DRAFT FISH AND WILDLIFE COORDINATION ACT REPORT

ON

SAVANNAH RIVER BASIN COMPREHENSIVE STUDY

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EXECUTIVE SUMMARY

The purpose of this study is to provide flow recommendations for the lower Savannah River and to examine potential benefits and impacts of implementing the recommendations. Recommendations were developed by scientists from state agencies, federal agencies, University of Georgia, and The Nature Conservancy through a collaborative process at the Savannah River Ecosystem Flows Workshop. This Fish and Wildlife Coordination Act Report evaluates existing conditions in the lower Savannah River, highlights Fish and Wildlife Service concerns and planning objectives, and makes recommendations to the Army Corps of Engineers related to the management of Savannah River projects.

The Savannah River is a highly regulated, structurally modified system. J. Strom Thurmond Dam regulates flow in the lower Savannah River. Significant river flow is diverted into the Augusta Canal at the Augusta Diversion Dam upstream of the only remnant shoal habitat. This diversion periodically results in dewatering of the shoals. New Savannah Bluff Lock and Dam impedes fish migration. The channel of the lower river has been deepened and straightened, resulting in habitat alteration, loss of river-floodplain connectivity, and reduced inundation magnitude. The estuary has been deepened for shipping purposes, resulting in loss of critical freshwater marsh habitat and an upstream increase in salinity. Consequently, the structure and function of the Savannah River ecosystem has been significantly altered.

Modifying the flow regime at J. Strom Thurmond Dam has the potential to ameliorate many of these impacts, restore ecosystem function, and improve commercial and recreational fishing in the lower Savannah River. This report provides recommendations for low flow, high pulse and flood flows in the Savannah River. Low flow recommendations have the potential to prevent dewatering of shoal habitats, allow fish passage into shoal habitats, facilitate reproduction of pelagic spawning fishes, protect shoal spider lilies, and restore some freshwater marsh in the estuary. Water withdrawals at the Augusta Diversion Dam for the Augusta Canal may be major constraint on providing a feasible low flow prescription. High pulse recommendations have the potential to facilitate anadromous fish spawning, remove accumulated silt, facilitate fish passage into the floodplain for foraging and spawning, and improve conditions in the estuary. Recommended flood flows may flood low-lying areas near the City of Augusta. However, flood flows have the potential to facilitate the geomorphic processes throughout the lower Savannah River.

Although, changes in the flow regime have the potential to benefit many ecosystem aspects, a combination of a change in dam operation and structural river restoration has even greater potential to benefit the entire ecosystem. As critical research needs are addressed, more informed management decisions can be made.

The Service recommends that the Army Corps of Engineers perform the following actions to address the problems associated with the Lower Savannah River projects.

1. Implement the Service Savannah River flow prescription outlined in this report. Consult the U.S. Fish and Wildlife Service regarding flood flows after an assessment of potential impacts to the City of Augusta has been made for various high flow scenarios.

2. Address critical research needs identified in the April, 2003 workshop (Appendix A) and modify the flow prescription based on results of the research and further coordination with resource agencies.

3. Evaluate biological and hydrological effects pre- and post-flow regime change.

4. Improve water quality, particularly dissolved oxygen levels and temperature, below J. Strom Thurmond Dam.

5. Discontinue any maintenance activities on the Savannah to Augusta navigation project. Seek deauthorization of this navigation project.

6. In conjunction with state and federal fish and wildlife agencies and other scientists, evaluate cutoff bend restoration sites based on potential benefits to fish, wildlife, and floodplain connectivity.

7. Restore flow to Savannah River cutoff bends when and where fish and wildlife and/or other benefits can be demonstrated. Evaluate restoration effectiveness.

8. Examine the ecological significance of shallow-water habitats in the lower Savannah River and evaluate the effects of flow regime on these habitats.

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INTRODUCTION

The Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 15 U.S.C. 661 et seq.) (FWCA) authorized the U.S. Fish and Wildlife Service's (Service) involvement in this study. The Service prepared this report with funds transferred from the U.S. Army Corps of Engineers (USACE) under the National Letter of Agreement between our agencies for funding of FWCA activities. The USACE initiated the Savannah River Basin Comprehensive Study to identify problems and opportunities in the basin. Operation of J. Strom Thurmond Dam was evaluated as part of that process. USACE, Service and The Nature Conservancy (TNC) collaborated with biologists from the University of Georgia to describe existing conditions in the Savannah River and define relationships between biota and flow regime. Information was compiled in the Savannah River Summary Report and made available to state and federal resource agencies prior to convening at the Savannah River Ecosystem Flows Workshop in April 2003. Participants used the report and expertise in their field to develop ecosystem flow recommendations for the Savannah River below J. Strom Thurmond Dam (i.e., the lower Savannah River). The purpose of this report is to evaluate existing ecosystem conditions, identify potential benefits of flow modification and provide flow recommendations.

PRIOR STUDIES AND REPORTS

Because of the high habitat diversity, the complexity of flow relationships to ecosystem structure and function, and the extensive structural modification to the system, numerous studies, reports, and data sources were used to develop and evaluate flow recommendations for the lower Savannah River. Detailed descriptions of relevant studies were prepared by the University of Georgia participants (Meyer et al., 2002). Several relevant studies merit description here.

The Savannah River Instream Flow Study (ENTRIX, 2002a) was conducted on the Augusta Shoals as part of the FERC relicensing process of the Augusta Canal Hydropower Project (FERC No. 11810). The Physical Habitat Simulation Model (PHABSIM) was used to address the spatial distribution of hydraulic conditions of river habitat for various species including striped bass *Morone saxatilis*, American shad *Alosa sapidissima,* robust redhorse *Moxostoma robustum*, and representative species in the deep-fast, deep-slow, shallow-fast, and shallow-slow guilds. Flow required for fish passage into shoal habitats was also assessed for Atlantic sturgeon *Acipenser oxyrinchus*, shortnose sturgeon *Acipenser brevirostrum*, and striped bass (ENTRIX, 2002a).

The Savannah River Summary Report (Meyer et al., 2003) was prepared for the Savannah River Ecosystem Flows Workshop by scientists affiliated with the University of Georgia and the U.S. Geological Survey. The report describes structural modifications to the system (e.g. dredging, straightening, and damming) and flow conditions in the Savannah River prior to and following the construction of J. Strom Thurmond Dam in 1954. Numerous reports and studies were compiled and summarized to identify known flow relationships to ecosystem processes and structure in the shoals, floodplain, and estuary. Unknown relationships, such as how flow affects natural and artificial oxbows, shallow water and gravel habitats, or life history stages, were also identified. Shoal spider lily *Hymenocalis coronaria*, wood stork *Mycteria americana*, Atlantic sturgeon, shortnose sturgeon, robust redhorse, American eel *Anguilla rostrata*, American shad, striped bass, bald cypress *Taxodium distichum*, and water tupelo *Nyssa aquatica*, were among the species considered (Meyer et al., 2003).

An assessment of the spatial and temporal distribution of estuarine-dependent fishes in the Savannah River Estuary was conducted in relation to proposed harbor deepening (Jennings and Weyers, 2002). Fish move seasonally among four salinity-defined habitats that are affected by freshwater inflow, tide, and harbor modification.

DESCRIPTION OF STUDY AREA

The Savannah River drainage area is 27,450 square kilometers, with headwaters in North Carolina, South Carolina and Georgia. The study area is the lower Savannah River below J. Strom Thurmond Dam at river kilometer 355.5 (Figure 1). It flows over the Fall Line, through the coastal plain, and into the estuary, encompassing a diversity of habitats and establishing the border between South Carolina and Georgia. Detailed summaries of shoal and floodplain habitats and alterations were provided in the Savannah River Summary Report (Meyer et al., 2003). Excerpts are included below.

