68, *Water Classifications and Standards*.

"It is the goal of the Department to maintain or restore groundwater quality so it is suitable as a drinking water source without any treatment. Recognizing the technical and economic difficulty in restoring groundwater quality, the Department will emphasize a preventive approach in protecting groundwater."

This goal fulfills the Core Adequacy Criteria #1 of Strategic Activity 1 in the implementation of the Comprehensive State Groundwater Protection Program (CSGWPP).

The groundwater quality data are to be presented in a series of tables and it is recognized that all states do not have all the information requested at this time. Therefore this year's report serves as a template by that future monitoring and reporting can be designed. The data presented were assembled from existing reports: the state wide ambient groundwater quality monitoring network, the groundwater contamination inventory that is updated annually, the volatile organic compound (VOC) monitoring program for public supply wells, and reports from domestic well owners.

1. Overview of Groundwater Contamination Sources

The major sources of contamination impacting groundwater are presented in Table 22. Underground storage tank (UST) releases account for 3493 of the 4214 total instances. The additional nine sources indicated were the next most numerous instances. Another factor indicated was human health and/or environmental risk for those sources for petroleum products and hazardous waste. The size of the population at risk was also indicated for USTs given the large number of releases. The next column on Table 22 indicates the contaminants associated with the highest priority sources. Petroleum compounds, halogenated solvents, metals and nitrates are the contaminants most frequently detected.

Table 22. Major Sources of Groundwater Contamination

Contaminant Source	Ten Highest-Priority Sources (T)	Factors Considered in Selecting a Contaminant Source	Contaminants
Agricultural Activities			
Agricultural chemical facilities			
Animal feedlots			
Drainage wells			
Fertilizer applications			
Irrigation practices			
Pesticide applications			
Storage and Treatment Activities			
Land application	T	D	E
Material stockpiles			
Storage tanks (above ground)	T	D,A	D
Storage tanks (underground)	T	D,A,B	D
Surface impoundments	T	D	C,E
Waste piles			
Waste tailing			
Disposal Activities			
Deep injection wells			
Landfills	T	D	C,D,H
Septic systems			
Shallow injection wells			
Other			
Hazardous waste generators	T	D,A	C,H
Hazardous waste sites	T	D,A	C,H
Industrial facilities	T	D	C,E
Material transfer operations			
Mining and mine drainage	T	A,C	A,M Acid mine drainage
Pipeline and sewer lines			
Salt storage and road salting			

Contaminant Source	Ten Highest-Priority Sources (T)	Factors Considered in Selecting a Contaminant Source	Contaminants
Salt water intrusion			
Spills	T	D	D
Transportation of materials			
Urban runoff			
Other sources (please specify)			
Other sources (please specify)			

1. Check (T) up to 10 contaminant sources identified as highest priority in your State.

2. Specify the factor(s) used to select each of the contaminant sources. Denote the following factors by their corresponding letter (A through G) and list in order of importance. Describe any additional or special factors that are important within your State in the accompanying narrative.

   A. Human health and/or environmental risk (toxicity)
   B. Size of the population at risk
   C. Location of the sources relative to drinking water sources
   D. Number and/or size of contaminant sources
   E. Hydrogeologic sensitivity
   F. State findings, other findings
   G. Other criteria (please add or describe in the narrative)

3. List the contaminants/classes of contaminants considered to be associated with each of the sources that was checked. Contaminants/contaminant classes should be selected based on data indicating that certain chemicals may be originating from an identified source. Denote contaminants/classes of contaminants by their corresponding letter (A through M).

   A. Inorganic pesticides
   B. Organic pesticides
   C. Halogenated solvents
   D. Petroleum compounds
   E. Nitrate
   F. Fluoride
   G. Salinity/brine
   H. Metals
   I. Radionuclides
   J. Bacteria
   K. Protozoa
   L. Viruses
   M. Other (please add or describe in the narrative)

Tables 23, 24, 25 and 26 were designed to report the stress that contaminated sites place on individual aquifers or hydrogeologic settings. The report on each identified aquifer is further subdivided by type of source based on program area, contaminants present, and degree of remediation accomplished thus far. South Carolina's major drinking water aquifers are in the subsurface of the Coastal Plain. The sources and contaminants indicated in Table 22 are generally present in the near surface, shallowest aquifers. At this point, contamination data is gathered on a site by site basis, rather than by aquifer. Thus, portions of these tables can be completed for the Piedmont saprolite/bedrock and the Coastal Plain water table aquifers only. The number of confirmed groundwater contamination cases that have been identified in the Coastal Plain is 2828 and 1385 have been confirmed in the Piedmont. This number was obtained by counting the sites county by county.

Table 23. Groundwater Contamination Summary

Aquifer Description: Above Fall Line
Aquifer Setting: Saprolite/Bedrock Aquifer
Data Reporting Period: Ending July 2001

Source Type	Present in reporting area	Number of sites in area	Number of sites that are listed and/or have confirmed releases	Number with confirmed ground water contamination	Contaminants
NPL	YES		13	13	C,H
CERCLIS (non-NPL)	YES		40	40	C,H
DOD/DOE	YES		11	11	D,C,H
LUST	YES		1100	1100	D
RCRA Corrective Action	YES		27	27	C,H
Underground Injection	NO	0	0	0	
State Sites	YES		37	37	C,H,A,B,D
Nonpoint Sources	YES		2	2	E
Other (specify)	YES		157	157	C,D,E,H
Totals			1387	1387	

NPL - National Priority List
CERCLIS (non-NPL) - Comprehensive Environmental Response, Compensation, and Liability Information System
DOE - Department of Energy
DOD - Department of Defense
LUST - Leaking Underground Storage Tanks
RCRA - Resource Conservation and Recovery Act

List of Contaminants:

A. Inorganic pesticides
B. Organic pesticides
C. Halogenated solvents
D. Petroleum compounds
E. Nitrate
F. Flouride
G. Salinity/brine
H. Metals
I. Radionuclides
J. Bacteria
K. Protozoa
L. Viruses
M. Other (please add or describe in the narrative)

Table 24. Groundwater Contamination Summary (above fall line)

Source Type	Number of Site Investigations (optional)	Number of sites that have been stabilized or have had the source removed (optional)	Number of sites with corrective action plans (optional)	Number of sites with active remediation (optional)	Number of sites with cleanup completed (optional)
NPL					
CERCLIS (non-NPL)					
DOD/DOE					
LUST					
RCRA Corrective Action					
Underground Injection					
State Sites					
Nonpoint Sources					
Other (specify)					

NPL - National Priority List
CERCLIS (non-NPL) - Comprehensive Environmental Response, Compensation, and Liability Information System
DOE - Department of Energy
DOD - Department of Defense
LUST - Leaking Underground Storage Tanks
RCRA - Resource Conservation and Recovery Act

Table 25. Groundwater Contamination Summary (2)

Aquifer Description: Below Fall Line
Aquifer Setting: Coastal Plain
Data Reporting Period: Ending July 2001

Source Type	Present in reporting area	Number of sites in area	Number of sites that are listed and/or have confirmed releases	Number with confirmed ground water contamination	Contaminants
NPL	YES		15	15	C,H
CERCLIS (non-NPL)	YES		65	65	C,H
DOD/DOE	YES		170	170	C,D,H
LUST	YES		2313	2313	D
RCRA Corrective Action	YES		27	27	C,H
Underground Injection	NO	0	0	0	
State Sites	YES		35	35	C,D,A,B,D
Nonpoint Sources	YES		8	8	E
Other (specify)	YES		196	196	C,D,E,H
Totals			2829	2829	

NPL - National Priority List
CERCLIS (non-NPL) - Comprehensive Environmental Response, Compensation, and Liability Information System
DOE - Department of Energy
DOD - Department of Defense
LUST - Leaking Underground Storage Tanks
RCRA - Resource Conservation and Recovery Act

List of Contaminants:

A. Inorganic pesticides
B. Organic pesticides
C. Halogenated solvents
D. Petroleum compounds
E. Nitrate
F. Flouride
G. Salinity/brine
H. Metals
I. Radionuclides
J. Bacteria
K. Protozoa
L. Viruses
M. Other (please add or describe in the narrative)

Table 26. Groundwater Contamination Summary (below fall line)

Source Type	Number of Site Investigations (optional)	Number of sites that have been stabilized or have had the source removed (optional)	Number of sites with corrective action plans (optional)	Number of sites with active remediation (optional)	Number of sites with cleanup completed (optional)
NPL					
CERCLIS (non-NPL)					
DOD/DOE					
LUST					
RCRA Corrective Action					
Underground Injection					
State Sites					
Nonpoint Sources					
Other (specify)					

NPL - National Priority List
CERCLIS (non-NPL) - Comprehensive Environmental Response, Compensation, and Liability Information System
DOE - Department of Energy
DOD - Department of Defense
LUST - Leaking Underground Storage Tanks
RCRA - Resource Conservation and Recovery Act

Each source type is listed in each area with the exception of underground injection as waste or contaminant injection, which is not permitted in this state. The "state" sites are state Superfund sites. The "Nonpoint Source" category contains spray irrigation sites only at this time. Pesticide and nitrate monitoring data is gathered by Clemson University, Department of Fertilizer and Pesticide Control. The "other" category includes spills and leaks; pits, ponds and lagoons; landfills; unpermitted disposal; aboveground storage tanks; and septic tanks/tile fields. The "number of sites in the area" is left blank because any number of facilities can be potential sources and that data is not tracked at this time. The number of sites that have confirmed groundwater contamination are listed along with the contaminants (using the contaminant classes from Table 22). The remediation status represented by Tables 24 and 26 is not fully completed because that information is not recorded in that format in all program areas.

2. Overview of Groundwater Protection Programs

The state's groundwater protection programs are summarized and characterized in Table 27. The Groundwater Working Group, which is comprised of SCDHEC's groundwater program managers, was formed to provide consistency across the programs.

Table 27. Summary of State Groundwater Protection Programs

Programs or Activities	Check (Y)	Implementation Status	Responsible State Agency
Active SARA Title III Program	Y	**Fully Established**	**SCDHEC/BL&WM/Emergency Response**
Ambient groundwater monitoring system	Y	**Fully Established**	**SCDHEC/BOW/GWM**
Aquifer vulnerability assessment	Y	**Under Development**	**SCDHEC/BOW/GWM**
Aquifer mapping	Y	**Continuing Efforts**	**DNR-SCDHEC/BOW/GWM**
Aquifer characterization	Y	**Continuing Efforts**	**DNR-SCDHEC/BOW/GWM**
Comprehensive data management system	Y	**Under Development**	**DNR-SCDHEC**
EPA-endorsed Core Comprehensive State Groundwater Protection Program (CSGWPP)	Y	**Under Development**	**SCDHEC/BOW/GWM**
Groundwater discharge permits	Y	**Fully Established**	**SCDHEC/BOW**
Groundwater Best Management Practices	Y	**Under Development**	**SCDHEC/BOW/IAWD**
Groundwater legislation	Y	**Continuing Efforts**	**SCDHEC-DNR**
Groundwater classification	Y	**Fully Established**	**SCDHEC/BOW**
Groundwater quality standards	Y	**Under Revision**	**SCDHEC**
Interagency coordination for groundwater protection initiatives	Y	**Under Development**	**SCDHEC-DNR-Clemson Univ.**
Nonpoint source controls	Y	**Under Development**	**SCDHEC/BOW**
Pesticide State Management Plan	Y	**Under Development**	**SCDHEC/BOW/GWM-Clemson Univ.**
Pollution Prevention Program	Y	**Fully Established**	**SCDHEC/BL&WM**
Resource Conservation and Recovery Act (RCRA) Primacy	Y	**Fully Established**	**SCDHEC/BL&WM**
State Superfund	Y	**Fully Established**	**SCDHEC/BL&WM/CERCLA**
State RCRA Program incorporating more stringent requirements than RCRA primacy		**Not Applicable**	
State septic system requirements	Y	**Fully Established**	**SCDHEC/ENV. HEALTH**
Underground storage tank installation requirements	Y	**Fully Established**	**SCDHEC/BL&WM/UST Program**
Underground Storage Tank Remediation Fund	Y	**Fully Established**	**SCDHEC/BL&WM/UST Program**
Underground Storage Tank Permit Program	Y	**Fully Established**	**SCDHEC/BL&WM/UST Program**
Underground Injection Control Program	Y	**Fully Established**	**SCDHEC/BOW/GWM**
Vulnerability assessment for drinking water/wellhead protection	Y	**Fully Established**	**SCDHEC/BOW/GWM**

Programs or Activities	Check (Y)	Implementation Status	Responsible State Agency
Well abandonment regulations	Y	**Fully Established**	**SCDHEC/BOW**
Wellhead Protection Program (EPA-approved)	Y	**Fully Established**	**SCDHEC/BOW/GWM**
Well installation regulations	Y	**Fully Established**	**SCDHEC/BOW**

Implementation of the Comprehensive State Ground-Water Protection Program (CSGWPP) is the major initiative undertaken since the last 305(b) report. The draft Core CSGWPP was completed and submitted to the Region IV EPA, Groundwater 106 Program, comments from EPA have been received. The Source Water Assessment and Protection Plan was approved to EPA Region IV. The Groundwater Contamination Inventory and the Ambient Groundwater Quality Monitoring Report were also completed last quarter.

3. Summary of Groundwater Quality

Aquifer Monitoring Data are presented in Tables 28 and 29. The state's ambient quality monitoring network is designed to develop a baseline for groundwater quality for each of the aquifers within the state. The wells were selected in areas to avoid known or potential contamination in order to test the assumption that variability in water chemistry reflects differences in geologic framework and/or spatial setting. In addition, neither VOCs nor SOCs are included in the analytical parameters. Accordingly, no data from the ambient monitoring network is included in Tables 28 and 29.

Table 28. Aquifer Monitoring Data

Aquifer Description____________
Aquifer Setting ____________

County(ies) (optional)
Longitude/Latitude (optional)
Data Reporting Period

			Number of Wells			
Monitoring Data Type	Total No. of Wells Used in the Assessment	Parameter Groups	No detections of Parameters above MDLs of background levels		No detections of parameters above MDLs or background levels and nitrate concentrations range from background levels to less than or equal to 5 mg/l.	
			ND	Number of Wells in Sensitive or Vulnerable Areas (optional)	ND/Nitrate # 5 mg/l	Number of wells in sensitive or vulnerable areas (optional)
Ambient Monitoring Network (optional)		VOC				
		SOC				
		NO				
		Other				
Raw Water		VOC				

Quality Data from Public Water Supply Wells		SOC				
		NO				
		Other				
Finished Water Quality Data from Public Water Supply Wells		VOC	1314		41	
		SOC	1252		22	
		NO	4343		4222	
		Other				

Table 29. Aquifer Monitoring Data (2)

Aquifer Description___________
Aquifer Setting ___________

County(ies) (optional)
Longitude/Latitude (optional)
Data Reporting Period

Number of Wells				
Parameters are detected at concentrations exceeding the MDL but are less than or equal to the MCLs and/or nitrate ranges from greater than 5 to less than or equal to 10 mg/l	Parameters are detected at concentrations exceeding the MCLs	Removed from Service	Special Treatment	Background parameters exceed MCLs
Finished Water Quality Data from Public Water Supply Wells	VOC			
	SOC			
	NO			
	Other			

4. Summary of Groundwater/Surface Water Interactions

The Drinking Water Program reports that no Public Water Supply well is under the influence of surface water. Although there are anecdotal reports of groundwater in wells being heavily pumped showing signs of influence by surface water, no instance of groundwater being impacted by surface water has been confirmed.

As groundwater serves to recharge most of the streams in South Carolina, instances where contaminated groundwater impacts surface water are more prevalent. In the Groundwater Contamination Inventory 131 cases of contaminated groundwater discharging from the surficial aquifer to surface water have been noted. A table was not included in this report because contaminant concentration levels in both the aquifer and surface water are not available. It is surmised that, due to dilution, levels in the surface water are very low or not detectable in most cases.

References

South Carolina Department of Health and Environmental Control. 1998. Laboratory Procedures Manual for Environmental Microbiology. Bureau of Environmental Services, Columbia, S.C.

South Carolina Department of Health and Environmental Control.2005. Procedures and Quality Control Manual for Chemistry Laboratories. Bureau of Environmental Services, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. Office of Environmental Quality Control. Columbia, SC.

South Carolina Department of Health and Environmental Control. 2004. Water Classifications and Standards (Regulation 61-68) and Classified Waters (Regulation 61-69) for the State of South Carolina. Office of Environmental Quality Control, Columbia, S.C.

South Carolina Department of Health and Environmental Control. 2005. State of South Carolina Monitoring Strategy for Calendar Year 2005. Technical Report 003-05. Bureau of Water Pollution Control, Columbia, S.C.

United States Environmental Protection Agency. 1992. National Toxics Rule, December 22, 1992. Federal Register Reference 57FR60848.

For Section 2.3.3

A draft 2006 303(d) list is available below for review and comment. Please submit written comments to the attention of Richelle Tolton, Bureau of Water, SCDHEC, 2600 Bull Street, Columbia, South Carolina 29201. To be considered, written comments on the draft list must be received by 5:00 PM on March 6, 2006.

- **2006 303(d) Draft List** - State of South Carolina Integrated Report Part I: Listing of Impaired Waters (PDF-435KB)

- **2004 303(d) List** - State of South Carolina Integrated Report Part I: Listing of Impaired Waters (PDF-341 KB)
  - **2004 305(b) Report** - State of South Carolina Integrated Report Part II: Assessment and Reporting
- **2002 303(d) List** (PDF-463 KB)
- **2000 303(d) List** (PDF-235 KB)
  - *Supplement to the 2000 303(d) List* - January 2001 (PDF-128KB)
  - *Supplement concerning Enoree River (BE-017)* - October 2001 (PDF-59K)
  - *Supplement to the 2000 303(d) List* - January 2002 (PDF-280KB)
- **1998 303(d) List**

Links

Exit DHEC Links to non-DHEC organizations found at this site are provided solely as a service to our users. The links do not constitute an endorsement of these organizations or their programs. DHEC is not responsible for the content of the individual organization web pages found at these links.

185

EPA Region IV TMDL Program
SCDHEC Watershed Management Program

EPA BASINS Training for TMDL Development
Hosted by: Utah State University http://www.tmdl.org/basins/

Contact: Mihir Mehta

Sect. 2.3.3 sec]

The State of South Carolina's 2006 Integrated Report
Part I: Listing of Impaired Waters

INTRODUCTION

The South Carolina Department of Health and Environmental Control (Department) developed this priority list of waterbodies pursuant to Section 303(d) of the Federal Clean Water Act (CWA) and Federal Regulation 40 CFR 130.7 last revised in 1992. The listing identifies South Carolina waterbodies that do not currently meet State water quality standards after application of required controls for point and nonpoint source pollutants. Use attainment determinations were made using water quality data collected from 2000-2004. Pollution severity and the classified uses of waterbodies were considered in establishing priorities and targets. The list will be used to target waterbodies for further investigation, additional monitoring, and water quality improvement measures, including Total Maximum Daily Loads (TMDLs).

Over the past three decades, impacts from point sources to waterbodies have been substantially reduced through point source controls achieved via National Pollutant Discharge Elimination System (NPDES) permits. Since 1990, steady progress in controlling nonpoint source impacts has also been made through implementation of South Carolina's Nonpoint Source Management Program. In conjunction with TMDL development and implementation, the continued expansion and promotion of these and other state and local water quality improvement programs are expected to be effective in reducing the number of impaired waterbodies.

In compliance with 40 CFR 25.4(c), the Department, beginning February 3rd 2006, issued a public notice in statewide newspapers, to ensure broad notice of the Department's intent to update its list of impaired waterbodies. Public input was solicited. The notice included a person to contact for information regarding the development of the list and asked for comments regarding the draft listing and methodology. The notice allowed for a minimum thirty day comment period in which to respond. The Department also provided direct notice to interested parties, including environmental groups, industries, private individuals, local governments, universities, research groups, federal agencies, other state agencies, and the USEPA. The Department also posted the public notice and the draft list on its Internet website. A copy of the notice of availability of the draft listing is provided in Appendix A. A summary of comments and responses will be provided in Appendix B.

Additional public input was solicited through regular interactions between Department staff, interested members of the public, and other resource agencies. Bureau of Water Watershed Managers have regular interaction with stakeholders throughout the eight major river basins during stakeholder meetings, educational events, and individual contact sessions. Through this process valuable information is received which supports list development and TMDL prioritization. Public participation in the §303(d) process will continue in accordance with the Department's watershed approach.

Part II of the integrated submittal makes use of the identical data and assessment methodology that follows; therefore, no separate consideration of the 305(b) report is required for these listings. In consideration of EPA's Assessment Data Base (ADB) initiative all 303(d) listed assessment units have been included in South Carolina's portion of that repository for the first time.

METHODOLOGY FOR DELISTING WATERBODIES FROM THE 2004 §303(d) LIST

The Department reviewed the final 2004 §303(d) list as the starting point for the development of the 2006 §303(d) list. All waterbodies on the 2004 §303(d) listing were evaluated for appropriate inclusion on the 2006 §303(d) list as defined in 40 CFR 130.2(j).

Good cause for delisting of waterbodies from the 2004 §303(d) list include the following: 1) the most recent data and information indicate that water quality standards are being met, 2) a TMDL has been developed and approved, and 3) the listing analysis conducted for the 2004 list contained errors (e.g., laboratory reporting error, QA/QC requirements not met, legal ruling). Any one or combination of these reasons may be used by the Department to delist waters.

For this list, a new 12-digit hydrologic unit code was instituted. All waterbodies appear on the 2006 §303(d) list under the new watershed code. Waterbodies listed for "BIO" (biological impairment, cause unknown) on the 2004 list have been removed for BIO if a pollutant responsible for the impairment has been identified. These waterbodies remain on the list for that pollutant and TMDLs will be developed for the pollutant of concern. Other waterbodies have been removed from the list when biological data have shown full use support despite other chemical and/or physical standards excursions.

Waterbodies that appeared on the 2004 §303(d) list that do not meet these justifications for delisting remain on the 2006 §303(d) list.

METHODOLOGY FOR LISTING: THE SOUTH CAROLINA 2006 §303(d) LIST

In accordance with federal guidelines, the Department evaluated waterbodies identified as impaired for appropriate inclusion on the 2006 §303(d) list. The Department uses a watershed approach, as encouraged in the August 8, 1997, EPA Guidance Memorandum: New Policies for Establishing and Implementing Total Maximum Daily Loads, to perform its permitting and water quality monitoring. This approach divides the state into five major river basin groups. Permitting and monitoring are performed according to a schedule that cycles through all basins in a five-year period. Information on SCDHEC's Watersheds Program can be found at: http://www.scdhec.gov/water/.