Shoals

> "Shoals typically harbor high species richness of fishes and mussels, owing in part to the complexity of habitats within them. Prior to mainstem impoundment, shoals existed in the Savannah River from the city of Augusta upstream to the mouth of the Tugaloo River, a distance of approximately 177 km (Brown, 1888). The only extant shoal habitat in the Savannah River is a 7.2 km reach extending downstream from the Augusta Diversion Dam. Other shoal habitats from river km 333.1 to 503.6 are submerged under mainstem impoundments created by five dams.
>
> Flow regime in the Augusta Shoals is largely controlled by flow release from Thurmond Dam, reregulation of flows at Stevens Creek Dam, and the diversion of water into a canal by the Augusta Diversion Dam (ADD; Figure 2)" (Meyer et al., 2003). According to one report, the ADD diverts water into the Augusta Canal at a nearly constant rate that varies around 2400 cfs (ENTRIX, 2002), but the actual diversion may be closer to 3500 cfs (pers. comm.. A. Hill, Charleston USFWS). Flow into the shoals can be calculated by subtracting flow into the Augusta Canal from the Savannah River at Augusta gauge (Figures 3, 4).
>
> "Low flow conditions in the shoals… (Figure 3) are lower compared to conditions prior to mainstem hydropower dam construction (1884-1954 data). Pre-dam low flows in the shoals ranged from 2840 cfs in September to 6410 cfs in April (median of lowest daily flows by month). Following the construction of all major mainstem dams (1984-2001 data) low flows ranged from 1870 to 3431 cfs in October and March, respectively. The shoals are also subject to fluctuations in flow governed largely by the periodicity of upstream hydropower generation. Extremely low flow

conditions occur on weekends when power demand and water release from Thurmond Dam are low (ENTRIX, 2002). These low flow conditions that occur on a seasonal and daily basis may harm both anadromous and resident fishes by inhibiting movement and reducing spawning and foraging habitat in the shoals" (Meyer et al., 2003).

Figure 1. Map of the lower Savannah River, courtesy of C. Straight and B. Freeman.

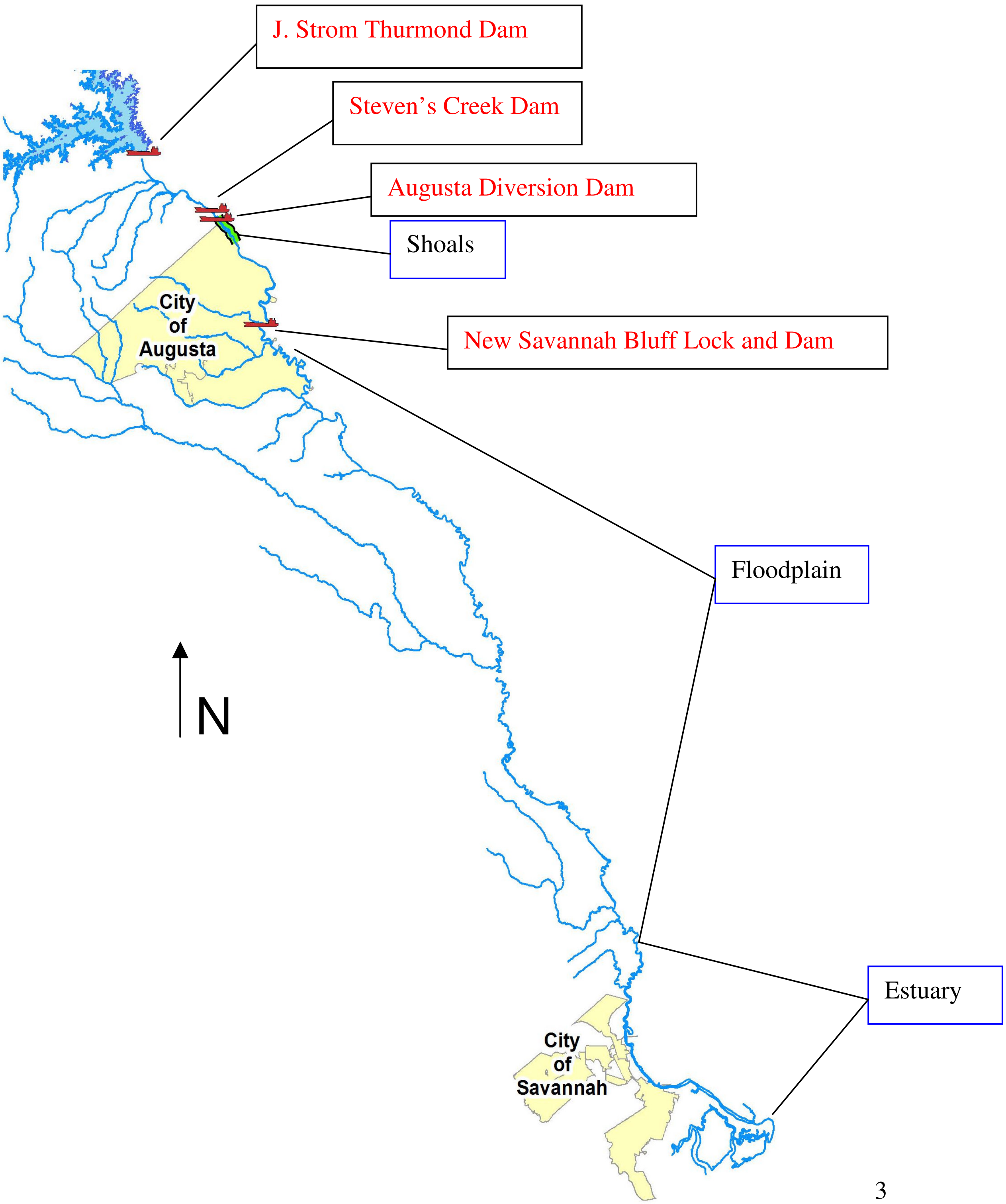


Figure 2. Map of the Augusta Shoals in the Savannah River, courtesy of C. Straight and B. Freeman. The shoals extend from the Augusta Diversion Dam to 7.2 km downstream.