The Department has an extensive fixed ambient surface water monitoring network throughout the state with more than 650 stations. The SCDHEC monitoring effort also includes over 450 shellfish sanitation stations, 75 aquatic macroinvertebrate stations, approximately 100 fish tissue stations, and several phytoplankton stations. Since 2002 a set of probability-based, or "random" sampling, stations has been added to the Department's water quality monitoring strategy. The use of this sampling methodology enhances the ability to make statistically valid inferences about large watershed areas based on a relatively few sampling stations. In collaboration with USEPA, numerous random stations are incorporated in the Department's monitoring program each year. DHEC's total monitoring effort for the assessment used for this 303(d) list included over 1400 stations and 209,000 water quality tests. DHEC's monitoring strategy can be found on the Internet at http://www.scdhec.gov/eqc/water/pubs/strategy.pdf.

The cyclical nature of the Department's permitting, monitoring, and data analysis results in a dynamic §303(d) listing. As new waters are monitored, new impaired sites may be discovered which require listing. As a result of increased monitoring, some waterbodies have been added to the 2006 §303(d) list. In compliance with water quality standards (SC Regulation 61-68), waterbodies with standards excursions attributable solely to natural conditions are not included on South Carolina's 303(d) list.

The Department has considered the South Carolina Short List of waterbodies which was prepared in 1989 pursuant to Section §304(l) of the CWA. This "one-time" §304(l) Short List identified waterbodies where the State did not expect applicable water quality standards to be achieved after technology-based requirements had been met due entirely or substantially to point source discharges of §307(a) toxics. The §304(l) Short List was considered as required, but not used for development of the 2006 §303(d) list since those water quality problems have already been addressed. If current data and information on water quality for the specific water bodies included on the 1989 §304(l) list ever indicate less than full support of uses, they will be included on the 303(d) list.

Sources of Data and Information and Their Use

For this listing cycle, the Department actively solicited data and information for the specific purpose of §303(d) listing. The Department has a standing data solicitation year round. This solicitation can be found on DHEC's website at: http://www.scdhec.gov/water/tmdl. This solicitation contains links and contacts to DHEC's Office of Quality Assurance for information regarding data specifications.

In addition, a solicitation notice was directly emailed to all state institutions known to collect environmental data (e.g., research universities). A copy of the solicitation notice is provided (Appendix C). Traditionally multiple sources of information have been considered when compiling the South Carolina §303(d) list. The Department has reviewed a comprehensive assemblage of sources of readily available data and information, including federal agencies, local governments, 319 project grantees, academic institutions, electric utilities, NPDES compliance contractors, and volunteer monitoring groups. SCDHEC considered data from North Carolina and Georgia with common water bodies. In addition, SCDHEC monitors water quality at the state line and in specific locations within North Carolina and Georgia.

The following data sources were considered for the 2006 303(d) listing:

DHEC: Environmental Quality Control

- Water chemistry and biological data from over 1225 surface water and sediment monitoring sites
- Approximately 465 shellfish growing monitoring sites
- Fish, oyster, and crab tissue monitoring data
- Stream macroinvertebrate assessments
- Lake water quality assessment data (§314)
- Environmental Surveillance Oversight Program (Savannah River Site)
- State Nonpoint Source Management Plan (§319)
- §304(l) Short List
- State Watershed Water Quality Assessments

- Special studies or general knowledge

Other biological data

- Adler Biological Consulting
- Coastal Science Associates, Inc.
- E.T.T. Environmental, Inc.
- North Carolina Department of Environment and Natural Resources
- Shealy Environmental Services, Inc.
- South Carolina Public Service Authority (Santee Cooper)
- Swearingen Ecology Associates
- United States Fish and Wildlife Service
- South Carolina Department of Natural Resources

Other tissue data

- Georgia Department of Natural Resources
- National Marine Fisheries Service
- United States Environmental Protection Agency
- North Carolina Department of Environment and Natural Resources
- Florida Department of Environmental Protection
- University of Texas

Other chemical and bacteriological data

- United States Geological Survey
- Haile Mining Company
- Breedlove Dennis Young and Associates, Inc.
- Clemson University Extension Service
- Friends of Lake Keowee Society
- Lower Saluda River Scenic Advisory Council
- Coastal Carolina University
- University of South Carolina
- National Oceans and Atmospheric Administration
- Furman University
- Clemson University
- Newberry Soil and Water Conservation District
- Research Planning Institute Inc.
- Lancaster Soil and Water Conservation District
- Pee Dee RC&D Council
- City of Isle of Palms
- Horry County
- Santee Cooper Public Service Authority

Other Water Quality Information

- Lake Murray Association
- Wateree Homeowners' Association

The Department's Quality Assurance Management Plan (QAMP) has been approved by the EPA as part of its requirements under Section 106 of the CWA. All data and information sources used for the 2006 §303(d) list were reviewed in accordance with the QAMP. All data and information used were readily accessible and met the Department's criteria for quality assurance. A checklist of QA/QC considerations used by the Department can be found at:

http://www.scdhec.gov/water/pubs/qaqc.pdf

The following is a brief description of how the above data and information were used by the Department to support determinations for aquatic life, recreation, and other designated uses.

DETERMINATION OF ATTAINMENT OF CLASSIFIED USES

Physical, chemical, and biological data were evaluated, as described below, to determine if water quality met the criteria established to protect the State classified uses as promulgated in Regulation 61-68, Water Classifications and Standards. These regulations are subject to a triennial review as required in section 303 of the Clean Water Act. To determine the appropriate classified uses and water quality criteria for specific waterbodies and locations, refer to Regulation 61-69, Classified Waters, in conjunction with Regulation 61-68. These regulations are located on the Internet at: http://www.scdhec.gov/water under Laws and Regulations.

Most data were used on the basis of a minimum five year assessment period. Trend analysis was considered using up to 15 years of data. Less current data may still be the basis for listing previously listed sites where no new data was collected.

The use attainment decision process follows the basic approach set forth in the USEPA guidance for the preparation of state §305(b) water quality assessments.

A more detailed discussion of DHEC's use attainment determination methodology is contained in Appendix D.

Aquatic Life Use Support

One important goal of the Clean Water Act and state standards is to maintain the quality of surface waters to provide for the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Aquatic life use support is assessed by comparing important water quality characteristics to criteria. Support of aquatic life uses is determined based on the percentage of criteria excursions and, where data are available, the composition and functional integrity of the biological community. Among the parameters assessed are: dissolved oxygen, pH, toxicants (priority pollutants, heavy metals, ammonia), nutrients, and turbidity. If the conclusion for any one parameter is that the criterion is not met, then it is concluded that aquatic life use is not supported and the waterbody is thus listed as impaired.

A number of waterbodies have been given waterbody-specific criteria for pH and dissolved oxygen, which reflect natural conditions. To determine the appropriate criteria and classified uses for specific waterbodies and locations, please refer to Regulation 61-68, Water Classifications and Standards, and Regulation 61-69, Classified Waters.

For D.O. and pH, if 10 percent or less of the samples contravene the appropriate criterion, then the criterion is said to be fully supported. A percentage of criterion excursions greater than 10% indicates impairment and results in inclusion on the current 303(d) list, unless excursions are due to natural conditions as described further below.

For toxicants such as heavy metals, priority pollutants, ammonia, etc., if the appropriate acute and chronic aquatic life criterion is exceeded more than once in five years, the waterbody is listed as impaired.

For turbidity in all waters, and for waters with numeric total phosphorus, total nitrogen, and/or chlorophyll-a criteria, if the appropriate criterion is exceeded in more that 25 percent of the samples, the criterion is not supported and the waterbody is listed as impaired. For waters with contraventions of standards between 10% and 25%, further site specific evaluation is necessary to determine if standards violations indicate actual aquatic life use impairment.

For aquatic life uses, the goal of the standards is the protection of a balanced indigenous aquatic community. Therefore, biological data are generally considered as the deciding factor, regardless of chemical conditions. South Carolina Regulation 61-68 Section E. 12 d. (2) states that if the ambient concentration is higher than the numeric criterion for toxic pollutants, the criterion is not considered violated if biological monitoring has demonstrated that the in-stream indigenous biological community is not adversely impacted. Section E. 15 b. states that biological assessment methods may be employed in other appropriate situations to assess and ensure the maintenance of a balanced indigenous aquatic community. These sections from the State water quality standards regulation provide the Department with discretion in data assessment for compliance with water quality standards. There are some waterbodies where the Department has gathered both chemical and biological data. After evaluation of the data, the Department has in some instances made the decision that the aquatic life use is fully supported based upon the biological data. As always when there is conflicting data, the Department will continue to carefully monitor these waters to ensure that all applicable water quality standards are met.

Additionally, as stated in Appendix D, certain state waters, such as blackwater systems in the Sandhills and Coastal Plain are frequently characterized by naturally low pH and D.O. concentrations, as are many tidally influenced systems along the coast. The Department used biological community data as a factor in determining whether pH and D.O. excursions represent natural conditions. On a case-by-case basis, departmental staff also considered other factors such as land use, and critical hydrology in assessing use attainment at individual locations where natural conditions were potentially involved. The Department does not believe that it is appropriate to develop TMDLs for these sites, per Regulation 61-68 Section C. 9.

In the assessment of biological data, aquatic and semi-aquatic macroinvertebrates are identified to the lowest practical taxonomic level depending on the condition and maturity of specimens collected. The EPT Index (Ephemeroptera, Plecoptera, Trichoptera) and the North Carolina Biotic Index (BI) are the main indices used in analyzing macroinvertebrate data. A habitat evaluation is conducted at each biological monitoring site, and is considered in the aquatic community assessment score.

Recreational Use Support

The degree to which the swimmable goal of the Clean Water Act is attained (Recreational Use Support) is based on the frequency of fecal coliform bacteria excursions. Standards for primary contact recreation were derived from public health data that estimate the potential risks to humans of contracting waterborne illnesses after swimming due to exposure to sewage-related pathogens. For all waters classified for recreational use support, South Carolina R.61-68 requires a geometric mean and instantaneous fecal coliform bacteria standard for both fresh and salt waters;

"Not to exceed a geometric mean of 200/100ml, based on five consecutive samples during any 30 day period; nor shall more than 10% of the total samples during any 30day period exceed 400/100 ml".

The standard is protective of primary contact recreational use; therefore, secondary contact recreational use is also protected.

For fecal coliform bacteria. If 10 percent or less of the samples exceed the instantaneous criteria then recreational uses are said to be fully supported. A percentage of criteria excursions greater than 10% indicates impairment of recreational uses and the waterbody is listed.

Some South Carolina coastal beaches are monitored for enterococcus levels. Advisories are issued for the period in which elevated levels persist. These advisories do not warrant listing for 303(d) purposes.

Fish and Shellfish Consumption

Fish consumption use support is determined by the occurrence of advisories on human consumption for a given waterbody. For the support of consumption uses, an advisory which prohibits or restricts fish consumption indicates nonsupport of uses. Shellfish use support is determined by the harvesting status for a given shellfish harvesting area. For harvesting uses, an advisory that prohibits or restricts shellfish harvesting indicates nonsupport of uses.

Fish consumption advisories and shellfish sanitation information are updated periodically. For background information and the most up-to-date advisories please visit the DHEC Bureau of Water webpage at http://www.scdhec.gov/water/ and click on "Advisories" beneath the Water Program Index. For shellfish growing area status reports click on "Shellfish Information".

Summary of Sites With Water Quality Measures Attaining Criteria

A list of monitoring sites and water quality measures attaining criteria will be contained in Appendix E.

TMDL Development: Methodology for Targeting Impaired Waterbodies

The *Integrated Report Part I: Listing of Impaired Waters* serves to identify those sites that need additional management actions to meet water quality standards. TMDL (Total Maximum Daily Load) development is one way in which the Clean Water Act §303(d) was intended to promote these management actions. TMDLs will be developed for all §303(d) listed sites pursuant to EPA guidance.

A TMDL is a calculation of the maximum amount of a specific pollutant that a waterbody can receive and still meet water quality standards. It is the sum of the allowable loads of a given pollutant from all contributing point and nonpoint sources. It also incorporates a margin of safety and consideration of seasonal variation. For an impaired waterbody, the TMDL document specifies the level of pollutant reductions needed for waterbody use attainment. Targeting for TMDL development is necessary to focus limited technical and monetary resources. As per Federal regulation 40CFR 130.7(b)(4), TMDLs targeted for completion over the next two years were based on the following factors:

> Severity of pollution
> Classified Use
>Aquatic endangered species: Species present and potentially adversely affected by a pollutant.
> Adequacy of existing and readily available data and information for TMDL development
> Adequacy of existing technical tools for TMDL development
> Hydrologic connection, allowing "nesting" or "bundling" of TMDLs
> Identified funding or cooperators
> Degree of public interest and support for improvement of the waterbody
> Ongoing activities and water quality related initiatives in the watershed
> Recreational, economic, and aesthetic importance
> Other national and departmental priorities and policies

In cooperation with EPA Region IV, SCDHEC Bureau of Water has developed TMDLs. At the time of publication of this list over 320 TMDLs in South Carolina have been approved by EPA. An updated listing of approved and draft TMDLs can be found at DHEC's TMDL webpage: http://www.scdhec.gov/water/tmdl.

These approved TMDLs have been incorporated into the Department's Continuing Planning Process in accordance with Section 303(e) of the Clean Water Act. TMDL development is continuing.

TMDL IMPLEMENTATION

DHEC Watershed Program staff has initiated a process for implementation of approved TMDLs. The Department's TMDL implementation program also includes stakeholder involvement and funding assistance. Periodically, requests for proposals are made for projects that will implement the nonpoint source components of existing TMDLs. Interested persons may send a message to npsgrants@dhec.sc.gov to be notified of grant opportunities.

As of February 2006 eighteen such TMDL implementation projects have been funded addressing 87 TMDLs. Implementation of TMDLs involving point sources is occurring through departmental NPDES permitting mechanisms. South Carolina's TMDL implementation plan for nonpoint sources can be viewed on the web at:

http://www.scdhec.gov/eqc/water/html/npsplan.html

LIST OF IMPAIRED WATERS

The South Carolina 2006 §303(d) list follows. Waterbodies are listed by point locations; however, the impairment is considered to extend for some distance upstream and/or downstream of the point location listed. The extent of the impairment of the waterbodies is determined during TMDL development and implementation.

The column headings included on the South Carolina 2006 list of impaired waters refer to the following:

BASIN – One of eight major basins contained in the State

HUC - Hydrologic Unit Code, a sub-basin unit in which the water body is located

LOCATION – Name and brief description of the location of the impaired waterbodies

STATION – The Department's station code where samples were collected

COUNTY – County in which station is located

USE – Use support impairment for aquatic life and/or recreational uses

Aquatic Life Use: AL
Fish Consumption: FISH
(For information on the full extent of fish advisories, see the current Fish Consumption Advisories on our website at http://www.scdhec.gov/fish)
Recreational Use (Swimming): REC
Shellfish Harvesting: SHELLFISH
(For information on the current shellfish harvesting areas status, see the current Annual Update Reports on our website at http://www.scdhec.gov/water/html/shellfish.html)

CAUSE – Pollutant(s) that resulted in impaired classified use. The parameters are denoted as follows:

Chlorophyll A: CHLA
Chromium: CR
Mercury: HG
Copper: CU
Dissolved Oxygen: D.O.
Fecal Coliform Bacteria: FC
Hydrogen Ion Concentration: PH
Total Nitrogen: TN
Cadmium: CD
Macroinvertebrate: BIO
Turbidity: TURBIDITY
Total Phosphorus: TP
Polychlorinated Biphenyls: PCB
Nickel: NI
Zinc: ZN
Organotins: ORGANOTINS

NOTE –
* TMDL to be developed within two years
# Further investigation planned

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	BROAD	030501050805	BUFFALO CK AT SC 5 1 MI W OF BLACKSBURG	B-057	CHEROKEE	AL	CU
	BROAD	030501050902	KINGS CREEK AT S-11-209, 3 MI W OF SMYRNA	B-333	CHEROKEE	REC	FC
	BROAD	030501051002	LITTLE THICKETTY CREEK AT S-42-307 1.2 MI NE OF COWPENS	RS-04376	SPARTANBURG	AL	BIO
	BROAD	030501051002	LITTLE THICKETTY CREEK AT S-42-307 1.2 MI NE OF COWPENS	RS-04376	SPARTANBURG	REC	FC
	BROAD	030501051003	GILKEY CK AT S-11-231, 9 MI SE OF GAFFNEY	B-334	CHEROKEE	AL	BIO
	BROAD	030501051101	CLARK FORK INTO CRAWFORD LK ON UN# RD NEAR SC 161 & 705-KINGS MT	B-325	YORK	AL	DO
	BROAD	030501051203	OBED CREEK AT UNNUMBERED CHRISTOPHER ROAD OFF SC 11	RS-03514	SPARTANBURG	AL	BIO
	BROAD	030501051203	OBED CREEK AT UNNUMBERED CHRISTOPHER ROAD OFF SC 11	RS-03514	SPARTANBURG	REC	FC
	BROAD	030501051301	MOTLOW CRK. AT SR 888	B-790	SPARTANBURG	AL	BIO
	BROAD	030501051401	LAWSONS FK CK AT S-42-40 BL INMAN MILL EFF	B-221	SPARTANBURG	AL	BIO
	BROAD	030501051401	MEADOW CRK. AT SR 56	B-531	SPARTANBURG	AL	BIO
*	BROAD	030501051401	MEADOW CK AT S-42-822	RS-02320	SPARTANBURG	REC	FC
	BROAD	030501051402	LAWSONS FORK CK AT S-42-108	BL-001	SPARTANBURG	AL	BIO
	BROAD	030501051501	LAKE BLALOCK 0.1 MI SE BUCK CREEK CHURCH/S-42-18(	RL-03345	SPARTANBURG	REC	FC
	BROAD	030501051502	LAKE BLALOCK AT US 221	RL-04461	SPARTANBURG	AL	CU
	BROAD	030501051504	POTTER BR ON RD 30 BL OUTFALL FROM HOUSING PROJ COWPENS	B-191	SPARTANBURG	AL	DO, PH
	BROAD	030501051505	MILL CREEK AT SR 73	B-780	UNION	AL	BIO
	BROAD	030501051601	BROAD RVR AT SC 18 4 MI NE GAFFNEY	B-042	CHEROKEE	AL	CU
	BROAD	030501051602	CHEROKEE CREEK AT SC 329	B-679	CHEROKEE	AL	BIO
	BROAD	030501051602	LAKE WELCHEL 2.7 M N OF GAFFNEY	RL-01029	CHEROKEE	AL	CHLA
	BROAD	030501051602	LAKE WELCHEL 2.7 MI NE OF GAFFNEY LAUNCH FROM GAFFNEY PUBLIC WORKS BOAT LANDING	RL-03341	CHEROKEE	AL	PH
	BROAD	030501060102	ROSS BR TO TURKEY CK AT SC 49 SW OF YORK	B-086	YORK	AL	TURBIDITY
	BROAD	030501060105	TURKEY CK AT SC 9, 14 MI NW OF CHESTER	B-136	CHESTER	AL	BIO
	BROAD	030501060202	DRY FORK AT S-12-304 2 MI SW OF CHESTER	B-074	CHESTER	AL	DO
	BROAD	030501060302	MENG CK AT SC 49 2.5 MI E OF UNION	B-064	UNION	AL	PH
	BROAD	030501060302	BROWNS CK AT S-44-86, 8 MI E OF UNION	B-155	UNION	AL	BIO
	BROAD	030501060302	TRIB TO MENG CK AT CLVT ON S-44-384 3 MI E OF UNION	B-243	UNION	AL	PH
	BROAD	030501060303	CLARKS CREEK (TRIBUTARY TO BROAD RIVER) AT FOREST SERVICE RD 305 IN WOODS FERRY PARK 13 MI W OF CHESTER	RS-04543	CHESTER	REC	FC
	BROAD	030501060305	BROAD RVR AT SC 72/215/121 3 MI E OF CARLISLE	B-046	CHESTER	AL	CU