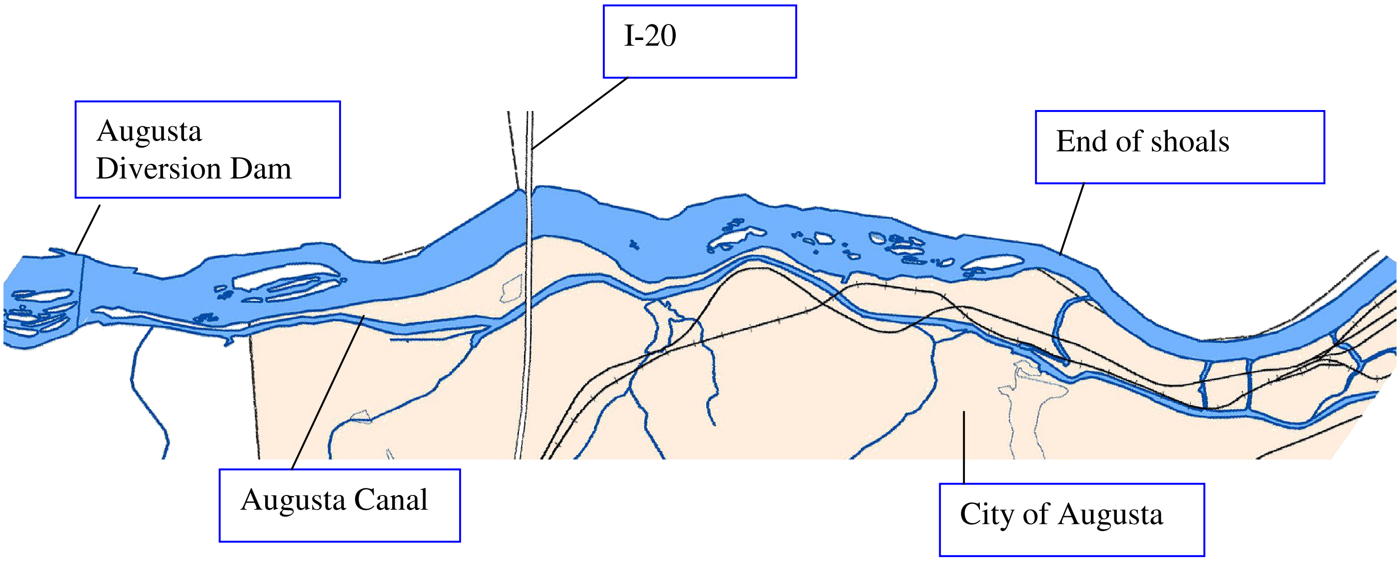


Figure 3. Hourly flow in the Savannah River at Augusta and expected flow in the Augusta Shoals. The Augusta gauge is located downstream of the City and downstream of return flow from the Augusta Canal.

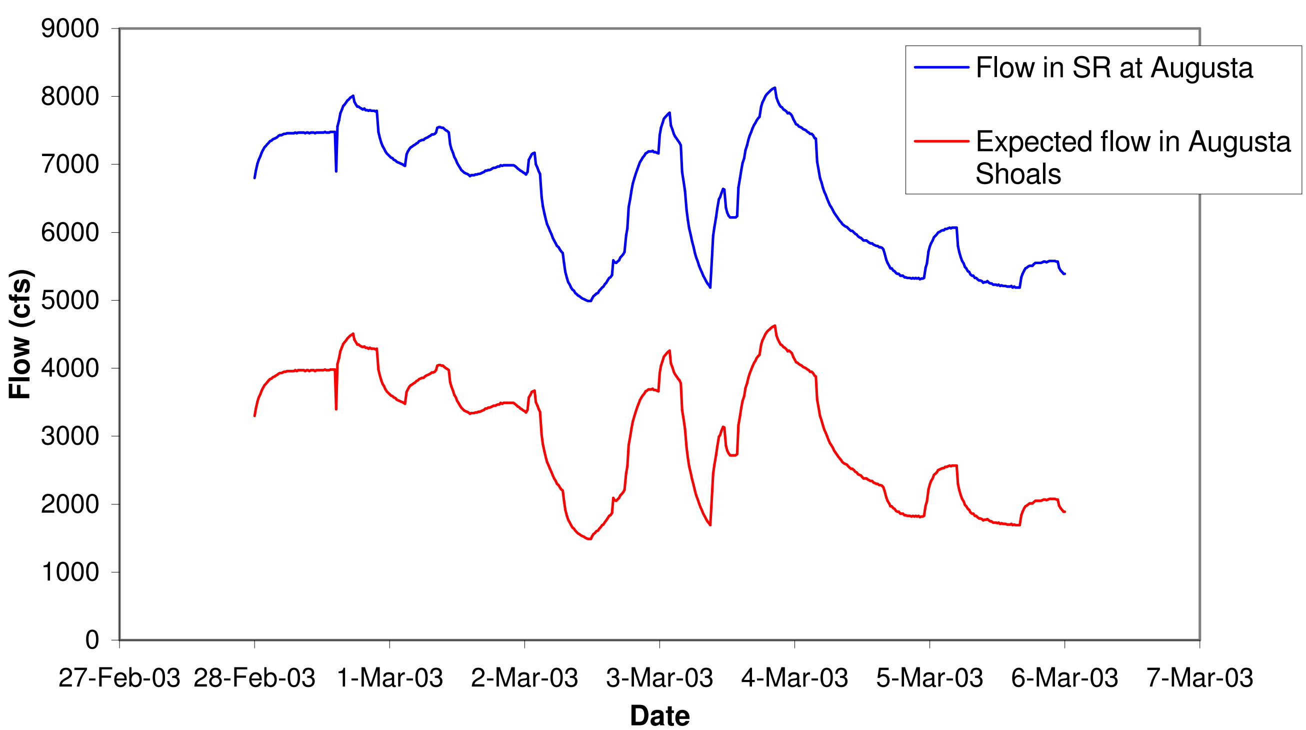
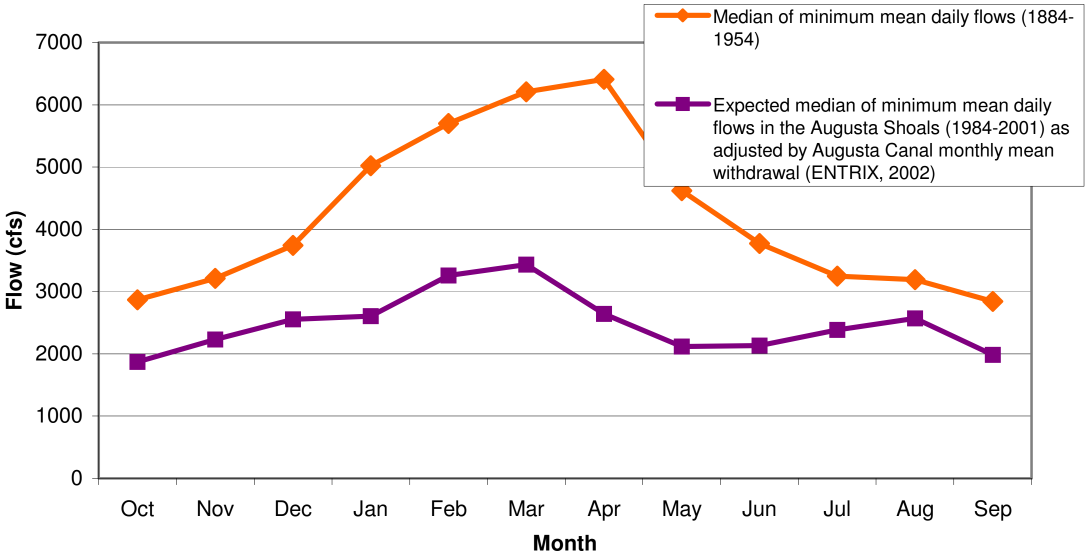


Figure 4. Seasonal flow in the Savannah River and expected flow in the Augusta Shoals



Floodplain

'In southeastern rivers, the floodplain is considered essential in maintaining the productivity of the system. Floodplains provide important habitat for reproduction, rearing, foraging, and refuge from predators for a wide array of fish species (Junk et al., 1989). The Savannah River floodplain extends from the bottom of the Augusta Shoals to the tidal portion of the river. The degree of inundation, once dependent upon natural peak flows in the winter and spring, is now largely dependent upon discharge out of Thurmond Dam. Peak flows in the Savannah River near Clyo, GA exceeded 100,000 cfs every four years prior to dam construction. Now, flows rarely exceed the maximum generation capacity of 35,000 cfs and only exceed 60,000 cfs every 20 years. Additionally, the main channel of the Savannah River has been extensively altered by dredging. The lower riverbed, reduced peak flows, and altered river discharge have altered the degree and frequency of floodplain inundation" (Meyer et al., 2003; see also *#3 Hydrologic Changes* for further discussion).