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	BROAD	030501060401	BEAVER CRK. AT SR 95	B-143	FAIRFIELD	AL	BIO
	BROAD	030501060401	MCCLURES CREEK AT SC-215 6.7 MI SE OF CARLISLE	RS-04527	FAIRFIELD	AL	BIO
	BROAD	030501060401	MCCLURES CREEK AT SC-215 6.7 MI SE OF CARLISLE	RS-04527	FAIRFIELD	REC	FC
	BROAD	030501060402	HELLERS CRK. AT SR 97	B-151	NEWBERRY	AL	BIO
	BROAD	030501060403	MONTICELLO LK-LOWER IMPOUNDMENT BETWEEN LARGE ISLANDS	B-327	FAIRFIELD	AL	PH
	BROAD	030501060405	CANNON CREEK AT OXNER ROAD	B-831	NEWBERRY	AL	BIO
	BROAD	030501060405	499	RS-03343	NEWBERRY	REC	FC
	BROAD	030501060406	PARR RESERVOIR IN FOREBAY NEAR DAM	B-345	NEWBERRY	AL	CU
	BROAD	030501060406	PARR RESERVOIR 4.8 KM N OF DAM, UPSTREAM MONTICELLO RESERVOIR	B-346	NEWBERRY	AL	TP
	BROAD	030501060504	WINNSBORO BR BELOW PLANT OUTFALL	B-077	FAIRFIELD	AL	CU
	BROAD	030501060504	JACKSON CK AT S-20-54, 5 MI W OF WINNSBORO	B-102	FAIRFIELD	AL	CU
	BROAD	030501060701	CRIMS CRK. AT SC 213	B-800	NEWBERRY	AL	BIO
	BROAD	030501060701	UNN TRIB TO CRIMS CREEK AT S-36-25 (DR BOWERS RD). SAMPLE BEFORE CONFL W/ LARGER CRIMS CREEK	RS-03517	NEWBERRY	REC	FC
	BROAD	030501060703	BROAD RVR AT SO. RR TRESTLE, 0.5 MI DS OF SC 213	B-236	FAIRFIELD	AL	CU
	BROAD	030501060707	CRANE CREEK AT US 321	B-081	RICHLAND	AL	BIO
	BROAD	030501060707	CRANE CK AT S-40-43 UNDER I-20 - N COLA	B-316	RICHLAND	AL	BIO
	BROAD	030501060708	SMITH BR AT N MAIN ST (US 21) IN COLA	B-280	RICHLAND	AL	BIO
	BROAD	030501070102	BEAVERDAM CRK. AT SC 357	B-784	SPARTANBURG	AL	BIO
	BROAD	030501070201	N TYGER RVR AT US 29 7.2 MI W OF SPARTANBURG	B-219	SPARTANBURG	AL	BIO
	BROAD	030501070201	LAKE COOLEY IN FOREBAY NEAR DAM	B-348	SPARTANBURG	AL	PH
	BROAD	030501070203	NORTH TYGER RVR AT S-42-231, 11 MI S OF SPARTANBURG	B-018A	SPARTANBURG	AL	CU
	BROAD	030501070301	LAKE ROBINSON, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CL-100	GREENVILLE	AL	PH
	BROAD	030501070303	SOUTH TYGER RVR AT S-42-63	B-005	SPARTANBURG	AL	CU
	BROAD	030501070303	SOUTH TYGER RIVER AT 293	B-005A	SPARTANBURG	AL	BIO
	BROAD	030501070401	TRIB TO FAIRFOREST CK 200 FT BL S-42-65	B-321	SPARTANBURG	AL	NI, PH
	BROAD	030501070402	FAIRFOREST CK AT SC 56	B-021	SPARTANBURG	AL	BIO
	BROAD	030501070402	LAKE JOHNSON AT SPILLWAY AT S-42-359	CL-035	SPARTANBURG	AL	CHLA, DO, PH, TP
	BROAD	030501070405	MITCHELL CREEK AT SR 19, IST REPLICATE OF TWO STATIONS, DOWNSTREAM OF BRIDGE	B-781	UNION	AL	BIO
	BROAD	030501070501	JIMMIES CRK. AT STEWART RD, 1 MILE UPSTREAM OF SR 113	B-786	SPARTANBURG	AL	BIO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	BROAD	030501070505	TINKER CK AT UN# CO RD 1.7 MI SSE OF UNION	B-287	UNION	AL	PH, TURBIDITY
	BROAD	030501070506	CANE CRK. AT SR 359	B-777	UNION	AL	BIO
	BROAD	030501070507	TYGER RVR AT S-44-35 3.5 MI S OF CARLISLE	B-349	UNION	AL	CU
*	BROAD	030501070507	TYGER RVR AT S-44-35 3.5 MI S OF CARLISLE	B-349	UNION	REC	FC
	BROAD	030501080101	BUCKHORN CRK. AT SR 562	B-795	GREENVILLE	AL	BIO
	BROAD	030501080101	BEAVERDAM CRK. AT SC 253	B-796	GREENVILLE	AL	BIO
	BROAD	030501080101	ENOREE R. AT PINE LOG FORD RD., 2ND CROSSING ABOVE SC 253 BRIDGE	B-797	GREENVILLE	AL	BIO
	BROAD	030501080101	ENOREE RVR AT UNNUM RD W US 25 N TRAVELERS REST	BE-001	GREENVILLE	AL	ZN
	BROAD	030501080101	MOUNTAIN CRK. AT SR 279	BE-008	GREENVILLE	AL	BIO
	BROAD	030501080101	BEAVERDAM CK AT RD 1967	BE-039	GREENVILLE	AL	PH
	BROAD	030501080102	PRINCESS CREEK AT SUBER MILL RD, SECOND RD S OF US 29 OFF S-23-540	B-192	GREENVILLE	AL	BIO
	BROAD	030501080102	ROCKY CK AT BRDG IN BATESVILLE 1 MI AB JCT WITH ENOREE	BE-007	GREENVILLE	AL	BIO
	BROAD	030501080102	BRUSHY CK AT S-23-164	BE-009	GREENVILLE	AL	BIO
	BROAD	030501080102	BRUSHY CK AT HOWELL RD (S-23-273/335) APPROX 5 MI NE OF GREENVILLE (BIO B-798)	BE-035	GREENVILLE	AL	BIO
	BROAD	030501080103	HORSE PEN CRK. AT SR 145	B-793	GREENVILLE	AL	BIO
	BROAD	030501080103	GILDER CK AT S-23-143 1/4 MI AB JCT WITH ENOREE RVR	BE-020	GREENVILLE	AL	BIO
	BROAD	030501080104	ENOREE RVR AT SC 296, 7.5 MI NE OF MAULDIN	BE-017	GREENVILLE	AL	BIO
	BROAD	030501080105	DURBIN CREEK AT SC 418	B-097	LAURENS	AL	PH
*	BROAD	030501080106	ENOREE RVR AT S-30-112	B-040	LAURENS	REC	FC
	BROAD	030501080106	ENOREE RVR AT S-30-75	BE-018	LAURENS	AL	BIO
	BROAD	030501080106	ENOREE RIVER AT SC HWY 418	BE-019	LAURENS	AL	BIO
	BROAD	030501080201	BEAVERDAM CK AT S-30-97, 7 MI NE OF GRAY COURT	B-246	LAURENS	AL	CU
	BROAD	030501080206	ENOREE RVR AT SC 72, 121, & US 176, 1 MI NE WHITMIRE	B-053	NEWBERRY	AL	CU
	BROAD	030501080301	BEARDS FORK CK AT US 276 (I-385) 3.7 MI NNE OF CLINTON	B-231	LAURENS	AL	DO
*	BROAD	030501080303	DUNCAN CREEK AT COUNTY RD 26, 4.5 M NE OF CLINTON	RS-01057	LAURENS	REC	FC
	BROAD	030501080501	KINGS CRK. AT US 176, DOWNSTREAM OF BRIDGE	B-799	NEWBERRY	AL	BIO
	BROAD	030501080502	ENOREE RVR AT S-36-45 3.5 MI AB JCT WITH BROAD RVR	B-054	NEWBERRY	AL	CU
	CATAWBA	030501011502	LAKE WYLIE AB MILL CK ARM AT END OF S-46-557	CW-197	YORK	AL	CU
	CATAWBA	030501011504	BROWN CREEK AT S-46-228 (GUINN ST), 0.3 MI WEST OF OLD NORTH MAIN STREET IN CLOVER, SC	CW-105	YORK	AL	TURBIDITY
	CATAWBA	030501011504	BEAVERDAM CK AT S-46-152 8 MI E OF CLOVER	CW-153	YORK	AL	TURBIDITY
	CATAWBA	030501011505	CROWDERS CK AT S-46-564 NE CLOVER	CW-023	YORK	AL	CD, CU
	CATAWBA	030501011505	CROWDERS CREEK AT S-46-1104	CW-024	YORK	AL	BIO
	CATAWBA	030501011505	LK WYLIE, CROWDERS CK ARM AT SC 49 AND SC 274	CW-027	YORK	AL	CU

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	CATAWBA	030501011506	ALLISON CK AT S-46-114	CW-249	YORK	AL	CU
*	CATAWBA	030501011506	ALLISON CK AT S-46-114	CW-249	YORK	REC	FC
	CATAWBA	030501030103	SUGAR CK US OF CONFLUENCE W/ MCALPINE CK	CW-246	YORK	AL	BIO
	CATAWBA	030501030107	MCALPINE CK AT S-29-64	CW-064	LANCASTER	AL	BIO
	CATAWBA	030501030108	STEELE CK AT S-46-22 N OF FORT MILL	CW-009	YORK	AL	DO
*	CATAWBA	030501030108	STEELE CK AT S-46-22 N OF FORT MILL	CW-009	YORK	REC	FC
*	CATAWBA	030501030108	STEELE CK AT S-46-270	CW-011	YORK	REC	FC
*	CATAWBA	030501030108	STEELE CK AT S-46-98	CW-203	YORK	REC	FC
	CATAWBA	030501030108	STEEL CR. AT US BY-PASS 21	CW-681	YORK	AL	BIO
	CATAWBA	030501030109	SUGAR CK AT SC 160 E OF FORT MILL	CW-013	LANCASTER	AL	BIO
	CATAWBA	030501030109	SUGAR CREEK AT S-46-36	CW-036	LANCASTER	AL	CU
	CATAWBA	030501030203	SIXMILE CREEK AT S-29-54	CW-176	LANCASTER	AL	TURBIDITY
	CATAWBA	030501030204	TWELVEMILE CK AT S-29-55 0.3 MI NW OF VAN WYCK	CW-083	LANCASTER	AL	CU, TURBIDITY
	CATAWBA	030501030302	CANE CK AT SC 200 5 MI NNE OF LANCASTER	CW-185	LANCASTER	AL	DO
	CATAWBA	030501030303	BEAR CK AT S-29-362 3.5 MI SE OF LANCASTER	CW-151	LANCASTER	AL	DO
#	CATAWBA	030501030304	GILLS CK AT US 521 NNW OF LANCASTER	CW-047	LANCASTER	AL	DO
	CATAWBA	030501030304	BEAR CK AT S-29-292 1.6 MI W OF LANCASTER	CW-131	LANCASTER	AL	DO
	CATAWBA	030501030305	CANE CK AT S-29-50	CW-017	LANCASTER	AL	DO
	CATAWBA	030501030305	CANE CR. AT SC 9 BYPASS	CW-210	LANCASTER	AL	BIO
	CATAWBA	030501030305	RUM CK AT S-29-187	CW-232	LANCASTER	AL	DO
	CATAWBA	030501030401	WILDCAT CK AT S-46-650	CW-006	YORK	AL	DO, TURBIDITY
	CATAWBA	030501030401	WILDCAT CK AT S-46-998 9 MI ENE OF MCCONNELLS	CW-096	YORK	AL	DO, TURBIDITY
	CATAWBA	030501030401	TOOLS FORK AT S-46-195 7 MI NW OF ROCK HILL	CW-212	YORK	AL	TURBIDITY
	CATAWBA	030501030402	FISHING CK AT S-46-347 DS YORK WWTP	CW-005	YORK	AL	BIO
	CATAWBA	030501030402	FISHING CREEK AT S-46-503	CW-225	YORK	AL	CU
	CATAWBA	030501030403	STONEY FORK CRK. AT SC 121 & 72	CW-697	YORK	AL	BIO
	CATAWBA	030501030404	LAKE OLIPHANT, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CL-021	CHESTER	AL	CHLA
#	CATAWBA	030501030406	SOUTH FORK OF FISHING CRK. AT SR 50	CW-007	CHESTER	AL	BIO
	CATAWBA	030501030407	FISHING CR. AT SR 655	CW-654	YORK	AL	BIO
	CATAWBA	030501030407	TAYLORS CRK. AT SR 735	CW-695	YORK	AL	BIO
	CATAWBA	030501030408	TINKERS CK AT S-12-599	CW-234	CHESTER	AL	CU
	CATAWBA	030501030502	ROCKY CK AT S-12-335 3.5 MI E OF CHESTER	CW-002	CHESTER	AL	CU
	CATAWBA	030501030502	GRASSY RUN BR AT SC 72 1.6 MI NE CHESTER	CW-088	CHESTER	AL	DO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	CATAWBA	030501030503	BEAVER DAM CRK. AT SR 555	CW-691	CHESTER	AL	BIO
	CATAWBA	030501030505	CEDAR CK RESERVOIR/ROCKY CK AT S-12-141 SE OF GREAT FALLS	CW-175	CHESTER	AL	DO, TP, TURBIDITY
	CATAWBA	030501030505	ROCKY CK AT S-12-138	CW-236	CHESTER	AL	CU
#	CATAWBA	030501030603	WAXHAW CK AT S-29-29	CW-145	LANCASTER	AL	CU
	CATAWBA	030501030604	CATAWBA RVR AT SC 5 AB BOWATER	CW-041	LANCASTER	AL	CU
	CATAWBA	030501030604	GREENE CREEK AT S-12-465 8.2 MI N OF FORT LAWN	RS-03511	CHESTER	AL	BIO
	CATAWBA	030501030604	GREENE CREEK AT S-12-465 8.2 MI N OF FORT LAWN	RS-03511	CHESTER	REC	FC
	CATAWBA	030501030606	FISHING CK RES 2 MI BL CANE CREEK	CW-016F	CHESTER	AL	TP
	CATAWBA	030501030606	FISHING CK RES 75 FT AB DAM NR GREAT FALLS	CW-057	CHESTER	AL	TP
	CATAWBA	030501030606	CEDAR CK RESERVOIR AT UNIMP RD AB JCT WITH ROCKY CK	CW-174	CHESTER	AL	DO, TN, TP,
	CATAWBA	030501030606	CEDAR CK RES 2.15 M SE OF GREAT FALLS	RL-01007	LANCASTER	AL	CHLA, DO
	CATAWBA	030501030606	FISHING CK RES 3.8 M S OF FORT LAWN OFF W SHORE OF THE TOWN OF LAKE VIEW	RL-01012	CHESTER	AL	CHLA
	CATAWBA	030501030606	CEDAR CK RES FROM W OF BIG ISL 7 MI BELOW ROCKY CK CONFL	RL-02319	CHESTER	AL	TP
	CATAWBA	030501030606	CEDAR CK RES 0.15 MI SE OF S TIP PICKETT ISLAND	RL-02452	LANCASTER	AL	TP
	CATAWBA	030501030606	GREAT FALLS RESERVOIR 0.9 MI NE OF GREAT FALLS	RL-03332	CHESTER	AL	TN, TP, TURBIDITY
	CATAWBA	030501030606	CEDAR CREEK RESERVOIR 0.3 MI NE OF DAM AND W OF BIG ISLAND	RL-03351	CHESTER	AL	CU, TP, TURBIDITY
	CATAWBA	030501030606	CEDAR CREEK RESERVOIR 1.9 MI SE OF GREAT FALLS AND E OF BIG ISLAND	RL-03353	CHESTER	AL	TP, TURBIDITY
	CATAWBA	030501030606	GREAT FALLS RSVR 1 MI NE OF GREAT FALLS	RL-03458	CHESTER	AL	TP, TURBIDITY
	CATAWBA	030501030606	CEDAR CREEK RESERVOIR 2.2 MI SE OF GREAT FALLS SE OF BOWDEN ISLAND	RL-04375	LANCASTER	AL	TP
	CATAWBA	030501030606	CEDAR CREEK RESERVOIR 1.25 MI ESE OF GREAT FALLS NW OF HILL ISLAND	RL-04379	CHESTER	AL	TP
	CATAWBA	030501040102	LITTLE WATEREE CK AT S-20-41 5 MI E OF WINNSBORO	CW-040	FAIRFIELD	AL	DO
*	CATAWBA	030501040102	LITTLE WATEREE CK AT S-20-41 5 MI E OF WINNSBORO	CW-040	FAIRFIELD	REC	FC
	CATAWBA	030501040105	BIG WATEREE CK AT US 21	CW-072	FAIRFIELD	AL	DO
	CATAWBA	030501040106	CEDAR CK RESERVOIR 100 M N OF DAM	CW-033	LANCASTER	AL	TP, TURBIDITY
	CATAWBA	030501040106	LK WATEREE HEADWATERS APPROX 50 YDS DS CONFL CEDAR CK	CW-231	LANCASTER	AL	PH, TP, TURBIDITY
	CATAWBA	030501040108	LK WATEREE AT S-20-101 11 MI ENE WINNSBORO	CW-208	FAIRFIELD	AL	CHLA, PH, TP
*	CATAWBA	030501040108	DUTCHMANS CK AT S-20-106	RS-02321	FAIRFIELD	REC	FC
	CATAWBA	030501040111	LK WATEREE IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CL-089	KERSHAW	AL	PH
	CATAWBA	030501040111	LK WATEREE AT END OF S-20-291	CW-207	FAIRFIELD	AL	PH, TP
	CATAWBA	030501040111	LK WATEREE AT SMALL ISLAND 2.3 MI N OF DAM	CW-209	KERSHAW	AL	PH, TP
	CATAWBA	030501040111	LAKE WATEREE 1.0 MI SW FROM MOUTH OF BEAVER CK	RL-02314	KERSHAW	AL	PH, TP
	CATAWBA	030501040111	LAKE WATEREE NEARSHORE ALONG S-28-802 OPP COLONEL CK CONFL	RL-03336	KERSHAW	AL	PH, TP
*	CATAWBA	030501040202	GRANNIES QUARTER CK AT SC 97	CW-237	KERSHAW	REC	FC
	CATAWBA	030501040206	BEAR CK AT S-40-82	CW-229	RICHLAND	AL	DO
	CATAWBA	030501040207	TWENTYFIVE MILE CK AT S-28-05 3.7 MI W OF CAMDEN	CW-080	KERSHAW	AL	BIO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	CATAWBA	030501040208	WATEREE RIVER BELOW LAKE WATEREE DAM	CW-039	KERSHAW	FISH	HG
*	CATAWBA	030501040302	LITTLE PINE TREE CREEK AT S-28-132	CW-223	KERSHAW	REC	FC
	CATAWBA	030501040304	WATEREE RVR AT US 1	CW-019	KERSHAW	AL	DO
	CATAWBA	030501040304	WATEREE RIVER AT I-20	CW-214	KERSHAW	AL	DO
	CATAWBA	030501040304	WATEREE RIVER AT I-20	CW-214	KERSHAW	FISH	HG
	CATAWBA	030501040305	SWIFT CK AT SC 261	CW-238	KERSHAW	AL	CU, DO
	CATAWBA	030501040402	SPEARS CK AT SC 12 3.6 MI SE OF ELGIN	CW-155	KERSHAW	REC	FC
	CATAWBA	030501040406	WATEREE RIVER @ US 378/76	CW-206	SUMTER	FISH	HG
	CATAWBA	030501040407	BIG LAKE @ SUMTER WATEREE HUNT CLUB	CW-698	SUMTER	FISH	HG
	EDISTO	030502030101	CHINQUAPIN CREEK AT SC 391 5.5 MI S BATESBURG	E-091	AIKEN	AL	PH
*	EDISTO	030502030101	CHINQUAPIN CREEK AT SC 391 5.5 MI S BATESBURG	E-091	AIKEN	REC	FC
*	EDISTO	030502030101	HORSE PEN CREEK AT UPSTREAM SIDE OF COUNTY RD 391, 1.5 M S OF BATESBURG	RS-01004	LEXINGTON	REC	FC
	EDISTO	030502030103	N FORK EDISTO RVR AT S-02-74	E-084	AIKEN	REC	FC
	EDISTO	030502030106	N FORK EDISTO RVR AT S-02-110	E-102	BAMBERG	FISH	HG
	EDISTO	030502030106	N FORK EDISTO RVR AT S-02-110	E-102	AIKEN	REC	FC
	EDISTO	030502030206	BULL SWP CK AT CLVT ON UNIMP RD 1.1 MI NW OF SWANSEA	E-034	LEXINGTON	AL	DO
	EDISTO	030502030206	BULL SWAMP CREEK AT SC 6	E-591	LEXINGTON	AL	BIO
	EDISTO	030502030210	NORTH EDISTO RIVER @ SLAB LANDING	E-704	ORANGEBURG	FISH	HG
*	EDISTO	030502030306	CAW CAW SWAMP AT S-38-1032	E-105	ORANGEBURG	REC	FC
	EDISTO	030502030308	N FORK EDISTO RVR AT US 601 AT ORANGEBURG	E-007	ORANGEBURG	AL	PH
	EDISTO	030502030308	NORTH EDISTO RIVER @ ORANGEBURG CITY	E-007	ORANGEBURG	FISH	HG
*	EDISTO	030502030308	N FORK EDISTO RVR AT POWER LINE CROSSING 2 MI BL E-007	E-007A	ORANGEBURG	REC	FC
*	EDISTO	030502030308	N FORK EDISTO RVR 4 MI BL E-007 AT A CABIN	E-007B	ORANGEBURG	REC	FC
	EDISTO	030502030308	N FORK EDISTO RVR AT POLICEMANS CAMP 6 MI BL E-007	E-007C	ORANGEBURG	AL	PH
	EDISTO	030502030308	N FORK EDISTO RVR AT POLICEMANS CAMP 6 MI BL E-007	E-007C	ORANGEBURG	FISH	HG
	EDISTO	030502030308	NORTH EDISTO RIVER @ SEC RD 39	E-008	ORANGEBURG	FISH	HG
	EDISTO	030502030308	NORTH EDISTO RIVER @ KILL KARE	E-008A	ORANGEBURG	FISH	HG
	EDISTO	030502040106	HILLYER BRANCH AT UNNAMED HILLYER BRANCH ROAD OFF S-19-75 3.5 MI NE OF TRENTON	RS-03344	EDGEFIELD	AL	PH
	EDISTO	030502040107	SHAW CREEK AT S-02-26 4.2 MI NE AIKEN	E-094	AIKEN	AL	PH
	EDISTO	030502040109	S FORK EDISTO RVR AT S-02-152	E-113	AIKEN	REC	FC
	EDISTO	030502040207	SOUTH EDISTO RIVER @ AIKEN STATE PARK	E-585	AIKEN	FISH	HG
	EDISTO	030502040207	SOUTH EDISTO RIVER @ KEADLE'S BRIDGE	E-600	AIKEN	FISH	HG