Estuary

The Savannah River Estuary (SRE) extends from river kilometer 72 to the Atlantic Ocean. It is a complex, tidally-driven system comprising multiple deltaic channels (Front, Middle, and Back Rivers) and habitats. 'The Front River is the largest channel, and it has been widened and deepened upstream as far as river kilometer 34 to provide shipping access to the industrial port. The Back and Middle rivers are relatively narrow and shallow (Will et al., 2002). This area contains 21% of the tidal freshwater marsh in South Carolina and Georgia and 25% of the freshwater marsh along the eastern coast of the United States (Pearlstine et al., 1993). The SRE is used for a variety of purposes, including a major industrial complex, the Savannah Harbor, and the relatively undisturbed Savannah National Wildlife Refuge (Will et al., 2002).

…Navigation-related, large scale modifications (e.g., channel dredging, deepening, widening, straightening) to the riverine channels within the SRE have been ongoing since the 1950's, and significant impacts on fishes have resulted, most notably, the striped bass population crash" (Duncan et al., 2003).

HYDROLOGIC CHANGES

A thorough description of modifications to the Savannah River and effects on hydrologic regime and floodplain inundation patterns is provided by Hale and Jackson (2003) and Meyer et al. (2003). These resources should be referred to for detailed description of hydrologic regime. A brief summary is provided here.

1. Dams have caused an approximate 10% reduction in mean annual flow due to increased evaporation.
2. J. Strom Thurmond Dam has caused a dampening effect on the annual hydrograph (Figure 5, 6).

Figure 5. Hydrograph for Water Year 1995 (Meyer et al., 2003)

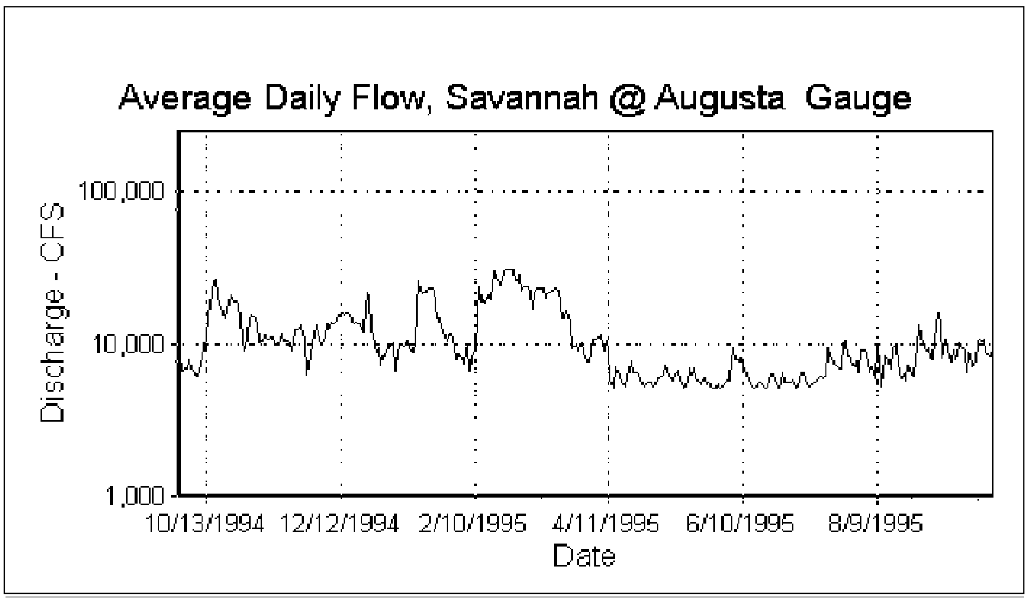
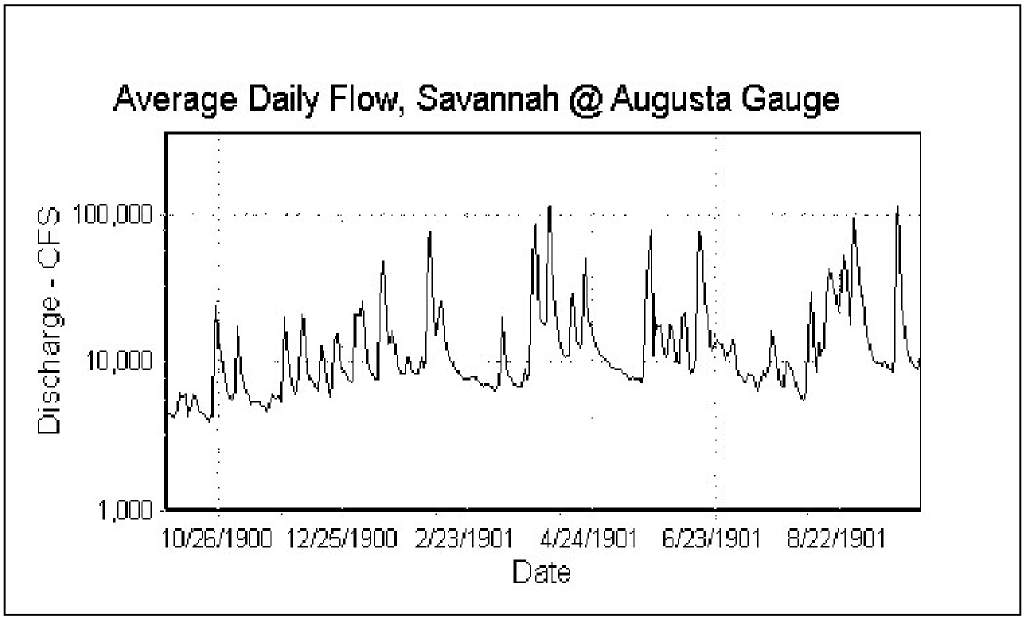
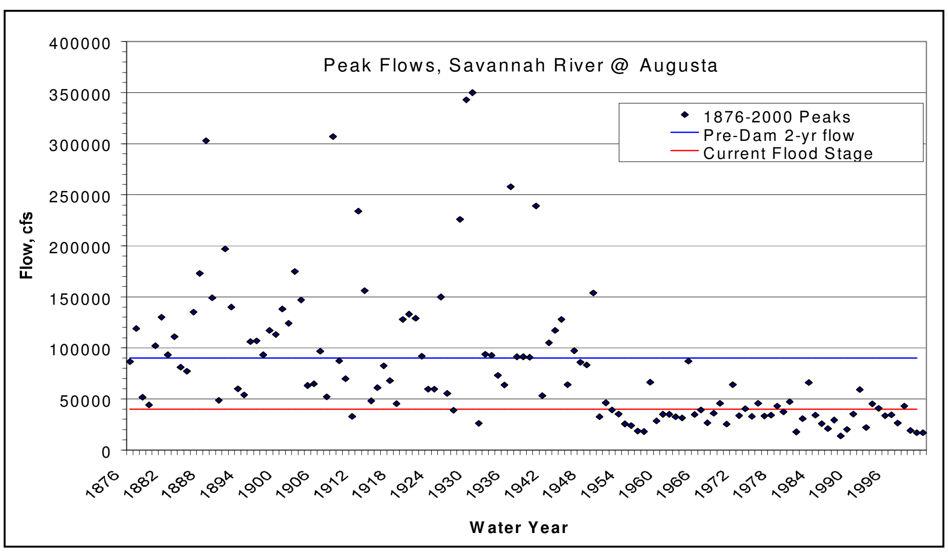


Figure 6. Hydrograph for Water Year 1901 (Meyer et al., 2003)



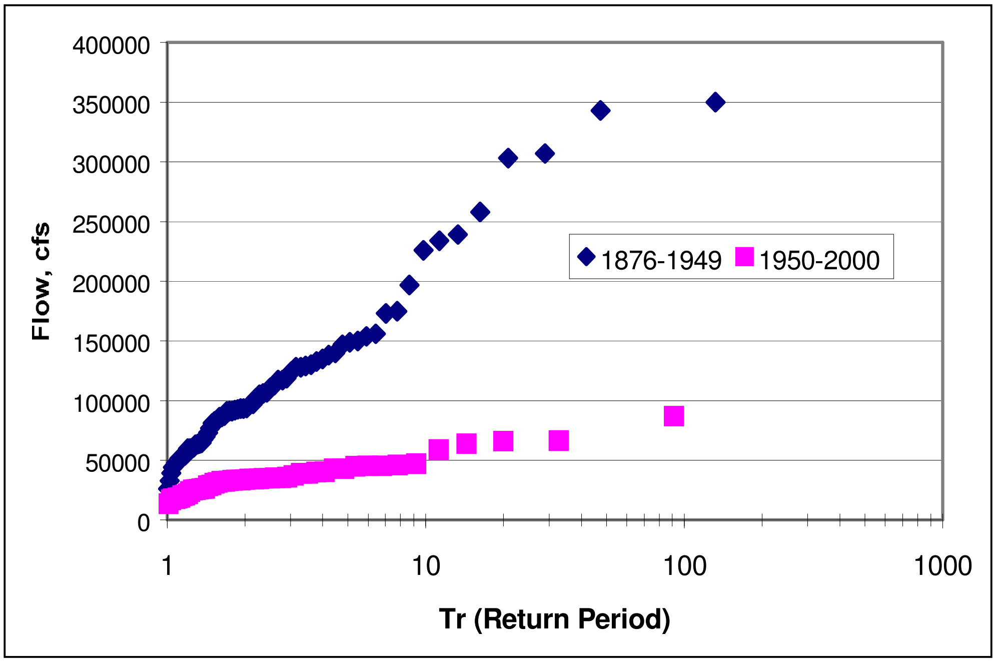
3. Damming has resulted in reduced frequency and magnitude of peak flows (Figure 7). An examination of flows in unregulated southeastern river systems, however, indicated some climatological changes. Extremely high flood flows occur with less frequency, but flood flows still occur (pers. comm. R. Jackson and B. Bader). The compressed hydrograph and the reduced frequency of flood flows and high pulses on the Savannah River are undoubtedly attributed to the construction and operation of the large dams and reservoirs.

Figure 7. Peak flows for the period of record at the USGS gauge #02197000 (Augusta, GA; Meyer et al., 2003).



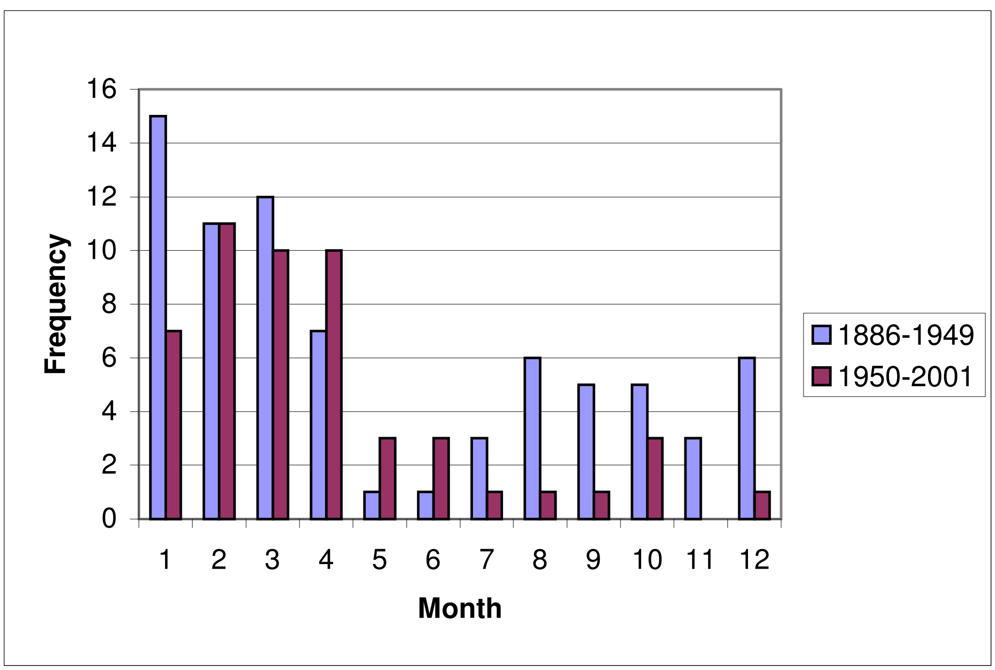
4. The flow return period has increased as a result of river regulation (Figure 8).

Figure 8. Peak flows for the period of record at the USGS gauge #02197000 (Augusta, GA; Meyer et al., 2003).



5. Winter peak flows are later and summer peaks have nearly disappeared (Figure 9);

Figure 9. Histogram of peak flow occurrence by month for USGS gauge #02197000 (Meyer et al., 2003).



6. The dam has altered the natural hydrology during drought conditions. The 7-day low flow has increased since installation of Thurmond Dam. The current 100-year, 7-day low flow is equal to the pre-dam's 1.5-year low flow (Figure 10, 11).

Figure 10. Comparison of pre and post-dam 7-day low flows at the USGS gauge #02197000 (Meyer et al., 2003).