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	EDISTO	030502040305	WINDY HILL CRK. AT SR 38	E-029	BARNWELL	AL	BIO
	EDISTO	030502040307	SOUTH EDISTO RIVER @ HWY 39 LANDING	E-011	BARNWELL	FISH	HG
	EDISTO	030502040309	ROBERTS SWAMP AT SR 690	E-592	ORANGEBURG	AL	BIO
	EDISTO	030502040311	SOUTH EDISTO RIVER @ BOBCAT LANDING	E-500	BAMBERG	FISH	HG
	EDISTO	030502040311	SOUTH EDISTO RIVER @ SC 365	E-501	BAMBERG	FISH	HG
	EDISTO	030502050101	GRAMLING CK AT CLVT ON SC 33 2 MI E OF ORANGEBURG	E-022	ORANGEBURG	AL	DO
*	EDISTO	030502050101	GRAMLING CK AT CLVT ON SC 33 2 MI E OF ORANGEBURG	E-022	ORANGEBURG	REC	FC
	EDISTO	030502050101	LITTLE BULL CK CK AT SC 33-BL UTICA TOOL CO	E-076	ORANGEBURG	AL	DO, PH
*	EDISTO	030502050101	LITTLE BULL CK CK AT SC 33-BL UTICA TOOL CO	E-076	ORANGEBURG	REC	FC
	EDISTO	030502050101	GRAMBLING CRK. AT SR 154	E-589	ORANGEBURG	AL	BIO
	EDISTO	030502050101	BULL SWAMP AT SR 65	E-590	ORANGEBURG	AL	BIO
	EDISTO	030502050105	GOODBYS SWAMP AT US 176 6 M SW OF ELLOREE	RS-01036	ORANGEBURG	AL	BIO
*	EDISTO	030502050105	GOODBYS SWAMP AT US 176 6 M SW OF ELLOREE	RS-01036	ORANGEBURG	REC	FC
*	EDISTO	030502050107	COW CASTLE CK AT S-38-170	E-050	ORANGEBURG	REC	FC
	EDISTO	030502050108	FOUR HOLE SWAMP @ US 301	E-048	ORANGEBURG	FISH	HG
	EDISTO	030502050108	FOUR HOLE SWAMP @ SEC RD 19	E-059	CALHOUN	FISH	HG
*	EDISTO	030502050108	FOUR HOLE SWP AT S-38-50 5.2 MI SE OF CAMERON	E-059	ORANGEBURG	REC	FC
*	EDISTO	030502050108	FOUR HOLE SWAMP AT SC 210	E-111	ORANGEBURG	REC	FC
	EDISTO	030502050108	UNNAMED TRIBUTARY TO FOUR HOLE SWAMP AT CO RD S-38-92 5.5 MI NE OF BOWMAN	RS-04537	ORANGEBURG	AL	BIO
	EDISTO	030502050108	UNNAMED TRIBUTARY TO FOUR HOLE SWAMP AT CO RD S-38-92 5.5 MI NE OF BOWMAN	RS-04537	ORANGEBURG	REC	FC
	EDISTO	030502050201	CEDAR SWAMP AT CEMENT BRIDGE RD. OFF SR 640	E-596	ORANGEBURG	AL	BIO
*	EDISTO	030502050301	HORSE RANGE SWAMP AT US 176	E-052	ORANGEBURG	REC	FC
*	EDISTO	030502050301	HORSE RANGE SWAMP AT S-38-1264	RS-02303	ORANGEBURG	REC	FC
	EDISTO	030502050302	PROVIDENCE SWP AT E FRONTAGE RD TO I-95 NW OF HOLLY HILL	E-051	ORANGEBURG	AL	CU, DO, PH
*	EDISTO	030502050302	PROVIDENCE SWP AT E FRONTAGE RD TO I-95 NW OF HOLLY HILL	E-051	ORANGEBURG	REC	FC
	EDISTO	030502050305	FOUR HOLE SWAMP AT SC 453	E-112	DORCHESTER	AL	DO
	EDISTO	030502050305	FOUR HOLE SWAMP AT SC 453	E-112	ORANGEBURG	FISH	HG
	EDISTO	030502060103	EDISTO RIVER @ ZIG ZAG LANDING	E-013	BAMBERG	FISH	HG
	EDISTO	030502060105	CATTLE CK AT S-18-19	E-108	DORCHESTER	AL	PH
	EDISTO	030502060108	EDISTO RIVER @ US 15 (T COKE WEEKS LDG..)	E-014	DORCHESTER	FISH	HG
	EDISTO	030502060203	POLK SWP AT UNIMP RD S-18-180 2 MI S OF ST GEORGE	E-016	DORCHESTER	AL	DO
*	EDISTO	030502060203	POLK SWP AT UNIMP RD S-18-180 2 MI S OF ST GEORGE	E-016	DORCHESTER	REC	FC
	EDISTO	030502060203	POLK SWAMP AT S-18-19	E-109	DORCHESTER	AL	DO
*	EDISTO	030502060203	POLK SWAMP AT S-18-19	E-109	DORCHESTER	REC	FC

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	EDISTO	030502060204	INDIAN FIELD SWAMP AT S-18-19	E-032	DORCHESTER	AL	DO
*	EDISTO	030502060204	INDIAN FIELD SWAMP AT S-18-19	E-032	DORCHESTER	REC	FC
	EDISTO	030502060204	INDIAN FIELDS CRK. AT US 78	E-597	DORCHESTER	AL	BIO
	EDISTO	030502060301	EDISTO RIVER @ MARS OLDFIELD	E-601	COLLETON	FISH	HG
	EDISTO	030502060302	EDISTO RIVER @ SC 61 (GIVHANS FERRY LDG.)	E-015	DORCHESTER	FISH	HG
	EDISTO	030502060302	EDISTO RIVER @ GOOD HOPE LANDING	E-602	COLLETON	FISH	HG
	EDISTO	030502060303	EDISTO RIVER @ SULLIVANS FERRY	E-087	COLLETON	FISH	HG
	EDISTO	030502060304	EDISTO RIVER ABOVE HWY 17 (MARTINS LANDING)	CSTL-589	CHARLESTON	FISH	HG
	EDISTO	030502060304	EDISTO RVR AT US 17 12.5 MI NW RAVENEL	MD-119	CHARLESTON	AL	PH
	EDISTO	030502060304	EDISTO RIVER BELOW HWY 17 (WEST BANK LDG..)	MD-119	COLLETON	FISH	HG
	EDISTO	030502060306	EDISTO RIVER @ WILLTOWN BLUFF	CSTL-590	CHARLESTON	FISH	HG
	EDISTO	030502060307	ST. PIERRE CREEK MOUTH	13-03	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060307	ST. PIERRE CREEK AT PETERS PT.	13-04	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060307	FISHING CREEK AT SANDY CREEK CONFLUENCE OF SHINGLE CREEK AND BAILEY CREEK (D7-01)	13-05	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060307	STORE CREEK OPPOSITE HOUSE WITH DOCKS ON RIGHT	13-07	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060307	FISHING CREEK AT POLLUTION LINE	13-10	COLLETON	SHELLFISH	FC
	EDISTO	030502060307	SHINGLE CREEK AND MILTON CREEK CONFLUENCE	13-28	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060307	BAILEY CREEK, FIRST BEND ADJACENT TO BLUFF ON BAILEYISLAND (NEAR CONFLUENCE WITH ST. PIERRE CREEK) (C7-01)	13-29	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060307	BAILEY CREEK AT CONFLUENCE WITH UNNAMED TRIBUTARY NEAR SOUTHWESTERN POINT OF SCANAWAH ISLAND (C7-01)	13-30	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060308	EDISTO RIVER AT ASHEPOO RIVER RUSSELL CREEK AT AREA 12/13 BOUNDARY (1993-98)	13-08	COLLETON	SHELLFISH	FC
	EDISTO	030502060308	BIG BAY CR. HDWTRS AT FIRST BEND TO RIGHT PAST THE NECK	13-21	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060308	SCOTT CREEK, HEADWATERS AT JEREMY INLET AT BOAT LANDING	13-22	COLLETON	SHELLFISH	FC
*	EDISTO	030502060308	JEREMY INLET AT ATLANTIC OCEAN	13-23	COLLETON	SHELLFISH	FC
	EDISTO	030502060308	BAILEY CREEK AT CONFLUENCE WITH SOUTH EDISTO RIVER	13-31	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060308	S EDISTO RVR AT NORTHERN CONFLUENCE WITH ALLIGATOR CREEK (13-20)	MD-260	CHARLESTON	AL	CU, TURBIDITY
#	EDISTO	030502060308	SOUTH EDISTO RIVER, 1 M MW OF EDISTO BEACH	RO-01123	COLLETON	AL	NH3N, TURBIDITY
	EDISTO	030502060401	TOOGOODOO CREEK SSG AT LAST CREEK BEFORE FORK	12B-34	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060401	TOOGOODOO CREEK LOWER, AT PUBLIC BOAT RAMP	12B-35	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060401	TOOGOODOO CREEK MIDWAY BETWEEN STATIONS 4 AND 34	12B-44	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060401	TOOGOODOO CREEK AT THE SECOND BEND PAST THE CONFLUENCE WITH LOWER TOOGOODOO CREEK	12B-45	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060402	STONO RIVER (AIWW) AT MARKER #63	11-15	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060402	RAVEN POINT CREEK AT CONFLUENCE WITH CHURCH CREEK	12A-29	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060402	CHURCH CREEK AT DRAINAGE DISCHARGE 1/8 MILE EAST OF POWER LINES, NORTH BANK OF	12A-38	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060402	PINE CREEK AT FIRST FORK	12A-40	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060402	CHURCH CREEK AND NEW CUT CONFLUENCE	12A-41	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060402	CHURCH CREEK, MOUTH AT MARKER #77	12B-01	CHARLESTON	SHELLFISH	FC

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	EDISTO	030502060402	WADMALAW SOUND AT GOSHEN POINT, MARKER #69	12B-02	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060404	BOHICKET CREEK AT FICKLING CREEK .	12A-13	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060404	S.C. HIGHWAY 700 BRIDGE OVER BOHICKET CREEK	12A-14	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060404	BOHICKET CREEK OPPOSITE HOOPSTICK ISLAND	12A-20	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060404	BOHICKETT CREEK OPPOSITE OLD DAM BEHIND RAST HOUSE RESTAURANT	12A-21	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060404	BOHICKETT CREEK OPPOSITE BOY SCOUT CAMP	12A-22	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060404	CHURCH CREEK ~ 350 YDS WEST S.C. HWY.700 BRIDGE	12A-39	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060404	BOHICKET CREEK MIDWAY BETWEEN STATIONS 21 AND 22 AT SMALL UNNAMED TRIBUTARY ON WEST BANK	12A-46	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060404	CHURCH CR AT SC 700 1 MI SW OF CEDAR SPRINGS	MD-195	CHARLESTON	AL	DO
	EDISTO	030502060404	BOHICKET CK AT FICKLING CK	MD-209	CHARLESTON	AL	DO
	EDISTO	030502060404	BOHICKET CK 3 MI SW SC 700 BRIDGE	RO-036041	CHARLESTON	AL	DO
	EDISTO	030502060405	DAWHO CREEK, MARKER #110	12B-05	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060405	DAWHO RIVER AT MARKER #119 (C8/00)	12B-09	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060405	TOM POINT CREEK AT PARK ISLAND	12B-30	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060405	NORTH EDISTO RIVER CONFLUENCE WITH TOM POINT CREEK	12B-36	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060405	STEAMBOAT CREEK AND RUSSELL CREEK CONFLUENCE	12B-37	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060405	RUSSELL CREEK AT ESTUARY ENTERING SUNBELT CLAM FARMS	12B-43	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060405	SAND CREEK BRIDGE AT HIGHWAY 174	12B-47	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060405	SAND CREEK AT INTAKE TO WESTENDORF CLAM FARM	12B-50	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060405	WHOOPING ISLAND CREEK AT CONFLUENCE OF STEAMBOAT CREEK	12B-52	CHARLESTON	SHELLFISH	FC
*	EDISTO	030502060405	DAWHO RIVER, MARKER #126	12B-53	CHARLESTON	SHELLFISH	FC
	EDISTO	030502060405	DAWHO RVR AT SC 174 9 MI N OF EDISTO BCH SP	MD-120	CHARLESTON	AL	DO
	EDISTO	030502060405	DAWHO RIVER, 10.5 M N OF EDISTO BEACH	RT-01665	CHARLESTON	AL	DO, TURBIDITY
	EDISTO	030502060405	FISHING CK NEAR JEHOSSEE ISLAND	RT-02005	CHARLESTON	AL	TURBIDITY
	PEEDEE	030402010402	THOMPSON CRK. AT SC 109	PD-673	CHESTERFIELD	AL	BIO
	PEEDEE	030402010402	CLAY CREEK AT S-13-55	RS-02305	CHESTERFIELD	AL	DO
	PEEDEE	030402010403	DEEP CREEK 75 FT UPSTREAM OF SC 9, 5.5 M W OF CHESTERFIELD	RS-01013	CHESTERFIELD	AL	TURBIDITY
*	PEEDEE	030402010403	DEEP CREEK 75 FT UPSTREAM OF SC 9, 5.5 M W OF CHESTERFIELD	RS-01013	CHESTERFIELD	REC	FC
	PEEDEE	030402010407	NORTH PRONG CRK. AT SC 102	PD-677	CHESTERFIELD	AL	BIO
	PEEDEE	030402010501	WESTFIELD CREEK AT US 52	PD-339	CHESTERFIELD	AL	DO, PH
	PEEDEE	030402010501	WESTFIELD CREEK AT SR 62	PD-641	CHESTERFIELD	AL	BIO
	PEEDEE	030402010504	GREAT PEE DEE RIVER @ SC 9/US 1	PD-012	CHESTERFIELD	FISH	HG
	PEEDEE	030402010510	GREAT PEE DEE RIVER @ SOCIETY HILL	PD-015	MARLBORO	FISH	HG
*	PEEDEE	030402010510	GREAT PEE DEE RVR AT US 15 & 401	PD-015	DARLINGTON	REC	FC
	PEEDEE	030402010606	LAKE HB ROBINSON	PD-327	CHESTERFIELD	FISH	HG
	PEEDEE	030402010702	BOGGY SWAMP AT S-16-50 4.9 MI NE OF HARTSVILLE	RS-03507	DARLINGTON	REC	FC
	PEEDEE	030402010704	BLACK CK AT S-16-18 1 MI NNE HARTSVILLE	PD-021	DARLINGTON	REC	FC
	PEEDEE	030402010704	SNAKE BR AT RR AVE IN HARTSVILLE	PD-258	DARLINGTON	AL	DO, PH
*	PEEDEE	030402010704	SNAKE BR AT RR AVE IN HARTSVILLE	PD-258	DARLINGTON	REC	FC
	PEEDEE	030402010704	BLACK CREEK NEAR DIRT ROAD OFF COUNTY RD 41, 6 M NE OF HARTSVILLE	RS-01043	DARLINGTON	AL	CU

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	PEEDEE	030402010707	60" TILE DISCHARGING TO DITCH ACROSS RD AT DARLINGTON STP	PD-141	DARLINGTON	AL	DO, NH3N
*	PEEDEE	030402010707	60" TILE DISCHARGING TO DITCH ACROSS RD AT DARLINGTON STP	PD-141	DARLINGTON	REC	FC
	PEEDEE	030402010707	TRIBUTARY TO SWIFT CREEK AT COUNTY RD 213 JUST NORTH OF DARLINGTON	RS-01023	DARLINGTON	AL	CU
*	PEEDEE	030402010707	TRIBUTARY TO SWIFT CREEK AT COUNTY RD 213 JUST NORTH OF DARLINGTON	RS-01023	DARLINGTON	REC	FC
	PEEDEE	030402010709	BLACK CK AT US 401 & 52 6 MI NW DARLINGTON	PD-024A	DARLINGTON	AL	CU
	PEEDEE	030402010709	BLACK CK AT S-16-133 2.25 MI NE OF DARLINGTON	PD-025	DARLINGTON	AL	PH
*	PEEDEE	030402010709	BLACK CK AT S-16-133 2.25 MI NE OF DARLINGTON	PD-025	DARLINGTON	REC	FC
	PEEDEE	030402010710	BLACK CREEK @ SC 327	PD-623	FLORENCE	FISH	HG
	PEEDEE	030402010805	GREAT PEE DEE RIVER @ BLUE'S LANDING	PD-242	MARLBORO	FISH	HG
	PEEDEE	030402010805	THREE CREEKS AT SC 38, S OF BLENHEIM	PD-367	MARLBORO	AL	CU
	PEEDEE	030402010808	GREAT PEE DEE RIVER @ SC 34	PD-028	DARLINGTON	FISH	HG
	PEEDEE	030402010810	LOUTHER'S LAKE	PD-666	DARLINGTON	FISH	HG
	PEEDEE	030402010901	MIDDLE SWP AT SC 51 3.5 MI SSE OF FLORENCE	PD-230	FLORENCE	AL	DO
	PEEDEE	030402010901	MIDDLE SWP AT SC 51 3.5 MI SSE OF FLORENCE	PD-230	FLORENCE	REC	FC
	PEEDEE	030402010902	GULLEY BR AT S-21-13, TIMROD PARK	PD-065	FLORENCE	AL	BIO
	PEEDEE	030402010902	JEFFRIES CK AT SC 340 6.8 MI SSW OF DARLINGTON	PD-255	DARLINGTON	AL	DO
	PEEDEE	030402010902	JEFFRIES CK AT S-21-112 4.8 MI W OF FLORENCE	PD-256	FLORENCE	AL	DO
	PEEDEE	030402010902	JEFFRIES CK AT S-21-112 4.8 MI W OF FLORENCE	PD-256	FLORENCE	REC	FC
	PEEDEE	030402010902	JEFFERIES CREEK AT S-16-13	PD-639	DARLINGTON	AL	BIO
	PEEDEE	030402010904	WILLOW CREEK AT S-21-57	PD-167	FLORENCE	REC	FC
	PEEDEE	030402010904	WILLOW CREEK AT SC 327	PD-630	FLORENCE	AL	BIO
	PEEDEE	030402010905	JEFFRIES CK AT UN# RD 3.3 MI ESE OF CLAUSSEN	PD-231	FLORENCE	AL	CU
	PEEDEE	030402011003	GREAT PEE DEE RVR AT US 301/76	PD-337	FLORENCE	AL	NI
	PEEDEE	030402011003	GREAT PEE DEE RVR AT US 301/76	PD-337	MARION	FISH	HG
	PEEDEE	030402011102	SMITH SWP AT US 501 1.9 MI SSE OF MARION	PD-187	MARION	AL	DO
	PEEDEE	030402011102	SMITH SWP AT S-34-19 1 MI E OF MARION	PD-320	MARION	AL	DO
	PEEDEE	030402011105	CATFISH CANAL AT S-34-34 6 MI SW OF MARION	PD-097	MARION	AL	DO
	PEEDEE	030402011201	GREAT PEE DEE RIVER @ DEWITT BLUFF	PD-622	FLORENCE	FISH	HG
	PEEDEE	030402011202	GREAT PEE DEE RIVER @ POSTON (ELLISON'S)	PD-076	FLORENCE	FISH	HG
	PEEDEE	030402011202	GREAT PEE DEE RIVER @ BOSTICK	PD-662	FLORENCE	FISH	HG
	PEEDEE	030402020101	HILLS CREEK AT S-13-105	PD-333	CHESTERFIELD	AL	BIO
	PEEDEE	030402020101	HILLS CRK. AT SR 105	PD-672	CHESTERFIELD	AL	BIO
	PEEDEE	030402020103	S BR WILDCAT CK AT S-29-39 2 MI S OF TRADESVILLE	PD-180	LANCASTER	AL	BIO
	PEEDEE	030402020103	NORTH BRANCH OF WILDCAT CRK. AT SR 178	PD-679	LANCASTER	AL	BIO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
#	PEEDEE	030402020104	FLAT CR. AT US 601	PD-162	LANCASTER	AL	BIO
#	PEEDEE	030402020104	FLAT CREEK AT S-29-123	PD-342	LANCASTER	AL	CU
	PEEDEE	030402020105	LYNCHES RVR AT SC 9 W OF PAGELAND	PD-113	CHESTERFIELD	AL	CU
*	PEEDEE	030402020201	TODD'S BR AT S-29-564 1.5 MI NE OF KERSHAW	PD-005	LANCASTER	REC	FC
*	PEEDEE	030402020201	HORTON CREEK AT S-29-95	PD-335	LANCASTER	REC	FC
	PEEDEE	030402020201	LITTLE LYNCHES R. AT SR 88	PD-640	LANCASTER	AL	BIO
	PEEDEE	030402020202	HANGING ROCK CRK. AT SR 770	PD-669	LANCASTER	AL	BIO
	PEEDEE	030402020202	UNNAMED TRIBUTARY TO HANGING ROCK CREEK AT CULVERT ON CO RD S-29-773. 3.25 MI SSE OF KERSHAW.	RS-04549	LANCASTER	REC	FC
	PEEDEE	030402020203	LITTLE LYNCHES RVR AT US 601 2 MI NE KERSHAW	PD-006	LANCASTER	AL	CU
*	PEEDEE	030402020203	LITTLE LYNCHES RVR AT US 601 2 MI NE KERSHAW	PD-006	LANCASTER	REC	FC
	PEEDEE	030402020203	LITTLE LYNCHES R. AT SC 157	PD-632	LANCASTER	AL	BIO
	PEEDEE	030402020206	LITTLE LYNCHES RIVER AT S-28-42	PD-343	KERSHAW	AL	PH
	PEEDEE	030402020301	FORK CK AT UN# RD 1.5 MI SW JEFFERSON	PD-068	CHESTERFIELD	AL	BIO
	PEEDEE	030402020301	LITTLE FORK CK AT S-13-265 1.5 MI SW JEFFERSON	PD-215	CHESTERFIELD	AL	CU
	PEEDEE	030402020301	LITTLE FORK CK AT S-13-265 1.5 MI SW JEFFERSON	PD-215	CHESTERFIELD	REC	FC
	PEEDEE	030402020301	LITTLE FORK CRK. AT CO.RD. 39 UPSTREAM OF BREWER GOLD MINE	PD-647	CHESTERFIELD	AL	BIO
	PEEDEE	030402020403	NEWMAN SWP AT S-16-449 0.9 MI NE OF LAMAR	PD-229	DARLINGTON	AL	DO
	PEEDEE	030402020403	NEWMAN SWP AT S-16-449 0.9 MI NE OF LAMAR	PD-229	DARLINGTON	REC	FC
*	PEEDEE	030402020405	SPARROW SWP AT S-16-697 2.5 MI E OF LAMAR	PD-072	DARLINGTON	REC	FC
	PEEDEE	030402020405	SPARROW SWAMP AT US 76 1.1 MI SOUTHWEST OF TIMMONSVILLE. SITE IS A USGS GAUGING SITE.	RS-04548	FLORENCE	AL	CR, CU, NI
	PEEDEE	030402020406	LAKE SWAMP AT S-21-38	PD-345	FLORENCE	AL	CR, CU, NI
	PEEDEE	030402020503	LYNCHES RIVER @ HWY 15	PD-071	LEE	FISH	HG
	PEEDEE	030402020503	COUSAR BR 1/4 MI BELOW BISHOPVILLE FINISHING CO	PD-112	LEE	AL	PH
	PEEDEE	030402020504	LYNCHES RIVER @ SC 401	PD-364	LEE	FISH	HG
	PEEDEE	030402020505	LYNCHES RIVER AT S-21-55	PD-093	FLORENCE	AL	PH
	PEEDEE	030402020505	LYNCHES RIVER AT SC 403	PD-319	FLORENCE	AL	PH
	PEEDEE	030402020601	CAMP BRANCH AT S-21-278	PD-346	FLORENCE	AL	DO
	PEEDEE	030402020602	SINGLETON SWAMP AT S-21-67	PD-314	FLORENCE	AL	DO, PH
	PEEDEE	030402020603	LAKE SWAMP ON SC 341	PD-086A	FLORENCE	AL	DO
	PEEDEE	030402020604	LAKE SWAMP AT SC 341 2.6 MI W OF JOHNSONVILLE	PD-087	FLORENCE	AL	CU, NI
	PEEDEE	030402020701	LYNCHES RVR AT US 52 NEAR EFFINGHAM	PD-041	FLORENCE	AL	PH
	PEEDEE	030402020701	LYNCHES RIVER @ US 52	PD-624	FLORENCE	FISH	HG