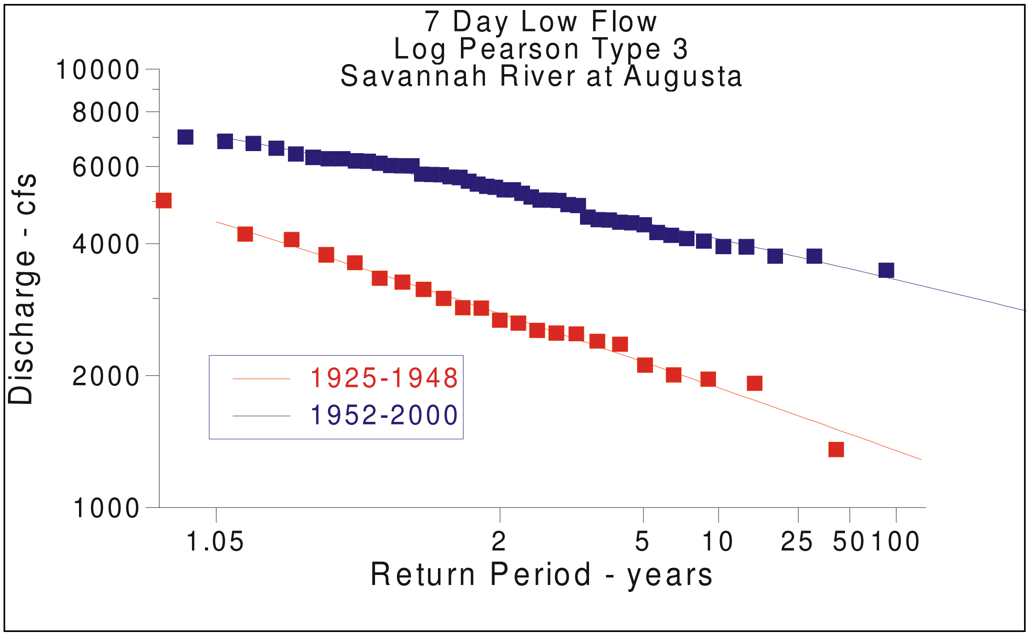
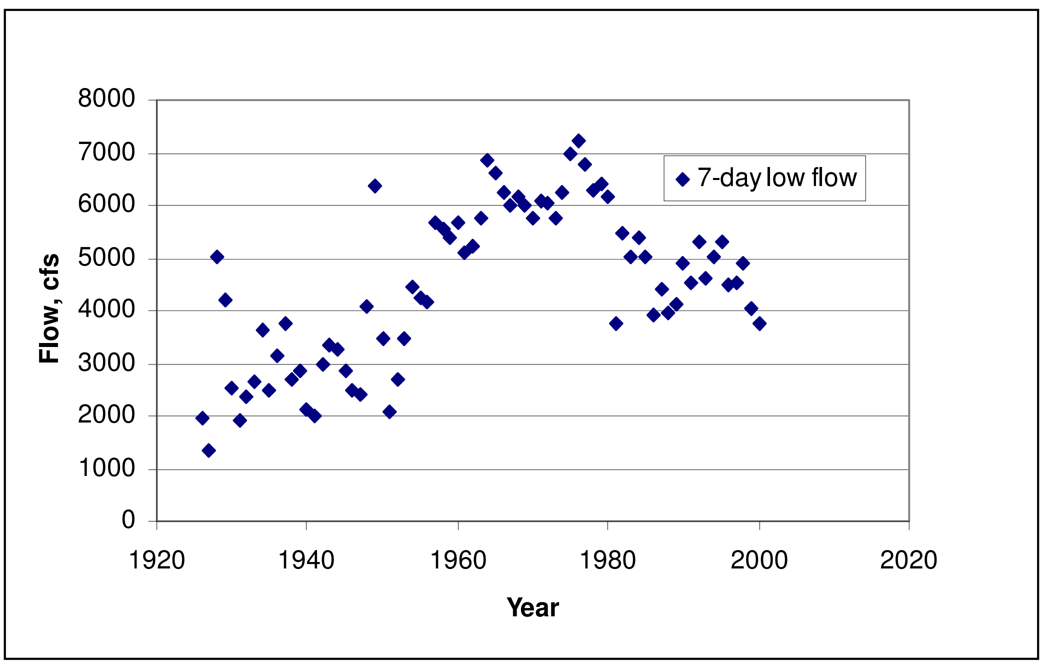
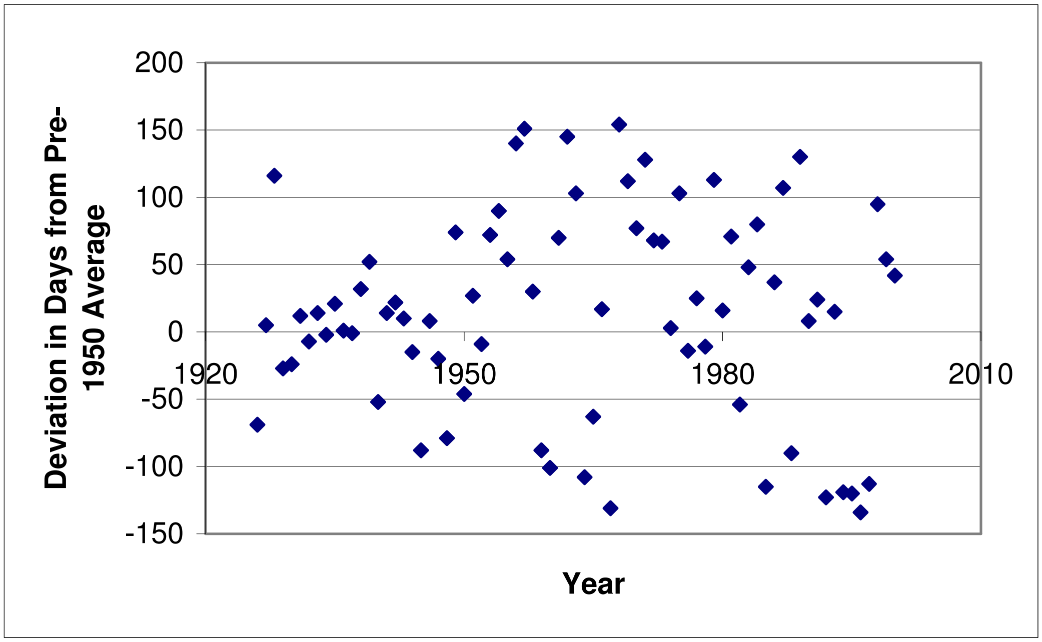


Figure 11. 7-day low flows for USGS gauge #02197000 (Meyer et al., 2003).



7. Occurrence of the low flow has shifted from within 1-2 months of the mean 7-day low flow date to 3-4 months (Meyer et al., 2003; Figure 12).

Figure 12. Julian date deviation of the 7-day low flow occurrence from USGS gauge #02197000's pre-1950 mean (Meyer et al., 2003).



8. Mean monthly flows have been reduced during the wetter portion of the year, likely a result of dam operation (Figure 13, 14).

Figure 13. Pre- and post-dam mean monthly flows for USGS gauge #02197000 (Augusta; Meyer et al., 2003).

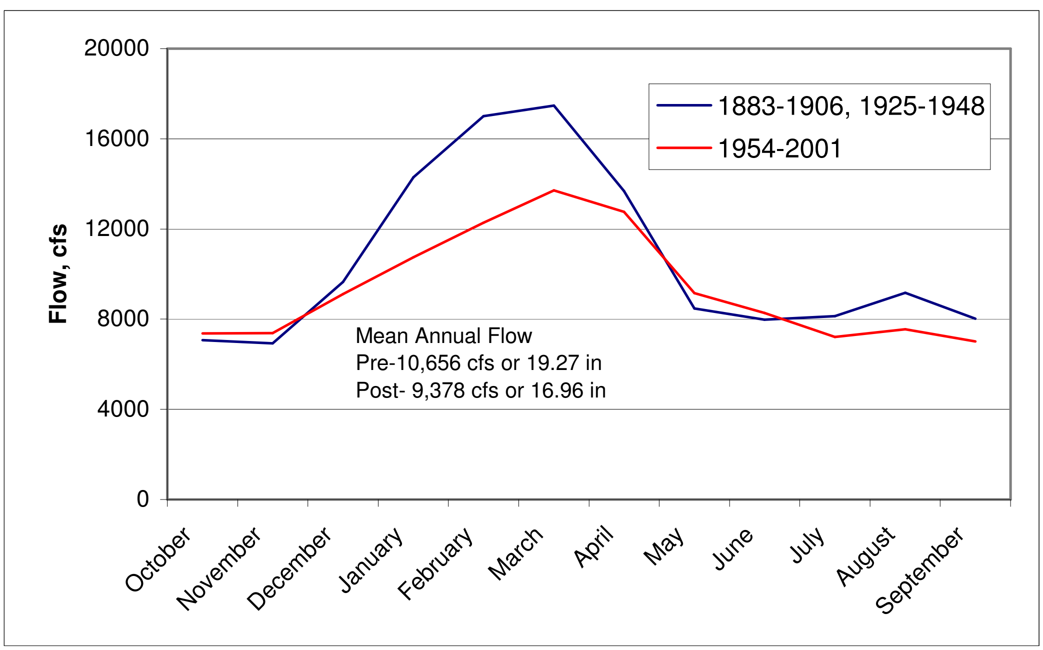
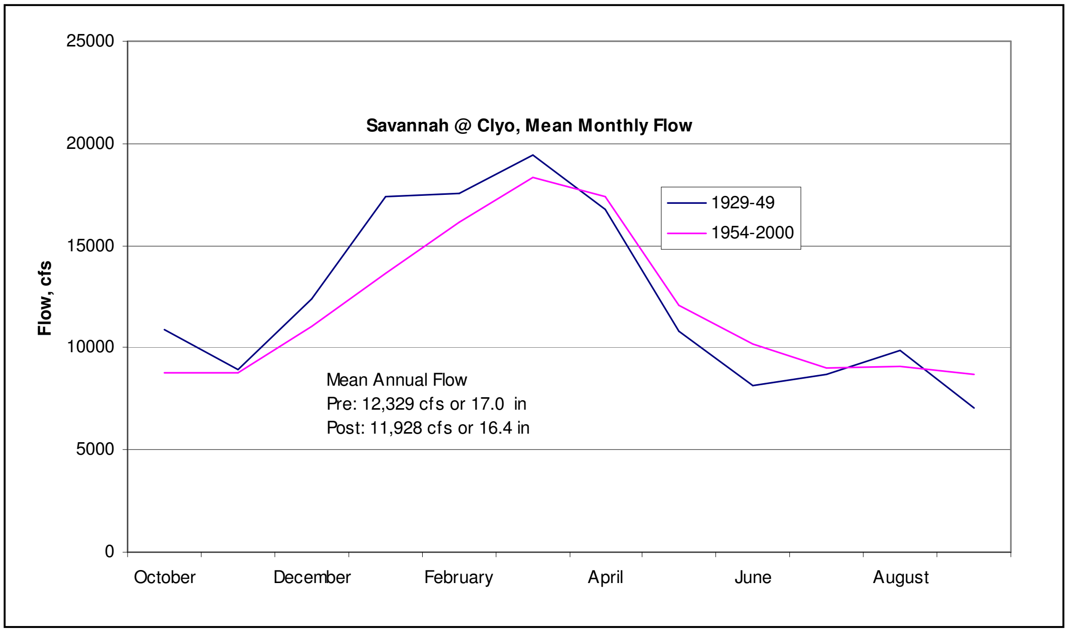


Figure 14. Pre- and post-dam mean monthly flows for USGS gauge #02198500 (Clyo; Meyer et al., 2003).



9. Base flows are higher in dry months since the installation of Thurmond Dam, and interannual variability has been reduced (Figures 15-17).

Figure 15. Average baseflow for the month of August at USGS gauge #02197000 (Meyer et al., 2003).

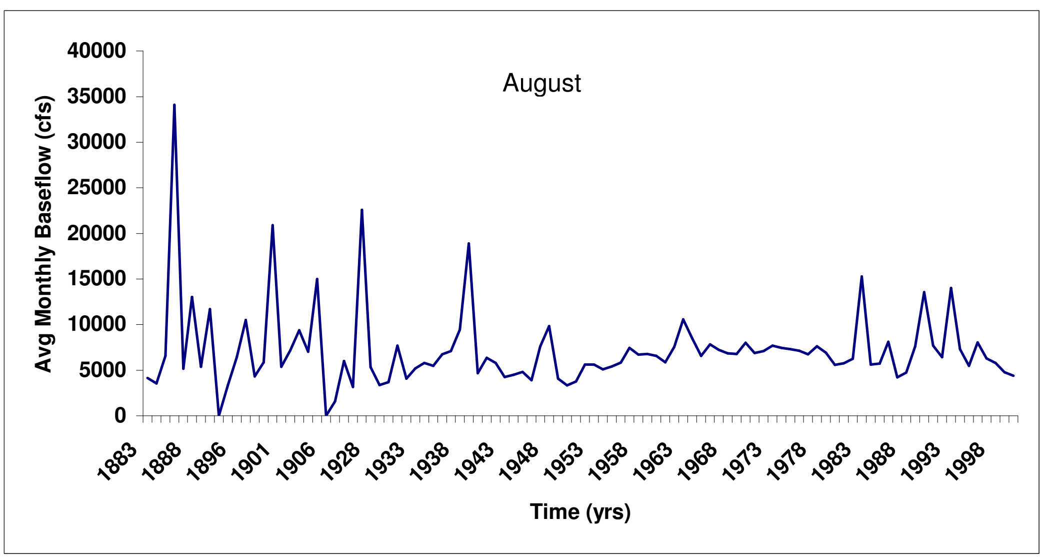


Figure 16. Average baseflow for the month of September at USGS gauge #02197000 (Meyer et al., 2003).

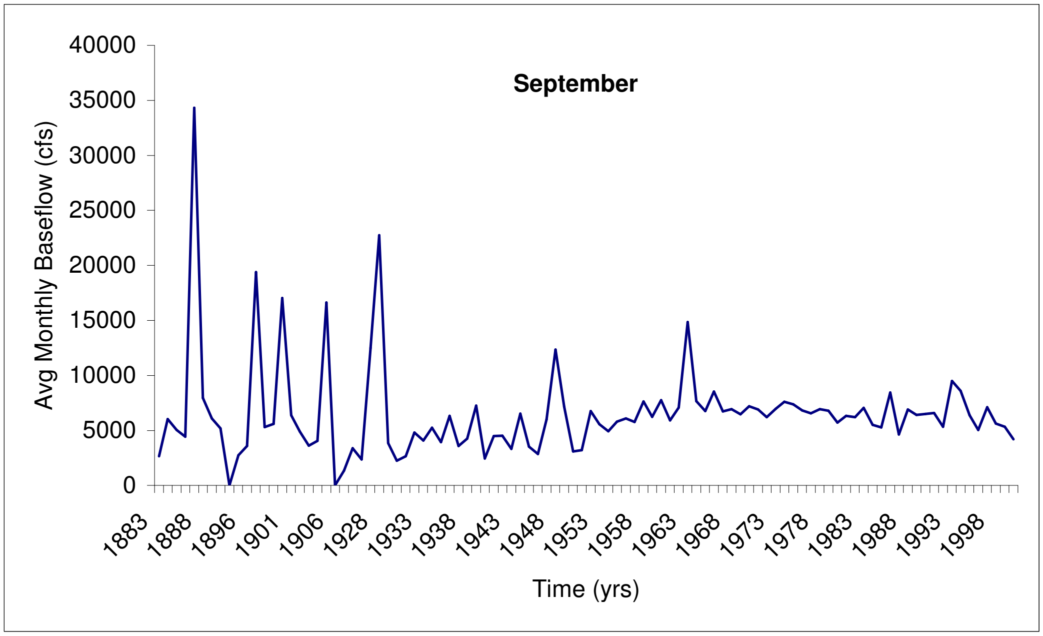
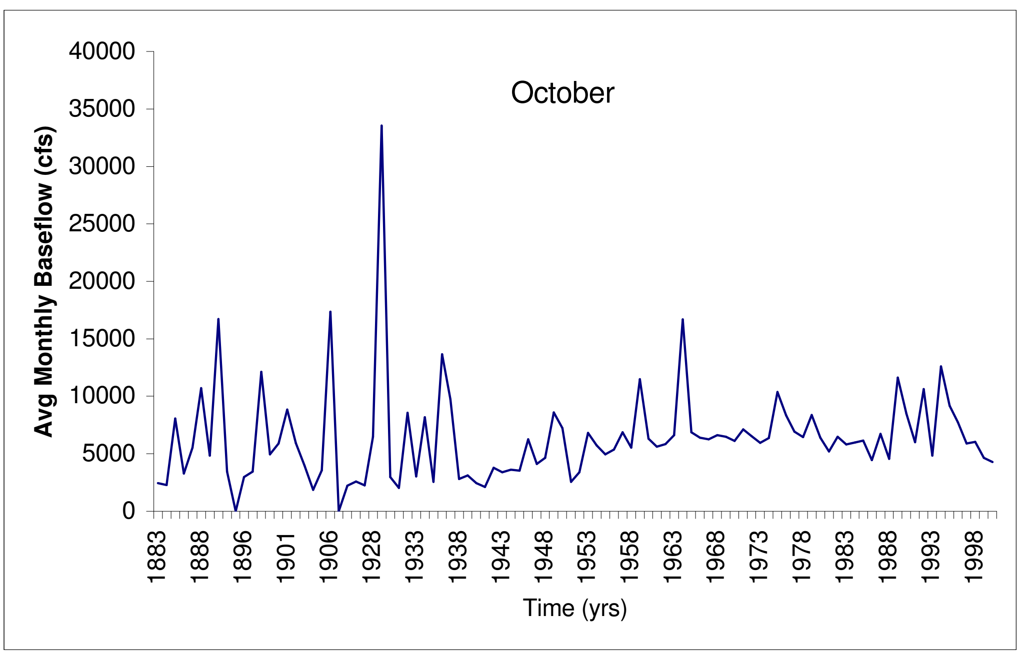