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	PEEDEE	030402020703	BIG SWP AT S-21-360 1.1 MI W OF PAMPLICO	PD-168	FLORENCE	AL	DO
	PEEDEE	030402020703	BIG SWP AT S-21-360 1.1 MI W OF PAMPLICO	PD-168	FLORENCE	REC	FC
	PEEDEE	030402020703	BIG SWP AT US 378 & SC 51 0.9 MI W OF SALEM	PD-169	FLORENCE	AL	DO
*	PEEDEE	030402020703	BIG SWP AT US 378 & SC 51 0.9 MI W OF SALEM	PD-169	FLORENCE	REC	FC
	PEEDEE	030402020704	LYNCHES RVR AT S-21-49 5 MI NW JOHNSONVILLE	PD-281	FLORENCE	AL	CU, NI, PH
	PEEDEE	030402020705	LYNCHES RIVER @ JOHNSONVILLE	PD-048	FLORENCE	FISH	HG
	PEEDEE	030402031302	BEAR SWAMP AT S-17-56	PD-368	DILLON	AL	DO
	PEEDEE	030402031404	LUMBER RIVER @ RICEFIELD COVE	PD-038	HORRY	FISH	HG
	PEEDEE	030402031404	LUMBER RIVER @ CAUSEY LANDING	PD-664	HORRY	FISH	HG
	PEEDEE	030402040403	BUCK SWP AT S-17-33	PD-031	DILLON	AL	DO
	PEEDEE	030402040404	BUCK SWAMP AT S-17-42	PD-349	DILLON	AL	DO
	PEEDEE	030402040404	BUCK SWAMP AT S-17-42	PD-349	DILLON	REC	FC
	PEEDEE	030402040504	LITTLE PEE DEE RVR AT S-17-23	PD-029E	DILLON	REC	FC
	PEEDEE	030402040504	LITTLE PEE DEE RIVER @ MOCOCASIN'S BLUFF	PD-283	DILLON	FISH	HG
	PEEDEE	030402040505	MAPLE SWP AT SC 57	PD-030	DILLON	AL	DO
	PEEDEE	030402040506	LITTLE PEE DEE RIVER @ DILLON COUNTY PARK	PD-030A	DILLON	FISH	HG
	PEEDEE	030402040506	LITTLE PEE DEE RIVER @ FLOYDALE BRIDGE	PD-618	DILLON	FISH	HG
	PEEDEE	030402040508	LITTLE PEE DEE AT S-34-60	PD-052	MARION	AL	CU
	PEEDEE	030402040508	LITTLE PEE DEE RIVER @ GILCREST LANDING	PD-053	MARION	FISH	HG
	PEEDEE	030402040604	LOOSING SWAMP AT S-26-23 3.7 MI NE OF AYNOR	RS-03513	HORRY	AL	DO
	PEEDEE	030402040801	CEDAR CREEK AT S-26-23	PD-351	HORRY	AL	DO
	PEEDEE	030402040803	WHITE OAK CK AT S-34-31	PD-037	MARION	AL	DO
	PEEDEE	030402040803	LITTLE PEE DEE RIVER @ SANDY BLUFF	PD-054	HORRY	FISH	HG
	PEEDEE	030402040803	LITTLE PEE DEE RIVER @ RED BLUFF	PD-654	MARION	FISH	HG
	PEEDEE	030402040804	LITTLE PEE DEE RIVER @ GALAVANTS FERRY	PD-619	MARION	FISH	HG
	PEEDEE	030402040804	LITTLE PEE DEE RIVER @ DAVIS LANDING	PD-655	MARION	FISH	HG
	PEEDEE	030402040808	LITTLE PEE DEE RIVER @ LOCUST TREE LANDING	PD-656	MARION	FISH	HG
	PEEDEE	030402040808	LITTLE PEE DEE RIVER @ GUNTER'S LAKE	PD-657	HORRY	FISH	HG
	PEEDEE	030402040808	LITTLE PEE DEE @ HUGHES LANDING	PD-691	HORRY	FISH	HG
	PEEDEE	030402040810	LITTLE PEE DEE RIVER @ PUNCHBOWL LAND	PD-350	HORRY	FISH	HG
	PEEDEE	030402040810	LITTLE PEE DEE RIVER @ HWY 378	PD-620	HORRY	FISH	HG
	PEEDEE	030402040810	LITTLE PEE DEE RIVER @ SAMPSON LANDING	PD-658	MARION	FISH	HG
	PEEDEE	030402040810	RUSS CREEK @ PARKERS LANDING	PD-665	MARION	FISH	HG
	PEEDEE	030402050103	BEAVER DAM CREEK AT S-31-313	PD-636	LEE	AL	BIO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	PEEDEE	030402050104	LAKE ASHWOOD, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CL-077	LEE	AL	CHLA, TN
	PEEDEE	030402050104	MECHANICSVILLE SWAMP AT S-31-500	PD-356	LEE	AL	DO
	PEEDEE	030402050104	MCGRITS CREEK AT COUNTY RD 73, 7.5 M SW OF BISHOPVILLE	RS-01017	LEE	AL	DO, TURBIDITY
•	PEEDEE	030402050104	MCGRITS CREEK AT COUNTY RD 73, 7.5 M SW OF BISHOPVILLE	RS-01017	LEE	REC	FC
	PEEDEE	030402050105	SCAPE ORE SWAMP AT S-31-108	PD-355	LEE	REC	FC
	PEEDEE	030402050203	UNNAMED DRAINAGE CANAL TO ATKINS CANAL AT SC 527 (3/4 MI N OF US 76,	PD-354	LEE	AL	DO
	PEEDEE	030402050301	GREEN SWP AT S-43-33	PD-039	SUMTER	AL	DO
	PEEDEE	030402050302	NASTY BR AT S-43-251 7.5 MI SW OF SUMTER	PD-239	SUMTER	AL	DO
	PEEDEE	030402050303	BRUNSON SWAMP CREEK AT S-43-251 - 1.3 MI W OF SC 120 - 9.25 MI SW SUMTER	RS-03345	SUMTER	AL	BIO
	PEEDEE	030402050303	BRUNSON SWAMP CREEK AT S-43-251 - 1.3 MI W OF SC 120 - 9.25 MI SW SUMTER	RS-03345	SUMTER	REC	FC
	PEEDEE	030402050401	TURKEY CREEK	PD-040	SUMTER	FISH	HG
	PEEDEE	030402050401	POCOTALIGO RVR AT US 15 3.5 MI S SUMTER	PD-091	SUMTER	AL	DO
	PEEDEE	030402050401	POCOTALIGO RVR AT S-43-32 9 MI SSE OF SUMTER	PD-202	SUMTER	AL	DO
	PEEDEE	030402050401	BRIAR BRANCH AT S-43-459	PD-617	SUMTER	AL	BIO
	PEEDEE	030402050404	BIG BR. AT SC 261	PD-627	CLARENDON	AL	BIO
	PEEDEE	030402050406	DEEP CREEK AT S-14-25 AND 1.2 MI NE OF BLOOMVILLE	RS-03347	CLARENDON	AL	BIO
	PEEDEE	030402050406	DEEP CREEK AT S-14-25 AND 1.2 MI NE OF BLOOMVILLE	RS-03347	CLARENDON	REC	FC
	PEEDEE	030402050407	POCOTALIGO RVR AT S-14-50 9.5 MI NE MANNING	PD-043	CLARENDON	AL	DO
	PEEDEE	030402050407	POCOTALIGO RVR AT S-14-50 9.5 MI NE MANNING	PD-043	CLARENDON	FISH	HG
	PEEDEE	030402050407	POCOTALIGO RVR AT 3RD BRDG N OF MANNING ON US 301	PD-115	CLARENDON	AL	DO
	PEEDEE	030402050502	DOUGLAS SWAMP OFF THIGPEN ROAD BEHIND WHITE HOUSE, 3.5 M E OF TURBEVILLE	RS-01002	FLORENCE	AL	DO
	PEEDEE	030402050603	BLACK RVR AT S-14-40 E OF MANNING	PD-116	CLARENDON	AL	DO
	PEEDEE	030402050701	CLAPP SWAMP AT SC 527	RS-02325	WILLIAMSBURG	AL	DO
	PEEDEE	030402050710	BLACK RIVER @ KINGSTREE	PD-044	WILLIAMSBURG	FISH	HG
	PEEDEE	030402050805	BLACK MINGO CREEK AT S-45-121	PD-360	WILLIAMSBURG	AL	DO
	PEEDEE	030402050806	MINGO CREEK	PD-172	GEORGETOWN	FISH	HG
	PEEDEE	030402050901	BLACK RIVER AT S-45-30	PD-359	WILLIAMSBURG	AL	DO
	PEEDEE	030402050903	SPRING GULLY AT BRIDGE ON US 521 3.8 MI NE OF TRIC	RS-04533	WILLIAMSBURG	AL	BIO
	PEEDEE	030402050906	BLACK RIVER @ PINE TREE LANDING	PD-046	GEORGETOWN	FISH	HG
	PEEDEE	030402050906	BLACK RVR AT SC 51 11.6 MI NE OF ANDREWS	PD-170	GEORGETOWN	AL	CU, DO, NI
	PEEDEE	030402050906	BLACK RVR AT SC 51 11.6 MI NE OF ANDREWS	PD-170	GEORGETOWN	FISH	HG
	PEEDEE	030402050906	BLACK RIVER @ PUMPHOUSE LANDING	PD-626	WILLIAMSBURG	FISH	HG
	PEEDEE	030402050906	BLACK RIVER @ OLD PUMP STATION	PD-659	GEORGETOWN	FISH	HG

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	PEEDEE	030402050906	BLACK RIVER @ PEA HOUSE LANDING	PD-692	GEORGETOWN	FISH	HG
	PEEDEE	030402050908	GREENS CREEK AT S-22-318 (JOHNSON ROAD) 7.7 MI NW OF GEORGETOWN	RS-03353	GEORGETOWN	REC	FC
	PEEDEE	030402050909	BLACK RIVER @ PETER'S CREEK	PD-171	GEORGETOWN	FISH	HG
	PEEDEE	030402050909	BLACK RIVER @ ROCKY POINT	PD-660	GEORGETOWN	FISH	HG
	PEEDEE	030402050910	BLACK RIVER @ PRINGLE'S FERRY	PD-661	GEORGETOWN	FISH	HG
	PEEDEE	030402060703	BUCK CREEK AT SC 905	PD-362	HORRY	AL	CU, NI
	PEEDEE	030402060704	WACCAMAW RVR AT SC 9 7.0 MI W OF CHERRY GROVE	MD-124	HORRY	AL	CU
	PEEDEE	030402060704	WACCAMAW RIVER @ SC HWY 9	MD-124	HORRY	FISH	HG
	PEEDEE	030402060705	SIMPSON CREEK AT SC 905	PD-363	HORRY	AL	NI, ZN
	PEEDEE	030402060803	KINGSTON LK NR PUMP STA ON LAKESIDE DR CONWAY	MD-107	HORRY	REC	FC
*	PEEDEE	030402060803	CRAB TREE SWAMP AT LONG ST BL OUTFALL OF CONWAY #1 POND	MD-158	HORRY	REC	FC
	PEEDEE	030402060803	CRAB TREE SWAMP AT BRIDGE ON US 501 1.5 MI NW OF CONWAY	RS-04375	HORRY	REC	FC
	PEEDEE	030402060902	WACCAMAW RIVER @ SC 31	CSTL-553	HORRY	FISH	HG
	PEEDEE	030402060902	WACCAMAW RIVER @ SEC RD 105	CSTL-554	HORRY	FISH	HG
	PEEDEE	030402060904	WACCAMAW RIVER @ SEC RD 901	CSTL-555	HORRY	FISH	HG
	PEEDEE	030402060905	WACCAMAW RIVER @ PITCH LANDING	CSTL-556	HORRY	FISH	HG
	PEEDEE	030402060905	WACCAMAW RIVER @ TODDVILLE	MD-144	HORRY	FISH	HG
	PEEDEE	030402060905	BEAR SWAMP AT S-26-110	PD-638	HORRY	AL	BIO
	PEEDEE	030402060906	INTRACOASTAL WATERWAY @ SOCASTEE	CSTL-558	HORRY	FISH	HG
	PEEDEE	030402060906	UNNAMED TRIBUTARYTO INTERCOASTAL WATERWAY AT SC 707 1.2 MI ENE OF SOCASTEE & SC 544	RS-03332	HORRY	REC	FC
	PEEDEE	030402060907	WACCAMAW RIVER @ PEACH TREE	MD-136	HORRY	FISH	HG
	PEEDEE	030402060907	WACCAMAW RIVER @ BUCKSVILLE	MD-145	HORRY	FISH	HG
	PEEDEE	030402061002	WACCAMAW RIVER @ BUCKSPORT LANDING	CSTL-557	HORRY	FISH	HG
	PEEDEE	030402061002	WACCAMAW RIVER @ WACCA WACHE LANDING	MD-138	GEORGETOWN	FISH	HG
	PEEDEE	030402061003	WACCAMAW RIVER @ SANDY ISLAND	MD-140	GEORGETOWN	FISH	HG
	PEEDEE	030402061003	WACCAMAW RIVER @ HAGLEY LANDING	MD-141	GEORGETOWN	FISH	HG
	PEEDEE	030402070103	SAMPIT RVR BTWN MOUTHS OF PORTS CK & PENNY ROYAL CK	MD-075	GEORGETOWN	AL	DO
#	PEEDEE	030402070106	SAMPIT RVR OPP AMER CYANAMID CHEM CO	MD-073	GEORGETOWN	AL	DO, PH
#	PEEDEE	030402070106	SAMPIT RVR AT CHANNEL MARKER #30	MD-074	GEORGETOWN	AL	DO, PH
#	PEEDEE	030402070106	SAMPIT RVR AT US 17	MD-077	GEORGETOWN	AL	DO
	PEEDEE	030402070106	SAMPIT RIVER APPROXIMATELY 1.4 MILES WEST OF US 17 BRIDGE	PD-628	GEORGETOWN	FISH	HG
	PEEDEE	030402070203	CLARKS CREEK @ SNOW LAKE	PD-317	WILLIAMSBURG	FISH	HG
	PEEDEE	030402070203	GREAT PEE DEE RIVER @ STAPLES LAKE	PD-621	WILLIAMSBURG	FISH	HG

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	PEEDEE	030402070204	PEE DEE RVR AT PETERS FIELD LANDING OFF S-22-36 US IP PUMP STATION	PD-060	GEORGETOWN	AL	CU
	PEEDEE	030402070204	PEE DEE RVR AT PETERS FIELD LANDING OFF S-22-36 US IP PUMP STATION	PD-060	GEORGETOWN	FISH	HG
	PEEDEE	030402070205	GREAT PEE DEE RIVER ABOVE HWY 701 BRIDGE	CSTL-559	GEORGETOWN	FISH	HG
#	PEEDEE	030402070207	WINYAH BAY AT JCT OF PEE DEE & WACCAMAW AT MARKER 92	MD-080	GEORGETOWN	AL	PH
#	PEEDEE	030402070207	PEE DEE RVR AT WHITE HOUSE PLANTATION	MD-275	GEORGETOWN	AL	CU
	PEEDEE	030402070207	GREAT PEE DEE RIVER @ SAMWORTH WMA	PD-663	GEORGETOWN	FISH	HG
*	PEEDEE	030402070208	JONES CREEK AT NANCY CREEK	05-01	GEORGETOWN	SHELLFISH	FC
	PEEDEE	030402070208	NOBLE SLOUGH	05-02	GEORGETOWN	SHELLFISH	FC
*	PEEDEE	030402070208	OYSTER BAY NEAR CUTOFF CREEK	05-05	GEORGETOWN	SHELLFISH	FC
*	PEEDEE	030402070208	MUD BAY AT NO MAN'S FRIEND CREEK	05-06	GEORGETOWN	SHELLFISH	FC
*	PEEDEE	030402070208	JONES CREEK AT MUD BAY	05-07	GEORGETOWN	SHELLFISH	FC
*	PEEDEE	030402070208	WINYAH BAY MAIN CHANNEL, BUOY 19A, RANGE E	05-20	GEORGETOWN	SHELLFISH	FC
	PEEDEE	030402070208	WINYAH BAY MAIN CHANNEL, BUOY 17, RANGE E	05-21	GEORGETOWN	SHELLFISH	FC
*	PEEDEE	030402070208	WINYAH BAY, TIP OF WESTERN CHANNEL ISLAND	05-25	GEORGETOWN	SHELLFISH	FC
	PEEDEE	030402080301	INTRACOASTAL WTRWAY AT PT 3 MI N OF BRDG ON US 501	MD-085	HORRY	AL	CU
	PEEDEE	030402080301	INTRACOASTAL WTRWY (LITTLE RVR) ON SC 9 (US 17)	MD-125	HORRY	AL	CU
	PEEDEE	030402080301	INTRACOASTAL WATERWAY @ NORTH MYRTLE	MD-163	HORRY	FISH	HG
	PEEDEE	030402080305	LITTLE RIVER JETTY	01-01	HORRY	SHELLFISH	FC
*	PEEDEE	030402080305	MOUTH OF DUNN SOUND CREEK	01-02	HORRY	SHELLFISH	FC
*	PEEDEE	030402080305	BIG BEND UP DUNN SOUND CREEK	01-05	HORRY	SHELLFISH	FC
*	PEEDEE	030402080305	BRIDGE TO WAITES ISLAND	01-06	HORRY	SHELLFISH	FC
*	PEEDEE	030402080306	HOG INLET	01-07	HORRY	SHELLFISH	FC
*	PEEDEE	030402080306	42ND AVENUE - CHERRY GROVE	01-17	HORRY	SHELLFISH	FC
*	PEEDEE	030402080306	53RD AVENUE BRIDGE ON CANAL	01-17A	HORRY	SHELLFISH	FC
*	PEEDEE	030402080306	DUNN SOUND AT HOG INLET	01-18	HORRY	SHELLFISH	FC
*	PEEDEE	030402080306	MAIN CREEK AT 53RD AVENUE	01-19	HORRY	SHELLFISH	FC
*	PEEDEE	030402080306	WHITE POINT SWASH	02-01	HORRY	SHELLFISH	FC
	PEEDEE	030402080306	HOUSE CK AT 53RD AVE OUT FROM BOAT LANDING (01-19)	MD-276	HORRY	AL	CU
*	PEEDEE	030402080307	SINGLETON SWASH	02-02	HORRY	SHELLFISH	FC
*	PEEDEE	030402080307	CANEPATCH SWASH	02-03	HORRY	SHELLFISH	FC
*	PEEDEE	030402080308	WITHERS SWASH	03-01	HORRY	SHELLFISH	FC
*	PEEDEE	030402080308	MIDWAY SWASH - PEBBLE BEACH	03-02	HORRY	SHELLFISH	FC
	PEEDEE	030402080402	TOWN CREEK AT SIXTY BASS CREEK	05-08	GEORGETOWN	SHELLFISH	FC
*	PEEDEE	030402080402	TOWN CREEK AT SOUTHERN REACH OF CLAMBANK CREEK	05-09	GEORGETOWN	SHELLFISH	FC
*	PEEDEE	030402080402	DEBIDUE CREEK AT BOAT BASIN	05-13	GEORGETOWN	SHELLFISH	FC
	PEEDEE	030402080402	DEBIDUE CREEK AND BASS HOLE BAY	05-16	GEORGETOWN	SHELLFISH	FC
	SALKEHATCHIE	030502060308	TRIB TO PINE ISLAND CK W OF PINE ISLAND	RT-02019	COLLETON	AL	CU
	SALKEHATCHIE	030502070103	TURKEY CK 1 MI BL MILLIKEN BARNWELL OUTFALL AT CLINTON ST.	CSTL-001B	BARNWELL	REC	FC
*	SALKEHATCHIE	030502070110	WELLS BRCH AT SC 300	RS-02472	ALLENDALE	REC	FC

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
*	SALKEHATCHIE	030502070111	SALKEHATCHIE RVR AT SC 278 2.5 MI S BARNWELL	CSTL-003	BARNWELL	REC	FC
*	SALKEHATCHIE	030502070302	LEMON CREEK AT S-05-541	CSTL-116	BAMBERG	REC	FC
	SALKEHATCHIE	030502070302	LEMON CREEK AT S-74	CSTL-576	BAMBERG	AL	BIO
	SALKEHATCHIE	030502070401	LITTLE SALKEHATCHIE @ SC 70	CSTL-566	BAMBERG	FISH	HG
	SALKEHATCHIE	030502070403	LITTLE SALKEHATCHIE RIVER AT U.S. 601	CSTL-115	BAMBERG	REC	FC
*	SALKEHATCHIE	030502070504	BUCKHEAD CREEK AT SC 212	CSTL-119	COLLETON	REC	FC
	SALKEHATCHIE	030502070505	WILLOW SWAMP AT S-15-27	CSTL-118	COLLETON	REC	FC
	SALKEHATCHIE	030502070505	WILLOW CRK. AT SR 42	CSTL-570	COLLETON	AL	BIO
*	SALKEHATCHIE	030502070506	LITTLE SALKEHATCHIE RIVER AT SC 64	CSTL-117	COLLETON	REC	FC
	SALKEHATCHIE	030502070508	LITTLE SALKEHATCHIE RIVER AT SC 63	CSTL-120	COLLETON	AL	CU, ZN
	SALKEHATCHIE	030502070508	LITTLE SALKEHATCHIE RIVER AT SC 63	CSTL-120	COLLETON	FISH	HG
	SALKEHATCHIE	030502070508	SANDY RUN CREEK AT US 21	CSTL-585	COLLETON	AL	BIO
	SALKEHATCHIE	030502070602	SAVANNAH CREEK AT S.R.-87	CSTL-053	BAMBERG	AL	BIO
	SALKEHATCHIE	030502070603	SALKEHATCHIE RIVER @ HWY 301	CSTL-048	BAMBERG	FISH	HG
	SALKEHATCHIE	030502070603	SALKEHATCHIE RIVER @ SC 641	CSTL-105	BAMBERG	FISH	HG
	SALKEHATCHIE	030502070604	RICEPATCH CRK. AT SC 63	CSTL-569	COLLETON	AL	BIO
	SALKEHATCHIE	030502070606	SALKEHATCHIE RIVER @ US 601	CSTL-562	HAMPTON	FISH	HG
	SALKEHATCHIE	030502070703	REMICK SWAMP CRK. AT SR 41	CSTL-584	COLLETON	AL	BIO
	SALKEHATCHIE	030502070704	COMBAHEE RVR AT US 17 10 MI ESE YEMASSEE	CSTL-098	BEAUFORT	AL	DO
	SALKEHATCHIE	030502070704	COMBAHEE RVR AT US 17 10 MI ESE YEMASSEE	CSTL-098	BEAUFORT	FISH	HG
	SALKEHATCHIE	030502070704	COMBAHEE RIVER @ SEC RD 756	CSTL-561	COLLETON	FISH	HG
	SALKEHATCHIE	030502070705	CHEHAW RVR AT OLD CHEHAW BOAT LANDING ON S-15-161	RT-02017	COLLETON	AL	ZN
*	SALKEHATCHIE	030502070803	IRELAND CK AT S-15-116 5 1/2 MI N OF WALTERBORO	CSTL-044	COLLETON	REC	FC
	SALKEHATCHIE	030502070902	CHESSIE CREEK @ CHESSIE LANDING	CSTL-070	COLLETON	FISH	HG
	SALKEHATCHIE	030502070903	HORSESHOE CREEK AT SC 64	CSTL-071	COLLETON	AL	CU, ZN
	SALKEHATCHIE	030502070903	HORSESHOE CREEK AT SC 64	CSTL-071	COLLETON	FISH	HG
	SALKEHATCHIE	030502070903	HORSESHOE CREEK AT SC 64	CSTL-071	COLLETON	REC	FC
	SALKEHATCHIE	030502070903	CHESSEY CREEK AT S.R. 45	CSTL-580	COLLETON	AL	BIO
	SALKEHATCHIE	030502070903	FULLER SWAMP CRK. AT US 17A	CSTL-581	COLLETON	AL	BIO
	SALKEHATCHIE	030502071001	ASHEPOO RVR AT SC 303 10 MI SSW OF WALTERBORO	CSTL-068	COLLETON	AL	ZN
*	SALKEHATCHIE	030502071001	ASHEPOO RVR AT SC 303 10 MI SSW OF WALTERBORO	CSTL-068	COLLETON	REC	FC
	SALKEHATCHIE	030502071002	ASHEPOO RVR AT US 17 3.4 MI ESE OF GREEN POND	CSTL-069	COLLETON	AL	DO
	SALKEHATCHIE	030502071002	ASHEPOO RIVER @ HWY 17	CSTL-069	COLLETON	FISH	HG

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SALKEHATCHIE	030502071003	ASHEPO RIVER POG	14-19	COLLETON	SHELLFISH	FC
	SALKEHATCHIE	030502071003	S. EDISTO RVR & ASHEPOO RVR CUT	14-20	COLLETON	SHELLFISH	FC
•	SALKEHATCHIE	030502071003	SCOTT CREEK, HEADWATERS AT JEREMY INLET AT BOAT LANDING	14-21	COLLETON	SHELLFISH	FC
	SALKEHATCHIE	030502071003	ASHEPOO RIVER AT S-15-26	MD-251	COLLETON	AL	TURBIDITY
	SALKEHATCHIE	030502071003	ASHEPOO RIVER AT PUBLIC OYSTER GROUND (14-19)	MD-253	COLLETON	AL	CU, TURBIDITY
	SALKEHATCHIE	030502071003	ASHEPOO RIVER AT HOLE-IN-THE-WALL OXBOW 0.5 MI SW (DOWNRIVER) OF S-15-26	RO-046071	COLLETON	AL	TURBIDITY
#	SALKEHATCHIE	030502071003	ROCK CK 0.75 MI SW CONFL W/ ASHEPOO RVR	RT-032035	COLLETON	AL	TURBIDITY
	SALKEHATCHIE	030502071101	COOSAW RVR NEAR MOUTH OF BULL RVR	RO-02005	BEAUFORT	AL	CU, TURBIDITY
	SALKEHATCHIE	030502071101	WIMBEE CK 0.7 MI SE OF MOUTH OF S WIMBEE CK	RO-036037	BEAUFORT	AL	TURBIDITY
	SALKEHATCHIE	030502071101	TRIBUTARY TO BULL RIVER, 7.5 M NE OF BEAUFORT	RT-01643	BEAUFORT	AL	TURBIDITY
	SALKEHATCHIE	030502071102	CAMPBELL CREEK AT WHALE BRANCH	14-02	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071102	LUCY POINT CREEK AT ROCKY SPRINGS CREEK	16A-13	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071102	LUCY POINT CREEK CSZ AT POLLUTION LINE NORTH EDGE	16A-13B	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071102	TIDAL CK NEAR CONFL OF COOSAW AND BULL RVRS CHISOLM ISL	RT-02015	BEAUFORT	AL	CU, TURBIDITY
	SALKEHATCHIE	030502071103	LUCY POINT CREEK CSZ AT POLLUTION LINE SOUTH EDGE	16A-13A	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071103	DOE CR BEHIND COASTAL SEAFOOD - BEHIND DATAW ISLAND	16A-14	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071103	EDDING CREEK AT SHRIMP DOCK	16A-18	BEAUFORT	SHELLFISH	FC
•	SALKEHATCHIE	030502071103	ROCK SPRINGS CREEK,UPPER REACHES	16A-19	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071103	EDDING CR AT SMALL TRIBUTARY BETWEEN STATIONS 9 AND 18	16A-23	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071103	JENKINS CREEK AT SMALL UNNAMED TRIBUTARY NORTH SIDE OF WARSAW ISLAND	16A-25	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071103	COFFIN CREEK MOUTH AT MORGAN RIVER	16A-27	BEAUFORT	SHELLFISH	FC
•	SALKEHATCHIE	030502071103	COFFIN CREEK, HEADWATERS AT SHRIMP DOCKS	16A-28	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071103	JENKINS CREEK, 500FT. NORTH OF STORMWATER AT DAWTAW ISLAND GOLF COURSE,	16A-30	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502071103	TRIB TO SPARROW NEST CK NEAR DATHA ISLAND	RT-02027	BEAUFORT	AL	CU
	SALKEHATCHIE	030502071103	COFFIN CK 0.7 MI SE OF CONFL W/ MORGAN RVR	RT-032033	BEAUFORT	AL	TURBIDITY
	SALKEHATCHIE	030502071104	SAINT HELENA SOUND, 7 M SW OF EDISTO BEACH	RO-01163	BEAUFORT	AL	TURBIDITY
	SALKEHATCHIE	030502071104	COOSAW RVR NEAR MOUTH OF COMBAHEE RVR	RO-02001	BEAUFORT	AL	TURBIDITY
	SALKEHATCHIE	030502080102	LAKE GEORGE WARREN IN FOREBAY NEAR DAM	CL-062	HAMPTON	AL	ZN
	SALKEHATCHIE	030502080102	LAKE WARREN, BLACK CK ARM, AT S-25-41 5 MI SW OF HAMPTON	CSTL-075	HAMPTON	AL	ZN
	SALKEHATCHIE	030502080102	LAKE GEORGE WARREN 0.2 MI W OF SPILLWAY NE CORNER OF LAKE CLOSER TO LAKE WARREN ST PARK SHORELINE	RL-03331	HAMPTON	AL	CHLA, TN, TP, ZN
	SALKEHATCHIE	030502080201	DUCK CREEK AT THE DOWNSTREAM SIDE OF US 278, 2.6 M SE OF ALLENDALE	RS-01025	ALLENDALE	AL	DO
	SALKEHATCHIE	030502080202	COOSAWHATCHIE RVR AT S-03-47	CSTL-110	ALLENDALE	AL	DO
	SALKEHATCHIE	030502080202	COOSAWHATCHIE RVR AT S-03-47	CSTL-110	ALLENDALE	REC	FC
	SALKEHATCHIE	030502080204	COOSAWHATCHIE RIVER AT SC 363	CSTL-121	HAMPTON	AL	DO, ZN
	SALKEHATCHIE	030502080204	COOSAWHATCHIE RIVER AT SC 363	CSTL-121	HAMPTON	REC	FC
	SALKEHATCHIE	030502080204	BLOOD HILL CREEK AT S-25-69 2.4 MI NE OF GIFFORD	RS-03360	HAMPTON	REC	FC
	SALKEHATCHIE	030502080302	CYPRESS CREEK AT S-27-108	CSTL-122	JASPER	AL	ZN
	SALKEHATCHIE	030502080302	CYPRESS CREEK AT SC 3	CSTL-582	JASPER	AL	BIO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
*	SALKEHATCHIE	030502080401	SANDERS BR AT SC 278	CSTL-010	HAMPTON	REC	FC
	SALKEHATCHIE	030502080401	SANDERS BR AT S-25-50	CSTL-011	HAMPTON	AL	BIO
*	SALKEHATCHIE	030502080401	SANDERS BR AT S-25-50	CSTL-011	HAMPTON	REC	FC
*	SALKEHATCHIE	030502080401	SANDERS BRANCH AT SC RD 363	CSTL-108	HAMPTON	REC	FC
	SALKEHATCHIE	030502080401	SANDERS BR FROM BRIDGE AT PAVED RD FROM SC 363 N	RS-02488	HAMPTON	AL	ZN
*	SALKEHATCHIE	030502080401	SANDERS BR FROM BRIDGE AT PAVED RD FROM SC 363 N	RS-02488	HAMPTON	REC	FC
	SALKEHATCHIE	030502080405	COOSAWHATCHIE RIVER @ SEC RD 36	CSTL-077	JASPER	FISH	HG
	SALKEHATCHIE	030502080406	BEES CK AT SC 462 5.9 MI NE OF RIDGELAND	MD-128	JASPER	AL	DO
	SALKEHATCHIE	030502080407	COOSAWHATCHIE RVR AT US 17 AT COOSAWHATCHIE	CSTL-107	JASPER	AL	DO, PH
	SALKEHATCHIE	030502080501	BATTERY CREEK AT FIVE POINTS CREEK	15-10	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080501	BATTERY CREEK 1000 FEET BELOW RABBIT ISLAND	15-19	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080501	BATTERY CREEK AT UNNAMED CREEK AT (FORMER) DISCHARGE OF BC HIGH AND CHERRY HILL HIGH	15-21	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080501	BATTERY CREEK - DOWLINGWOOD TRIBUTARY (C6-97)	15-25	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080501	BATTERY CREEK - PICKET FENCE TRIBUTARY (C6-97)	15-26	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080501	BATTERY CREEK - CHERRY HILL TRIBUTARY (C6-97)	15-27	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080501	BATTERY CREEK - STORM WATER OUTFALL UNDER RR TRACK (C6-97)	15-28	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080501	BATTERY CREEK - TRIBUTARY ON R SIDE BEFORE BATTERY SHORES (C6-97)	15-29	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080501	BATTERY CREEK - COTTAGE FARMS COMMUNITY DOCK (C6-97)	15-30	BEAUFORT	SHELLFISH	FC
*	SALKEHATCHIE	030502080501	BATTERY CREEK - BATTERY POINT COMMUNITY DOCK	15-31	BEAUFORT	SHELLFISH	FC
*	SALKEHATCHIE	030502080501	BATTERY CREEK - UNDER POWER LINE	15-32	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080503	COWEN CREEK SECOND MIDDLE MARSH	15-18	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080503	CAPERS CR SSG AT PENN COMMUNITY SRVCS RETREAT CTR	15-20	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080601	POCOTALIGO RVR AT US 17 AT POCOTALIGO	MD-007	BEAUFORT	AL	DO
*	SALKEHATCHIE	030502080601	POCOTALIGO RVR AT US 17 AT POCOTALIGO	MD-007	BEAUFORT	REC	FC
	SALKEHATCHIE	030502080602	HUSPAH CREEK AT RAILROAD TRESTLE	14-14	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080602	HUSPAH CREEK AT BULL POINT - WHALE BRANCH POG	14-18	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080602	HUSPAH CREEK AT RAILROAD TRESTLE (14-14)	MD-254	BEAUFORT	AL	CU
	SALKEHATCHIE	030502080605	HABERSHAM CREEK ABOVE STATION #16, FIRST SPLIT	17-16A	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080606	CHECHESSEE CREEK AT OKATIE RIVER	18-03	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080606	OKATIE RIVER AT DOCK WITHOUT HOUSE	18-08	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080606	CHECHESSEE CREEK FIRST UNNAMED TRIBUTARY FROM COLLETON RIVER	18-09	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080606	OKATIE RV AT CONFLUENCE OF PINKNEY COLONY TRIBU. (C10-97)	18-16	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080606	COLLETON RVR AT COLLETON NECK-AT JCT WITH CHECHESSEE RV	MD-176	BEAUFORT	AL	DO
	SALKEHATCHIE	030502080606	COLLETON RVR NEAR MOUTH (SHELLFISH STATION 18-5)	MD-245	BEAUFORT	AL	DO
	SALKEHATCHIE	030502080606	COLLETON RIVER AT MOUTH OF CALLAWASSIE CREEK, 4.5 M N OF BLUFFTON	RO-01125	BEAUFORT	AL	DO
	SALKEHATCHIE	030502080607	CHECHESSEE CREEK SECOND BRIDGE TO CALLAWASSIE ISLAND	18-10	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080607	CHECHESSEE CREEK FIRST BRIDGE TO CALLAWASSIE ISLAND	18-11	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080607	CHECHESSEE CREEK TRIBUTARY FROM SPRING ISLAND SHRIMP POND	18-14	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030502080607	CHECHESSEE RVR AT SC 170 10.5 MI SW OF BEAUFORT	MD-117	BEAUFORT	AL	DO
	SALKEHATCHIE	030502080607	CHECHESEE RIVER, 6.5 M WEST OF PORT ROYAL	RO-01146	BEAUFORT	AL	DO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SALKEHATCHIE	030502080607	CHECHESSEE RVR 1.4 MI SE CONFL W/ COLLETON RVR	RO-036032	BEAUFORT	AL	DO
*	SALKEHATCHIE	030502080608	FISH HAUL CREEK AT PORT ROYAL SOUND	20-27	Beaufort	SHELLFISH	FC
	SALKEHATCHIE	030502080608	BROAD RVR AT MOUTH OF ARCHER CK ON SW SIDE OF USMC	MD-172	BEAUFORT	AL	DO
	SALKEHATCHIE	030502080608	PORT ROYAL SOUND 1.8 MI SW OF TIP OF PARRIS ISLAND	RO-036034	BEAUFORT	AL	CU
	SALKEHATCHIE	030601090406	WRIGHT RIVER 1.9 MI SE OF TURN BRIDGE LANDING	RT-032032	JASPER	AL	TURBIDITY
	SALKEHATCHIE	030601100103	GREAT SWAMP AT U.S. 17	MD-129	JASPER	AL	CU, ZN
*	SALKEHATCHIE	030601100103	GREAT SWAMP AT U.S. 17	MD-129	JASPER	REC	FC
	SALKEHATCHIE	030601100201	NEW RIVER @ SC 170	MD-118	JASPER	FISH	HG
*	SALKEHATCHIE	030601100201	NEW RVR AT SC 170 9 MI W OF BLUFFTON	MD-118	JASPER	REC	FC
	SALKEHATCHIE	030601100202	RAMSHORN CREEK AT NEW RIVER (19-07)	MD-258	JASPER	AL	NI
	SALKEHATCHIE	030601100302	BROAD CREEK AT SHARK BANK AND - CSZ SEA PINES WWTP, MARKER #2	20-03	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030601100302	BROAD CREEK AT PALMETTO BAY MARINA CSZ **(COMBINED 20-04E&F)	20-04A	BEAUFORT	SHELLFISH	FC
*	SALKEHATCHIE	030601100302	CREEK BEHIND LYNN SMITH'S OYSTER PLANT AT BROAD CREEK	20-16	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030601100302	BROAD CREEK AT BROAD CREEK MARINA CSZ **(COMBINED 20-17E&F)	20-17B	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030601100302	BROAD CREEK AT SHELTER COVE MARINA	20-18	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030601100302	BROAD CREEK AT FIRST MAJOR CREEK RIGHT AFTER MARKER #18 (C6-97)	20-24	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030601100302	BROAD CREEK AT CONFLUENCE OF CHANNEL LEADING TO OLD OYSTER FACTORY (C2-99)	20-25	BEAUFORT	SHELLFISH	FC
	SALKEHATCHIE	030601100304	BROAD CREEK AT CALIBOGUE SOUND - NORTH END OF BUCK ISLAND	20-15A	BEAUFORT	SHELLFISH	FC
	SALUDA	030501090102	N SALUDA RVR AT BRDG AB JCT WITH SALUDA RVR E OF SC 186	S-004	GREENVILLE	AL	BIO
	SALUDA	030501090201	ADAMS CK AT UNPVD RD FROM SC 8 AND END OF S-39-34	RS-02330	PICKENS	AL	TURBIDITY
	SALUDA	030501090204	SOUTH SALUDA RVR AT SC 186	S-299	GREENVILLE	AL	PH
	SALUDA	030501090303	BIG BRUSHY CK AT S-04-143	S-301	ANDERSON	AL	DO
	SALUDA	030501090305	GROVE CR. AT SEC. RD. 541	S-774	GREENVILLE	AL	BIO
	SALUDA	030501090307	TRIB TO SALUDA RVR 350 FT BL W PELZER STP ON S-23-53	S-267	ANDERSON	AL	DO
	SALUDA	030501090307	MILL CK AT BENT BRIDGE RD, BL CAROLINA PLATING	S-315	GREENVILLE	AL	CR, CU
*	SALUDA	030501090401	REEDY RVR AT UN# RD OFF US 276 .75 MI W TRAVELERS REST	S-073	GREENVILLE	REC	FC
*	SALUDA	030501090401	LANGSTON CK AT SC 253	S-264	GREENVILLE	REC	FC
	SALUDA	030501090401	REEDY RIVER AT SR 133	S-868	GREENVILLE	AL	BIO
	SALUDA	030501090401	REEDY RIVER AT SR 88	S-928	GREENVILLE	AL	BIO
	SALUDA	030501090402	REEDY RVR AT S-23-30 3.9 MI SE GREENVILLE	S-013	GREENVILLE	AL	CU
*	SALUDA	030501090402	REEDY RVR AT S-23-30 3.9 MI SE GREENVILLE	S-013	GREENVILLE	REC	FC
*	SALUDA	030501090402	BRUSHY CK ON GREEN ST EXT BL DUNEAN MILL ON SC 20	S-067	GREENVILLE	REC	FC
	SALUDA	030501090402	REEDY RVR AT RIVERS ST, DOWNTOWN GREENVILLE	S-319	GREENVILLE	AL	BIO
*	SALUDA	030501090402	REEDY RVR AT RIVERS ST, DOWNTOWN GREENVILLE	S-319	GREENVILLE	REC	FC
	SALUDA	030501090402	BRUSHY CREEK AT SR 30	S-867	GREENVILLE	AL	BIO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
*	SALUDA	030501090403	HUFF CK AT SC 418 1.6 MI NW FORK SHOALS	S-178	GREENVILLE	REC	FC
	SALUDA	030501090403	HUFF CREEK AT SR 459	S-863	GREENVILLE	AL	BIO
	SALUDA	030501090404	REEDY RVR AT S-23-448 1.75 MI SE CONESTEE	S-018	GREENVILLE	AL	BIO
*	SALUDA	030501090404	REEDY RVR AT S-23-448 1.75 MI SE CONESTEE	S-018	GREENVILLE	REC	FC
*	SALUDA	030501090404	REEDY RVR ON HWY 418 AT FORK SHOALS	S-072	GREENVILLE	REC	FC
	SALUDA	030501090404	ROCKY CK AT S-23-453 3.5 MI SW OF SIMPSONVILLE	S-091	GREENVILLE	AL	BIO
*	SALUDA	030501090404	ROCKY CK AT S-23-453 3.5 MI SW OF SIMPSONVILLE	S-091	GREENVILLE	REC	FC
	SALUDA	030501090404	REEDY RVR AT S-23-316 3.5 MI SSW OF MAULDIN	S-323	GREENVILLE	AL	CU, ZN
*	SALUDA	030501090404	REEDY RVR AT S-23-316 3.5 MI SSW OF MAULDIN	S-323	GREENVILLE	REC	FC
	SALUDA	030501090501	LAKE RABON, S RABON CK ARM, JUST DS S-30-312	S-312	LAURENS	AL	PH
*	SALUDA	030501090602	REEDY RVR AT U.S. 76	S-070	LAURENS	REC	FC
	SALUDA	030501090602	BOYD MILL POND .6 KM W DAM	S-311	LAURENS	AL	PH, TN, TP
	SALUDA	030501090602	REEDY R. AT SEC. RD. 68	S-778	GREENVILLE	AL	BIO
	SALUDA	030501090604	REEDY RVR AT S-30-06 E WARE SHOALS	S-021	LAURENS	REC	FC
	SALUDA	030501090604	REEDY FORK OF LK GREENWOOD AT S-30-29	S-022	LAURENS	AL	PH
	SALUDA	030501090604	LAKE GREENWOOD, REEDY RVR ARM, 150 YDS US RABON CK	S-308	LAURENS	AL	PH, TP
	SALUDA	030501090701	ROCKY CREEK AT SC 72 BY-PASS AND SC 254 IN GREENWOOD	RS-03346	GREENWOOD	AL	BIO
	SALUDA	030501090701	ROCKY CREEK AT SC 72 BY-PASS AND SC 254 IN GREENWOOD	RS-03346	GREENWOOD	REC	FC
	SALUDA	030501090701	CORONACA CK AT S-24-100 4 MI NW OF 96	S-092	GREENWOOD	AL	DO, PH
	SALUDA	030501090701	CORONACA CREEK AT SC HWY 221	S-184	GREENWOOD	AL	BIO
*	SALUDA	030501090702	WILSON CK AT S-24-101	S-233	GREENWOOD	REC	FC
	SALUDA	030501090702	WILSON CK AT S-24-124	S-235	GREENWOOD	AL	BIO
*	SALUDA	030501090702	WILSON CK AT S-24-124	S-235	GREENWOOD	REC	FC
	SALUDA	030501090704	NINETY SIX CK AT SC 702 5.2 MI ESE OF 96	S-093	GREENWOOD	AL	CU
*	SALUDA	030501090704	NINETY SIX CK AT SC 702 5.2 MI ESE OF 96	S-093	GREENWOOD	REC	FC
	SALUDA	030501090802	BROAD MOUTH CREEK AT BRIDGE ON CO RD S-04-265 (ROCKY FORD ROAD) 3.5 MI NNW OF HONEA PATH	RS-04364	ANDERSON	AL	BIO
	SALUDA	030501090802	TRIB.BROAD MOUTH CR. AT SEC. RD.205	S-776	ANDERSON	AL	BIO
	SALUDA	030501090804	TURKEY CREEK AT SR 96	S-858	GREENWOOD	AL	BIO
	SALUDA	030501090806	LAKE GREENWOOD - CANE CK ARM AT SC 72 3.1 MI SW CROSS HILL	S-097	LAURENS	AL	DO, TP
*	SALUDA	030501090806	LAKE GREENWOOD - CANE CK ARM AT SC 72 3.1 MI SW CROSS HILL	S-097	LAURENS	REC	FC
	SALUDA	030501090807	LAKE GREENWOOD 1.0 MI NW OF SEABOARD RR CROSSING	RL-02311	GREENWOOD	AL	PH
	SALUDA	030501090807	LAKE GREENWOOD, HEADWATERS, JUST US S-30-33	S-024	LAURENS	AL	PH
	SALUDA	030501090807	LK GREENWOOD AT US 221 7.6 MI NNW 96	S-131	GREENWOOD	AL	TP
	SALUDA	030501090808	LAKE GREENWOOD 200 FT US OF DAM	S-303	GREENWOOD	AL	PH
	SALUDA	030501090908	LITTLE RVR AT SC 34	S-305	NEWBERRY	AL	PH
	SALUDA	030501091003	CLOUDS CK AT S-41-26 4 MI NW BATESBURG	S-255	SALUDA	AL	DO, PH

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SALUDA	030501091103	BIG CREEK AT SR 122	S-855	SALUDA	AL	BIO
	SALUDA	030501091104	LITTLE SALUDA RVR AT US 378 E SALUDA	S-050	SALUDA	AL	DO
	SALUDA	030501091104	LITTLE SALUDA RVR AT S-41-39 5.2 MI NE SALUDA	S-123	SALUDA	AL	DO
	SALUDA	030501091105	LAKE MURRAY, LITTLE SALUDA ARM AT SC 391	S-222	SALUDA	AL	PH, TP
	SALUDA	030501091202	SALUDA RIVER AT S.C. ROUTE 39	S-295	SALUDA	AL	CU
	SALUDA	030501091204	BUSH RIVER AT SC 560 S OF JOANNA	S-042	NEWBERRY	AL	DO
	SALUDA	030501091206	BUSH RIVER AT COUNTY RD 395, 3 M S OF NEWBERRY	RS-01044	NEWBERRY	AL	BIO
	SALUDA	030501091206	LAKE MURRAY, BUSH RVR ARM, 4.6 KM US SC 391	S-309	NEWBERRY	AL	CHLA, PH, TP
	SALUDA	030501091207	SALUDA RVR AT SC 121	S-047	NEWBERRY	FISH	HG
	SALUDA	030501091207	SALUDA RVR AT SC 121	S-047	NEWBERRY	REC	FC
	SALUDA	030501091207	SALUDA RIVER @ SC 395	S-105	NEWBERRY	FISH	HG
	SALUDA	030501091207	BLACKS BR, LK MURRAY AT SC 391	S-223	NEWBERRY	AL	PH
	SALUDA	030501091207	LAKE MURRAY, SALUDA RVR ARM, US BUSH RVR, 3.8 KM US SC 391	S-310	NEWBERRY	AL	PH
	SALUDA	030501091302	HOLLANDS LANDING LK MURRAY OFF S-36-26 AT END OF S-36-3	S-211	NEWBERRY	AL	PH
	SALUDA	030501091306	LAKE MURRAY AT S-36-15	S-213	LEXINGTON	AL	PH
	SALUDA	030501091307	MACEDONIA LANDING LK MURRAY AT END OF S-36-26 MACEDONIA	S-212	NEWBERRY	AL	PH
	SALUDA	030501091307	LK MURRAY AT MARKER 63	S-279	LEXINGTON	AL	PH
	SALUDA	030501091311	LK MURRAY IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CL-083	LEXINGTON	AL	CU
	SALUDA	030501091311	LK MURRAY AT DAM AT SPILLWAY (MARKER 1)	S-204	LEXINGTON	AL	PH
	SALUDA	030501091402	TWELVE MILE CREEK AT SR 106	S-052	LEXINGTON	AL	BIO
	SALUDA	030501091402	TWELVEMILE CREEK AT U.S. ROUTE 378	S-294	LEXINGTON	AL	BIO
	SALUDA	030501091402	FOURTEEN MILE CREEK AT SR 28	S-848	LEXINGTON	AL	BIO
	SALUDA	030501091403	RAWLS CREEK AT COUNTY RD 175, 0.25 M W OF IRMO	RS-01012	LEXINGTON	AL	BIO
	SALUDA	030501091403	SALUDA RVR JUST BELOW LK MURRAY DAM	S-152	LEXINGTON	AL	PH
	SALUDA	030501091403	KINLEY CK AT S-32-36 (ST. ANDREWS RD) IN IRMO	S-260	LEXINGTON	AL	DO
	SALUDA	030501091403	RAWLS CREEK AT S-32-107	S-287	LEXINGTON	AL	DO
	SALUDA	030501100104	SIXMILE CK ON US 21 S OF CAYCE	C-005	LEXINGTON	AL	DO
	SALUDA	030501100104	LK CAROLINE SPILLWAY AT PLATT SPRINGS RD	C-025	LEXINGTON	AL	PH
	SALUDA	030501100104	CONGAREE CK AT S-32-66	C-070	LEXINGTON	REC	FC
	SALUDA	030501100201	SESQUICENTENNIAL STATE PARK	C-046	RICHLAND	FISH	HG
	SALUDA	030501100201	WINDSOR LK SPILLWAY ON WINSDOR LK BLVD	C-048	RICHLAND	AL	DO, PH
*	SALUDA	030501100203	GILLS CK AT BRDG ON US 76 (GARNERS FERRY ROAD)	C-001	RICHLAND	REC	FC
	SALUDA	030501100203	GILLS CK AT SC 48 (BLUFF ROAD)	C-017	RICHLAND	AL	DO
*	SALUDA	030501100203	GILLS CK AT SC 48 (BLUFF ROAD)	C-017	RICHLAND	REC	FC
	SALUDA	030501100203	FOREST LAKE AT DAM	C-068	RICHLAND	REC	FC
	SALUDA	030501100301	BROAD RIVER DIVERSION CANAL AT COLA WATER PLANT	B-080	RICHLAND	REC	FC

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
*	SALUDA	030501100304	MILL CK AT SC 262	C-021	RICHLAND	REC	FC
	SALUDA	030501100304	REEDER POINT BR AT SC 48	C-073	RICHLAND	AL	DO
*	SALUDA	030501100304	REEDER POINT BR AT SC 48	C-073	RICHLAND	REC	FC
	SALUDA	030501100310	CONGAREE RVR, WEST BOUNDARY OF CONGAREE SWAMP MONUMENT	C-074	RICHLAND	AL	CU
*	SALUDA	030501100310	CONGAREE RVR, WEST BOUNDARY OF CONGAREE SWAMP MONUMENT	C-074	RICHLAND	REC	FC
*	SALUDA	030501100401	TOMS CK AT SC 48	C-072	RICHLAND	REC	FC
	SALUDA	030501100401	TOMS CREEK AT POWER LINE AND RR TRACK	C-579	RICHLAND	AL	BIO
	SALUDA	030501100401	TOM'S CREEK AT RED BLUFF RD.	S-950	RICHLAND	AL	BIO
	SALUDA	030501100402	BUCKHEAD CREEK AT S-09-151 2.1 MI NE OF FORT MOTTE	RS-04521	CALHOUN	AL	BIO
#	SALUDA	030501100403	CONGAREE RVR AT US 601 (SC-001)	C-007	CALHOUN	AL	CU
	SALUDA	030501100403	CONGAREE RVR AT US 601 (SC-001)	C-007	CALHOUN	FISH	HG
	SALUDA	030501100403	CONGAREE RVR AT US 601 (SC-001)	C-007	CALHOUN	REC	FC
	SANTEE	030501110101	WARLEY CREEK AT CO RD S-09-287 3.4 MI NW OF LONE STAR	RS-04389	CALHOUN	AL	BIO
*	SANTEE	030501110102	SPRING CROVE CREEK @ SECONDARY ROAD 26 BRIDGE	SC-009	CLARENDON	REC	FC
	SANTEE	030501110103	LK INSPIRATION - ST MATTHEWS (FRONT OF HEALTH DEPT)	C-058	CALHOUN	AL	DO, PH, TN, TP, TURBIDITY
	SANTEE	030501110103	LYONS CREEK AT SC 6	ST-533	CALHOUN	AL	BIO
#	SANTEE	030501110104	UPPER LAKE MARION @ THE MOUTH OF HALFWAY SWAMP CREEK	SC-038	CALHOUN	AL	TP
	SANTEE	030501110104	HALFWAY SWAMP CREEK AT SR 157	ST-534	CALHOUN	AL	BIO
*	SANTEE	030501110106	BIG BRANCH AT S-14-41 (SC-047)	CW-243	CLARENDON	REC	FC
	SANTEE	030501110107	UNNAMED TRIBUTARY TO TAWCAW CREEK AT S-14-559 (WILLIAM BRUNSON ROAD) 4.6 MI SE OF SUMMERTON	RS-03505	CLARENDON	REC	FC
	SANTEE	030501110107	TAWCAW CK AT S-14-127 3.2 MI S OF SUMMERTON (SC-018)	ST-018	CLARENDON	AL	DO
*	SANTEE	030501110107	TAWCAW CK AT S-14-127 3.2 MI S OF SUMMERTON (SC-018)	ST-018	CLARENDON	REC	FC
*	SANTEE	030501110108	WHITE OAK CREEK AT COUNTY RD 345, 4.5 M ESE OF SUMMERTON	RS-01051	CLARENDON	REC	FC
	SANTEE	030501110108	POTATO CREEK AT S-14-715 (ROGERS ROAD) 5.5 MI SE OF SUMMERTON	RS-03501	CLARENDON	REC	FC
	SANTEE	030501110108	LAKE MARION @ WYBOO CREEK	ST-024	CLARENDON	FISH	HG
	SANTEE	030501110108	POTATO CK AT S-14-127 3.2 MI S OF SUMMERTON (SC-020)	ST-035	CLARENDON	AL	DO
*	SANTEE	030501110108	POTATO CK AT S-14-127 3.2 MI S OF SUMMERTON (SC-020,	ST-035	CLARENDON	REC	FC
	SANTEE	030501110109	LAKE MARION @ TREZVANT'S LANDING	C-007K	CALHOUN	FISH	HG
	SANTEE	030501110109	LAKE MARION @ DANIELS 4H CAMP	C-057	CALHOUN	FISH	HG
	SANTEE	030501110109	LAKE MARION FOREBAY, SPILLWAY MARKER 44 (SC-022)	CL-042	ORANGEBURG	AL	CU
	SANTEE	030501110109	LAKE MARION 0.5 MI NE OF CALHOUN LANDING (USE SC-044)	RL-04388	CALHOUN	AL	TP
#	SANTEE	030501110109	UPPER SANTEE RIVER 0.2 KM UPSTRM OF MOUTH OF BROADWATER CR.	SC-004	SUMTER	AL	TP
	SANTEE	030501110109	UPPER LAKE MARION NEAR PACK'S LANDING	SC-005	SUMTER	AL	DO, TP
	SANTEE	030501110109	LAKE MARION AT RR TRESTLE AT LONE STAR (SC-008)	SC-008	CALHOUN	AL	TP
#	SANTEE	030501110109	UPPER LAKE MARION AT CHANNEL MARKER 150	SC-010	CALHOUN	AL	TP
	SANTEE	030501110109	UPPER LAKE MARION @ HEADWATERS OF CHAPEL BRANCH CREEK	SC-014	ORANGEBURG	AL	CHLA, PH, TP
	SANTEE	030501110109	UPPER LAKE MARION 2.0 KM BELOW RIMINI RAILROAD TRESTLE	SC-039	CLARENDON	AL	TP
	SANTEE	030501110109	SURFACE DRAINAGE FROM SAFETY KLEEN HAZARDOUS LANDFILL	SC-057	SUMTER	AL	NI

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SANTEE	030501110109	STREAM ORIGINATING UPSTRM OF SAFETY KLEEN HAZARDOUS LANDFILL	SC-058	SUMTER	AL	NI, PH, TP
	SANTEE	030501110109	LAKE MARION @ DAM	ST-027	CLARENDON	FISH	HG
	SANTEE	030501110109	LAKE MARION @ RIMINI	ST-519	SUMTER	FISH	HG
	SANTEE	030501110109	LAKE MARION @ LOW FALLS LANDING	ST-529	CALHOUN	FISH	HG
	SANTEE	030501120101	SANTEE RIVER BELOW LAKE MARION (WILSONS)	ST-532	BERKELEY	FISH	HG
	SANTEE	030501120102	BENNETTS BRANCH AT SR 351	ST-536	CLAREDON	AL	BIO
	SANTEE	030501120102	DOCTOR BRANCH AT SR 48	ST-537	CLAREDON	AL	BIO
	SANTEE	030501120105	REDIVERSION CANAL AT US 52 (SC-037A)	ST-031	BERKELEY	AL	CU, ZN
	SANTEE	030501120105	REDIVERSION CANAL	ST-031	BERKELEY	FISH	HG
	SANTEE	030501120106	SANTEE RIVER @ US 52 (HWY 52 LANDING)	ST-528	WILLIAMSBURG	FISH	HG
*	SANTEE	030501120205	ECHAW CK AT PITCH LANDING FRANCIS MARION NATL FOREST	RS-02467	BERKELEY	REC	FC
	SANTEE	030501120206	SANTEE RIVER @ SC 41/US 17A	ST-001	BERKELEY	FISH	HG
	SANTEE	030501120302	WAMBAW CREEK (STILL'S LANDING)	CSTL-112	CHARLESTON	FISH	HG
*	SANTEE	030501120303	SOUTH SANTEE RIVER AT ALLIGATOR CREEK	06A-01	GEORGETOWN	SHELLFISH	FC
	SANTEE	030501120303	SOUTH SANTEE RIVER NEAR THE MIDPOINT OF GRACE ISL. (C-3/01)	06A-01A	CHARLESTON	SHELLFISH	FC
	SANTEE	030501120303	SOUTH SANTEE INLET	06A-02	GEORGETOWN	SHELLFISH	FC
*	SANTEE	030501120303	ALLIGATOR CREEK NEAREST S. SANTEE RVR BTWN MRKRS 24&25	06B-13	CHARLESTON	SHELLFISH	FC
*	SANTEE	030501120303	CEDAR CREEK AT CNTY RD 857 HAMPTON PLANTATION STATE PARK	RS-01056	CHARLESTON	REC	FC
	SANTEE	030501120303	S SANTEE RVR AT US 17	ST-006	CHARLESTON	FISH	HG
*	SANTEE	030501120303	S SANTEE RVR AT US 17	ST-006	CHARLESTON	REC	FC
	SANTEE	030501120402	WADMACON CREEK @ SANDHOLE	CSTL-586	GEORGETOWN	FISH	HG
	SANTEE	030501120402	WADMACON CREEK @ THE BLUFF	CSTL-587	GEORGETOWN	FISH	HG
*	SANTEE	030501120403	NORTH SANTEE RIVER AT BEACH CREEK	06A-03	GEORGETOWN	SHELLFISH	FC
	SANTEE	030501120403	NORTH SANTEE INLET	06A-04	GEORGETOWN	SHELLFISH	FC
	SANTEE	030501120403	NORTH SANTEE BAY - E OF CANE ISLAND (C6-97)	06A-04A	GEORGETOWN	SHELLFISH	FC
	SANTEE	030501120403	NORTH SANTEE RIVER - SW OF CANE ISLAND (C6-97)	06A-04B	GEORGETOWN	SHELLFISH	FC
	SANTEE	030501120403	NORTH SANTEE RVR NEAR THE NORTHWESTERN TIP OF CONE ISL (C-3/-01)	06A-04C	GEORGETOWN	SHELLFISH	FC
*	SANTEE	030501120403	NORTH SANTEE RIVER AND MOSQUITO CREEK	06A-05	GEORGETOWN	SHELLFISH	FC
*	SANTEE	030501120403	AIWW AT MINUM CREEK	06A-11	GEORGETOWN	SHELLFISH	FC
	SANTEE	030501120403	NORTH SANTEE RIVER @ HARRIS LANDING	CSTL-593	GEORGETOWN	FISH	HG
	SANTEE	030501120403	SANTEE BAY AT BEACH CREEK (06A-03)	MD-263	GEORGETOWN	AL	CU
	SANTEE	030501120403	MINIM CREEK, 9 M S OF GEORGETOWN	RT-01654	GEORGETOWN	AL	TURBIDITY
	SANTEE	030501120403	NORTH SANTEE RIVER @ POLE YARD	ST-005	GEORGETOWN	FISH	HG
	SANTEE	030502010101	DIVERSION CANAL	CSTL-079	BERKELEY	FISH	HG
	SANTEE	030502010101	LAKE MOULTRIE @ DAM	CSTL-080	BERKELEY	FISH	HG
	SANTEE	030502010101	TRIBUTARY FLOWING TO LAKE MOULTRIE FROM CROSS GENER. STATION	SC-043	BERKELEY	REC	FC
	SANTEE	030502010101	LAKE MOULTRIE @ FRED L. DAY LANDING	ST-530	BERKELEY	FISH	HG
	SANTEE	030502010101	LAKE MOULTRIE @ HATCHERY LANDING	ST-531	BERKELEY	FISH	HG
*	SANTEE	030502010201	WADBOO SWAMP AT S-08-447 THIRD BRIDGE FROM WEST	RS-02461	BERKELEY	REC	FC
*	SANTEE	030502010201	WALKER SW AT US 52 2.5 MI S ST STEPHENS	ST-007	BERKELEY	REC	FC

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SANTEE	030502010203	WADBOO CREEK @ REMBERT C. DENNIS RAMP	CSTL-113	BERKELEY	FISH	HG
	SANTEE	030502010203	CANE GULLEY BRANCH AT S-08-97 6.1 MI NE OF MONCKS CORNER	RS-03333	BERKELEY	REC	FC
*	SANTEE	030502010301	TURKEY CK AT FOREST SERVICE RD 251 IRISHTOWN FM SC 402	RS-02483	BERKELEY	REC	FC
	SANTEE	030502010304	EAST FORK OF COOPER RIVER NEAR QUINBYCR	CSTL-564	BERKELEY	FISH	HG
*	SANTEE	030502010401	WANDO RIVER AT DEEP CREEK	09B-04	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010401	WANDO RIVER OPPOSITE BIG PARADISE ISLAND	09B-05	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010401	WANDO RIVER AT PARADISE BOAT LANDING	09B-06	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010401	DEEP CREEK - 1 MILE FROM CONFLUENCE WITH WANDO RIVER	09B-09	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010401	WANDO RIVER AT ALSTON CREEK CONFLUENCE	09B-10	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010401	WANDO RIVER AT GUERIN CREEK	09B-11	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010401	GUERIN CREEK AT OLD HOUSE CREEK	09B-12	BERKELEY	SHELLFISH	FC
	SANTEE	030502010402	WANDO RIVER AT NOWELL CREEK	09B-01	BERKELEY	SHELLFISH	FC
	SANTEE	030502010402	WANDO RIVER AT HORLBECK CREEK	09B-02	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010402	BOONE HALL CREEK OPPOSITE COUNTY RECREATION AREA	09B-07	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010402	NOWELL CREEK, AT CONFLUENCE WITH MARTIN CREEK	09B-16	BERKELEY	SHELLFISH	FC
	SANTEE	030502010402	WANDO RIVER MIDWAY BETWEEN STATIONS 3 AND 11(AT OLD DRY DOCK)	09B-17	BERKELEY	SHELLFISH	FC
*	SANTEE	030502010402	RAT HALL CRK AT CONFLUENCE WITH WANDO RVR. (C6-97/U4/01)	09B-18	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010402	FOSTER CREEK AT CONFLUENCE WITH WANDO RIVER (C4-99)	09B-19	CHARLESTON	SHELLFISH	FC
	SANTEE	030502010402	WANDO RVR AT SC 41	MD-115	BERKELEY	AL	CU
	SANTEE	030502010503	WASSAMASSAW SWP AT US 176	CSTL-063	BERKELEY	AL	CU
*	SANTEE	030502010503	WASSAMASSAW SWP AT US 176	CSTL-063	BERKELEY	REC	FC
	SANTEE	030502010505	CYPRESS SWP AT US 78	CSTL-078	DORCHESTER	AL	NI, ZN
	SANTEE	030502010601	DORCHESTER CK AT SC 165	CSTL-013	DORCHESTER	AL	DO, TURBIDITY
	SANTEE	030502010601	SAWMILL BR AT SC 78 E OF SUMMERVILLE	CSTL-043	DORCHESTER	AL	DO
*	SANTEE	030502010602	ASHLEY RVR AT SC 165 4.8 MI SSW OF SUMMERVILLE	CSTL-102	DORCHESTER	REC	FC
	SANTEE	030502010603	EAGLE CK AT SC 642 5 MI SSE OF SUMMERVILLE	CSTL-099	DORCHESTER	AL	TURBIDITY
*	SANTEE	030502010603	EAGLE CK AT SC 642 5 MI SSE OF SUMMERVILLE	CSTL-099	DORCHESTER	REC	FC
	SANTEE	030502010604	ASHLEY RVR AT MAGNOLIA GARDENS	MD-049	CHARLESTON	AL	CU, NI, TURBIDITY
*	SANTEE	030502010604	ASHLEY RVR AT MAGNOLIA GARDENS	MD-049	CHARLESTON	REC	FC
	SANTEE	030502010604	ASHLEY RV 1.8 MI NW RUNNYMEDE PLANTATION	RT-032046	CHARLESTON	REC	FC
*	SANTEE	030502010605	CHURCH CK MOUTH	MD-246	CHARLESTON	REC	FC
	SANTEE	030502010701	TAIL RACE CANAL AT US 52 & 17A BELOW LAKE MOULTRIE (SC-033)	CSTL-062	BERKELEY	AL	TP
	SANTEE	030502010701	TAIL RACE CANAL AT US 52 & 17A BELOW LAKE MOULTRIE (SC-033)	CSTL-062	BERKELEY	FISH	HG
	SANTEE	030502010703	FOSTER CREEK AT CHARLESTON CPW WATER INTAKE	MD-240	BERKELEY	AL	DO
	SANTEE	030502010703	FOSTER CREEK AT CHARLESTON CPW WATER INTAKE	MD-240	BERKELEY	REC	FC
	SANTEE	030502010704	BACK RIVER RES IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	CSTL-124	BERKELEY	AL	CU, DO
	SANTEE	030502010704	COOPER RIVER @ BUSHY PARK	MD-042	BERKELEY	FISH	HG

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SANTEE	030502010704	BACK RIVER RESERVOIR	MD-152	BERKELEY	FISH	HG
	SANTEE	030502010704	DURHAM CREEK	MD-217	BERKELEY	FISH	HG
*	SANTEE	030502010706	GOOSE CK AT S-08-136 BRIDGE	MD-039	BERKELEY	REC	FC
	SANTEE	030502010706	GOOSE CK AT US 52 N CHTN	MD-114	CHARLESTON	AL	DO
	SANTEE	030502010706	GOOSE CK RES 2.3 M S OF GOOSE CREEK TOWN CENTER	RL-01008	BERKELEY	AL	DO
	SANTEE	030502010706	GOOSE CREEK RESERVOIR 1.0 MI NW OF SPILLWAY NEAR W SHORELINE	RL-03340	BERKELEY	AL	CHLA, DO, TP
	SANTEE	030502010706	GOOSE CREEK RESERVOIR 2.8 MI NW OF SPILLWAY NEAR OTRANTO	RL-04390	BERKELEY	AL	DO, TP
	SANTEE	030502010706	GOOSE CREEK RESERVOIR 100 M US OF DAM	ST-032	BERKELEY	AL	CHLA, PH, TP
	SANTEE	030502010706	GOOSE CREEK RESERVOIR 100 M US OF DAM	ST-032	BERKELEY	FISH	HG
	SANTEE	030502010706	GOOSE CK RESERVOIR AT 2ND POWERLINES US OF BOAT RAMP	ST-033	BERKELEY	AL	CHLA, PH, TP
	SANTEE	030502010707	LIGHTHOUSE CREEK AT CONFLUENCE WITH FOLLY CREEK	10A-13	CHARLESTON	SHELLFISH	FC
	SANTEE	030502010707	SECESSIONVILLE CREEK AT PRIVATE DOCKS	10A-15	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010707	CLARK SOUND AT OCEAN VIEW FLATS	10A-16	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010707	FLUDD'S CREEK AT CLARK SOUND	10A-16A	CHARLESTON	SHELLFISH	FC
	SANTEE	030502010707	BLOCK ISL. CREEK - 100 YDS S. OF SPLIT FROM SPOIL AREA	10A-32	CHARLESTON	SHELLFISH	FC
	SANTEE	030502010707	LIGHTHOUSE CREEK AND CLARK SOUND CONFLUENCE	10A-33	CHARLESTON	SHELLFISH	FC
	SANTEE	030502010707	SECESSIONVILLE CREEK AT ITS CONFLUENCE WITH CLARK SOUND	10A-34	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502010707	POINT DEVELOPMENT	10A-35	CHARLESTON	SHELLFISH	FC
	SANTEE	030502010707	INTRACOASTAL WATERWAY AT SC 703 E MT PLEASANT	MD-069	CHARLESTON	AL	CU
#	SANTEE	030502010707	SHEM CK AT BRDG ON US 17	MD-071	CHARLESTON	AL	CU
*	SANTEE	030502010707	SHEM CK AT BRDG ON US 17	MD-071	CHARLESTON	REC	FC
#	SANTEE	030502010707	CHAS HBR AT FT JOHNSON PIER AT MARINE SCI LAB	MD-165	CHARLESTON	AL	CU
*	SANTEE	030502010707	FILBIN CREEK AT VIRGINIA AVE, NORTH CHARLESTON	MD-249	CHARLESTON	REC	FC
#	SANTEE	030502010707	CHARLESTON HARBOR 0.5 MI SE OF MOUTH OF SHEM CK	RO-036044	CHARLESTON	AL	CU
	SANTEE	030502010707	UNNAMED TRIBUTARY TO PARROT POINT CREEK 0.8 MI S OF FT JOHNSON	RT-042072	CHARLESTON	AL	TURBIDITY
*	SANTEE	030502020105	RANTOWLES CREEK AT CONFLUENCE OF STONO RIVER	11-18	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502020201	LOG BRIDGE CK AT SC 162	MD-121	CHARLESTON	REC	FC
*	SANTEE	030502020202	STONO RIVER (AIWW) AT MARKER #27	11-12	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502020202	STONO RIVER (AIWW) AT MARKER #51	11-16	CHARLESTON	SHELLFISH	FC
	SANTEE	030502020202	STONO RIVER (LOG BRIDGE CREEK) AT MARKER #54	11-17	CHARLESTON	SHELLFISH	FC
	SANTEE	030502020202	MOUTH OF ELLIOTT CUT AT EDGE WTR DR (S-10-26 OFF HW 17)	MD-025	CHARLESTON	AL	DO
	SANTEE	030502020202	STONO RVR AT SC 700	MD-026	CHARLESTON	AL	DO
	SANTEE	030502020202	STONO RVR AT S-10-20 2 MI UPSTRM OF CLEMSON EXP STA	MD-202	CHARLESTON	AL	CU
	SANTEE	030502020204	FOLLY CREEK AT CONFLUENCE WITH SECESSIONVILLE CREEK	10A-15A	CHARLESTON	SHELLFISH	FC
	SANTEE	030502020204	FOLLY RIVER AT SC 171	MD-130	CHARLESTON	AL	CU
	SANTEE	030502020205	ABBAPOOLA CREEK AT FIRST LARGE BEND	11-06	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502020205	ABBAPOOLA CREEK AT CONFLUENCE WITH SMALL CREEK ON WEST BANK AT SEVENTH BEND (C-4/99)	11-06A	CHARLESTON	SHELLFISH	FC
	SANTEE	030502020205	BASS CREEK AT CONFLUENCE WITH CINDER CREEK	11-32	CHARLESTON	SHELLFISH	FC
	SANTEE	030502020205	BASS CREEK AT PUBLIC DOCK (5TH BEND FROM CONFLUENCE WITH CINDER CREEK (C5-01)	11-35	CHARLESTON	SHELLFISH	FC
	SANTEE	030502020205	TRIBUTARY TO STONO INLET, 11 M SW OF CHARLESTON	RT-01642	CHARLESTON	AL	TURBIDITY
*	SANTEE	030502090101	ALLIGATOR CREEK AT MARKER #26	06B-07	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090101	CASINO CREEK AT MARKER #29	06B-08	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090101	DUPREE CREEK - 500 FEET N. OF NEW DOCK (S.OF MRKR #30)	06B-09	CHARLESTON	SHELLFISH	FC

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SANTEE	030502090101	AIWW AT MARKER #32	06B-10	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	ALLIGATOR CREEK STATE SHELLFISH GROUND	06B-12	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	CASINO CREEK MIDWAY BETWEEN STATIONS 19 AND 24 (AT SMALL UNNAMED CREEK ON RIGHT, SOUTHBOUND)	06B-16	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	DUPREE CREEK AND CLUBHOUSE CREEK,CONFLUENCE	06B-18	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	CASINO CREEK AND SKRINE CREEK,CONFLUENCE	06B-19	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	DUPREE CREEK 1,000 YARDS UP FROM CLUBHOUSE CREEK	06B-20	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	ALLIGATOR CREEK AND RAMHORN CREEK CONFLUENCE	06B-21	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	RAMHORN CREEK AND MILL CREEK CONFLUENCE	06B-22	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	SKRINE CREEK AND CONGAREE BOAT CREEK CONFLUENCE	06B-23	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	CLUBHOUSE CREEK-1/4 MILE NORTH OF FIVE FATHOM CREEK	07-08	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090101	ALLIGATOR CREEK AT STATE SHELLFISH GROUND (06B-12)	MD-265	CHARLESTON	AL	CU, TURBIDITY
	SANTEE	030502090101	CASINO CREEK AT CLOSURE LINE (06B-16)	MD-266	CHARLESTON	AL	CU
*	SANTEE	030502090101	E FORK OF DEVILS DEN CK HEADWATERS	RT-02016	CHARLESTON	AL	CU
*	SANTEE	030502090201	AWENDAW CREEK AT US 17	MD-250	CHARLESTON	REC	FC
*	SANTEE	030502090202	GRAHAM CREEK AT MARKER #64	07-02	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090202	AWENDAW CREEK AT MARKER #57	07-03	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090202	HARBOR RIVER AT MARKER #48	07-04	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090202	HARBOR RIVER AT BULLS BAY	07-04A	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090202	TIBWIN CREEK AT MARKER #42	07-05	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090202	FIVE FATHOM CREEK AT MARKER #20	07-06	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090202	DOEHALL CREEK AT CONFLUENCE OF AIWW - NORTH OF MARKER #46	07-09	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090202	DOEHALL CREEK-THIRD BEND	07-14	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090202	SANDY POINT CREEK - 4TH BEND	07-15	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090202	FIVE FATHOM CREEK MARKER #26	07-17	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090202	AIWW MARKER #65	07-18	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090202	AIWW AT CONFLUENCE WITH UNNAMED CREEK, 1.5 MILES SOUTHWEST OF GRAHAM CREEK (C4-99)	07-19	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090202	JEREMY CK NEAR BOAT LANDING AT MCCLELLANVILLE TOWN HALL	MD-203	CHARLESTON	AL	DO, TURBIDITY
*	SANTEE	030502090202	JEREMY CK NEAR BOAT LANDING AT MCCLELLANVILLE TOWN HALL	MD-203	CHARLESTON	REC	FC
	SANTEE	030502090202	FIVE FATHOM CREEK AT BULL RIVER (07-06A)	MD-267	CHARLESTON	AL	TURBIDITY
	SANTEE	030502090202	AWENDAW CREEK AT MARKER #57 (07-03)	MD-268	CHARLESTON	AL	CU, TURBIDITY
	SANTEE	030502090202	TRIBUTARY TO MATHEWS CREEK, 1 M S OF MCLELLANVILLE	RT-01623	CHARLESTON	AL	TURBIDITY
	SANTEE	030502090203	MORGAN CREEK AT NORTHERNMOST CONFLUENCE WITH AIWW - ADJACENT TO MARKER #115	08-01	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090203	DEWEES INLET AT AIWW - NORTH OF MARKER #110	08-03	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090203	GRAY BAY AT CONFLUENCE OF SEVEN REACHES	08-16	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090203	CEDAR CREEK ONE-HALF MILE UP FROM DEWEES INLET	08-18	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090203	AIWW ADJACENT TO WILD DUNES GOLF COURSE STORM DRAINAGE OUTFALL	09A-18	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090204	SWINTON CREEK UPPER END	09A-03	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090204	CONCH CREEK STATE SHELLFISH GROUND - SULLIVANS ISLAND SIDE	09A-17A	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090204	AIWW AT 25TH STREET - ISLE OF PALMS	09A-19	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090204	CONCH CREEK AT LOFTON CREEK	09A-20	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090204	UPPER REACHES OF INLET CREEK	09A-24	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090204	SWINTON CREEK UPPER REACHES	09A-25	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090204	UPPER INLET CREEK AT JENNIE CREEK	09A-30	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090204	BAY AT END OF UPPER INLET CREEK	09A-31	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090204	AIWW AT CONFLUENCE WITH SULLIVANS ISLAND NARROWS (ACROSS FROM ECOMC DOCK)	09A-34	CHARLESTON	SHELLFISH	FC

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SANTEE	030502090204	CONCH CREEK AT ITS CONFLUENCE WITH AIWW	09A-36	CHARLESTON	SHELLFISH	FC
*	SANTEE	030502090205	GRAHAM CREEK AND BULLS BAY	07-02A	CHARLESTON	SHELLFISH	FC
	SANTEE	030502090205	BULLS BAY - 1,000FT FROM CONFLUENCE WITH GRAHAM CREEK (C5-01)	07-20	CHARLESTON	SHELLFISH	FC
	SAVANNAH	030601010102	LAKE JOCASSEE TOXAWAY RIVER ARM	CL-018	OCONEE	FISH	HG
	SAVANNAH	030601010104	LAKE JOCASSEE @ END OF SEC RD 25	SV-313	OCONEE	FISH	HG
*	SAVANNAH	030601010302	BURGESS CK AT S-37-171	RS-02466	OCONEE	REC	FC
	SAVANNAH	030601010408	LAKE HARTWELL @ 12 MILE CREEK	SV-107	PICKENS	FISH	PCB
	SAVANNAH	030601010502	CONEROSS CK AT SC 59	SV-004	OCONEE	AL	ZN
	SAVANNAH	030601010502	CONEROSS CK AT S-37-13	SV-333	OCONEE	AL	CU
	SAVANNAH	030601010503	LAKE HARTWELL AT S-37-184 6.5 MI SSE OF SENECA	SV-236	OCONEE	AL	PH
	SAVANNAH	030601010503	LAKE HARTWELL @ CONEROSS CREEK	SV-799	OCONEE	FISH	PCB
	SAVANNAH	030601010601	EIGHTEENMILE CK AT UNNUMBERED CO RD 2.25 MI SSW OF EASLEY	SV-017	PICKENS	AL	TURBIDITY
	SAVANNAH	030601010601	WOODSIDE BR AT US 123 1.5 MI E OF LIBERTY	SV-241	PICKENS	AL	TURBIDITY
	SAVANNAH	030601010602	LAKE HARTWELL - EIGHTEEN MILE CK ARM AT S-04-1098	SV-268	ANDERSON	AL	DO, TP, TURBIDITY
	SAVANNAH	030601010701	CHARLES CREEK AT UNNUMBERED RIDGE ROAD OFF S-04-485	RS-03506	ANDERSON	AL	BIO
	SAVANNAH	030601010704	LAKE HARTWELL 6 M NNW OF ANDERSON	RL-01020	ANDERSON	AL	PH
	SAVANNAH	030601010801	LAKE ISSAQUEENA, FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	SV-360	PICKENS	AL	PH
	SAVANNAH	030601010803	LAKE HARTWELL @ MARTIN CREEK	SV-106	PICKENS	FISH	PCB
	SAVANNAH	030601020209	WHETSTONE CREEK, UPSTREAM PORTION NEAR MOUTH	MC-03	OCONEE	AL	BIO
	SAVANNAH	030601020210	TUGALOO LAKE	SV-599	OCONEE	FISH	HG
	SAVANNAH	030601020304	UNNAMED TRIB AT BRIDGE ON CO RD S-37-142 (BRIDGE ROAD) 5.8 MI SW OF WESTMINSTER. *BRIDGE IS 75 YARDS OFF CO RD S-37-160.*	RS-04380	OCONEE	REC	FC
	SAVANNAH	030601020403	LAKE YONAH	CL-015	OCONEE	FISH	HG
	SAVANNAH	030601020403	LAKE YONAH, 50% BETWEEN CENTER OF SPILLWAY AND OPPOSITE SHORE	SV-358	OCONEE	AL	TP
*	SAVANNAH	030601020502	CHOESTOEA CREEK AT S-37-49	SV-108	OCONEE	REC	FC
*	SAVANNAH	030601020502	NORRIS CK AT S-37-435 1 MI S OF WESTMINSTER	SV-301	OCONEE	REC	FC
	SAVANNAH	030601020502	TRIBUTARY OF CHOESTOEA CRK. AT SR 429	SV-790	OCONEE	AL	BIO
	SAVANNAH	030601020505	BEAVERDAM CREEK AT S-37-66	SV-345	OCONEE	AL	BIO
	SAVANNAH	030601030101	LK HARTWELL, MAIN BODY AT USACE WQ BUOY BTWN MRKRS 11 & 12	SV-340	ANDERSON	AL	CU
	SAVANNAH	030601030202	CUPBOARD CK AT S-04-733 AB BREAZEALE ST PLANT & BL BLAIR HILL	SV-139	ANDERSON	AL	DO

NOTE	BASIN	HUC	DESCRIPTION	STATION	COUNTY	USE	CAUSE
	SAVANNAH	030601030202	CUPBOARD CK AT S-04-209 BL EFF FROM BELTON 2 PLANT	SV-140	ANDERSON	AL	PH
	SAVANNAH	030601030202	BROADWAY CREEK AT US 76 BTWN ANDERSON & BELTON	SV-141	ANDERSON	AL	BIO
	SAVANNAH	030601030202	BROADWAY CRK. AT SR 48	SV-791	ANDERSON	AL	BIO
*	SAVANNAH	030601030203	ROCKY RIVER AT S-04-244	SV-346	ANDERSON	REC	FC
	SAVANNAH	030601030205	LK SECESSION, 1 1/4 MI BELOW SC ROUTE 28	SV-331	ANDERSON	AL	PH
	SAVANNAH	030601030205	LK SECESSION APPROX 400 YDS ABOVE DAM	SV-332	ABBEVILLE	AL	PH
	SAVANNAH	030601030207	LAKE RUSSELL, ROCKY RVR ARM BETWEEN MARKERS 48 & 49, DS FELKEL	SV-357	ABBEVILLE	AL	PH
*	SAVANNAH	030601030401	DEVILS FORK CK AT BUSBY RD OFF S-04-22	RS-02490	ANDERSON	REC	FC
	SAVANNAH	030601030402	BIG GENEROSTEE CR. AT SC 187	SV-101	ANDERSON	AL	BIO
	SAVANNAH	030601030405	LAKE HARTWELL @ DAM	SV-642	ANDERSON	FISH	PCB
	SAVANNAH	030601030503	JOHNS CREEK AT SR 159	SV-734	ABBEVILLE	AL	BIO
	SAVANNAH	030601030505	DOUBLE BRANCH AT S-01-33	SV-054	ABBEVILLE	AL	BIO
	SAVANNAH	030601030507	BIG CURLY TAIL CREEK AT US FOREST RD 509	SV-732	ABBEVILLE	AL	BIO
	SAVANNAH	030601030510	LONG CANE CR. AT SR 33	SV-056	ABBEVILLE	AL	BIO
	SAVANNAH	030601030510	LONG CANE CK AT S-33-117 7.0 MI NW MCCORMICK	SV-318	MCCORMICK	AL	BIO
	SAVANNAH	030601030602	LITTLE RIVER AT S-01-24	SV-164	ABBEVILLE	AL	DO
	SAVANNAH	030601030609	SAWNEY CK AT CO RD 1.5 MI SE OF CALHOUN FALLS	SV-052	ABBEVILLE	AL	DO
	SAVANNAH	030601030610	CALHOUN CREEK AT SC 28, 1.5 M NW OF ABBEVILLE	RS-01049	ABBEVILLE	AL	DO
	SAVANNAH	030601030612	LITTLE RIVER AT S-01-32	SV-348	ABBEVILLE	AL	BIO
	SAVANNAH	030601030708	CLARKS HILL RESERVOIR AT US 378 7 MI SW MCCORMICK	SV-291	MCCORMICK	AL	TP
	SAVANNAH	030601030709	STEVENS CK RESERVOIR HEADWATERS AT CLARKS HILL DAM BOAT RAMP	SV-294	MCCORMICK	AL	PH
	SAVANNAH	030601060201	VAUCLUSE POND	SV-685	AIKEN	FISH	HG
	SAVANNAH	030601060202	FLAT ROCK POND	SV-686	AIKEN	FISH	HG
	SAVANNAH	030601060203	LANGLEY POND	SV-531	AIKEN	FISH	HG
	SAVANNAH	030601060205	HORSE CK AT SC 125 1.5 MI SW CLEARWATER	SV-250	AIKEN	AL	CU
	SAVANNAH	030601060601	UNNAMED TRIBUTARY TO THE SAVANNAH RIVER AT RIVER BLUFF RD IN THE RAPIDS S/D IN NORTH AUGUSTA. SAMPLE AT THE END OF SERVICE RD FOR TELEPHONE LINES.	RS-04544	AIKEN	AL	BIO

SCEG-307

Water Users Downstream of VCSNS

Facility	Contact	Phone	2005 Reported use Year Total	Source
Fairfield Pump Storage			1967453.31 mg	Parr Reservoir
V C Summer			280533.48 mg	Monticello Reservoir
SCE&G Parr Hydro	Thomas Bowles	803-217-9615	942,861.81 mg	Broad
Columbia Canal Water Plant	Bud Summers	803-733-8336	12,587.46 mg	Broad-Canal
Columbia Canal Hydro	Thomas Bowles	803-217-9615	469,660.89 mg	Broad-Canal
W. Columbia Saluda Intake	Wayne Caroll	803-957-4596	1,208.00 mg	*Saluda
Martin Marietta Cayce Plant	Richard Broughton	803-779-6500	415.64 mg	Congaree
City Cayce Intake #2	Betty Hightower	803-739-5367	1,128.60 mg	Congaree
Eastman Chemical Voridian Div.	Hanneke Counts	803-926-5043	26,392.68 mg	Congaree
Santee Cooper Resort C.C.	Herman Keller	803-854-2152	39.54 mg	L. Marion
St. Julian Plantation	Robert Norris	803-492-7824	7.06 mg (4 mos.)	L. Marion
Santee Cooper L. Marion Hydro	W.M. Lankford	843-761-8311	142,890.28 mg	L. Marion (spillway)
Santee Cooper Cross Station	H. Levon Strickland	843-351-4586	2,1794.14 mg	L. Moultrie
Ga. Pacific Russellville Plywood	Charles King	843-567-3252	112.78 mg	L. Moultrie (rediversion canal)
US Army / St Stephen			2,079,847 mg**	L. Moultrie (rediversion canal)
Santee Cooper Reg. Water	Chris Hively	843-761-8000	5,071.40 mg	L. Moultrie
Santee Cooper Jeffries Hydro	W.M. Lankford	843-761-8311	1,108,728.73 mg	L. Moultrie
SCE&G A.M. Williams Station	Thomas Bowles	803-217-9615	191,813.00 mg	Back River Rsvr.
Amoco Chemical Cooper River Plant	Envrnmnt.&Hlth Safety	843-971-5501	1,983.41 mg	Back River Rsvr.
Bayer Corp. Bushy Park (Sun Chemical)	Patrick Hunkler	843-820-6000	876.40 mg	Back River Rsvr.
Charleston CPW Bushy Park	Dr. Jane Byrne	843-723-9411	16,871.60 mg	Back River Rsvr.
Chargeurs Wool Prouvost	Kay Lambert	843-257-2212	49.80 mg	Santee
SCSPA Winyah Steam Station.	Don Watts	803-546-4171	289.7 mg	N. Santee

*intake is in the confluence of the Saluda and Broad and at times does receive water from the Broad River

** flow computed from daily mean discharge at USGS 02171645

SCDHEC 2006

South Carolina Ambient Groundwater Quality Monitoring Network Annual Report, 2004 Summary

Technical Report: 005-06

well data for 2 supply wells Jenkinsville Water.

Bureau of Water

South Carolina Department of Health and Environmental Control

www.scdhec.net/water

D H E C

PROMOTE PROTECT PROSPER