Figure 17. Average baseflow for the month of October at USGS gauge #02197000 (Meyer et al., 2003).



10. Since the installation of Thurmond Dam, there has been a general trend of less frequent overbank flow and less extensive floodplain inundation. Although this trend is certain, peak flow depths (Figure 18) and inundated floodplain percentages (Figure 19) are estimates and are likely to be revised as more data becomes available. These calculations have likely under-predicted the frequency and magnitude of flooding at these sites (Meyer et al., 2003).

    Our field observations on the Savannah River during high flow from June 16-18, 2003 indicate that flows of 20,000 cfs have the potential to inundate portions of the floodplain along the longitudinal river profile below Augusta. These observations also indicate that flows between 28-32,000 cfs probably result in extensive floodplain inundation downstream of Augusta. The lateral extent of floodplain inundation remains uncertain.

Figure 18. Peak flow depth above or below flood stage at River Mile 179.8 (Meyer et al., 2003).

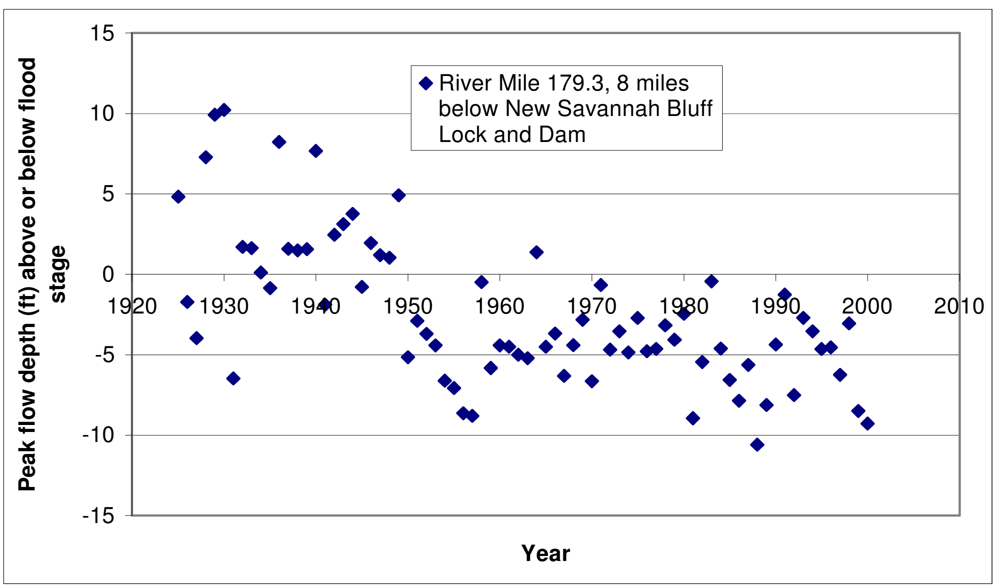
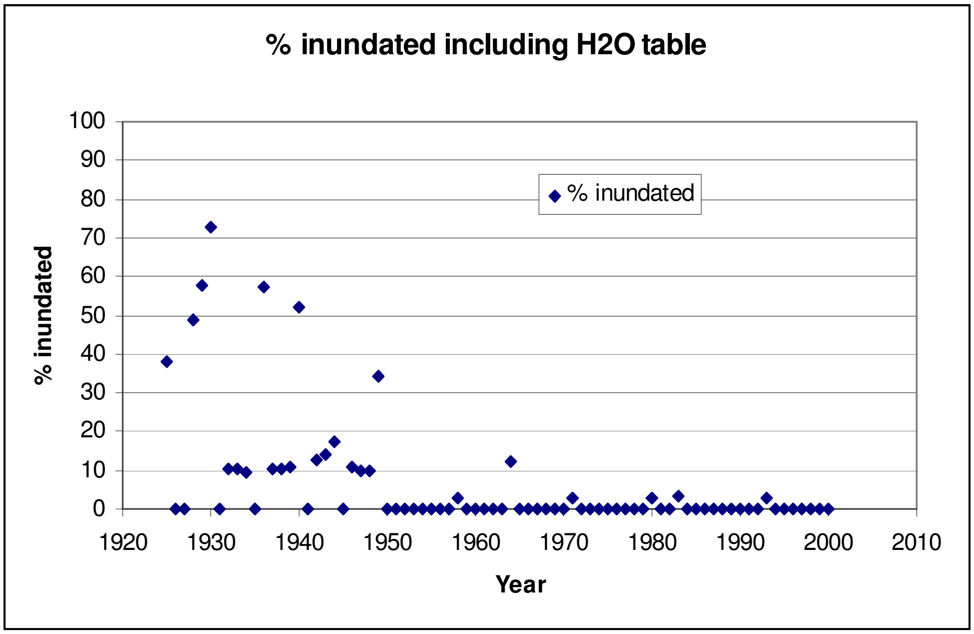


Figure 19. Percent of inundated floodplain assuming water table rise (Meyer et al., 2003).



RESOURCE CONCERNS AND PLANNING OBJECTIVES

The following fish and wildlife planning objectives were developed to address identified problems in the lower Savannah River basin. Although some of the following objectives are similar to those outlined in the Reconnaissance Planning Aid Report on Savannah River Basin Study (EuDaly, 1999), it should be noted that each has been reevaluated in relation to current management and conservation initiatives.

1. Implement a Savannah River flow regime that will provide for more natural ecosystem function, diversity, productivity, and fish and wildlife habitat throughout the lower Savannah River. The flow regime should be established by evaluating the quantity, duration, and periodicity of flows.

In the Savannah River, the hydrograph fluctuates on a daily basis with more extreme fluctuations closer to Thurmond Dam (Figure 3). Peak springtime flows are reduced (Figure 7, 13), floods are rare and lower in magnitude (Figure 7, 8), and inter-annual variability in some months is suppressed (Meyer et al., 2003).

It has been long recognized that ecosystem structure and function changes following the construction of hydropower dams. However, it is not until relatively recently that scientist have understood the mechanisms through which some of these changes occur. Hydrographs that fluctuate on a daily basis favor habitat generalists (Bowen et al., 1998; Travnichek et al., 2001). Fluctuating hydrographs reduce shallow-water habitat persistence and this habitat is essential for young-of-year fish rearing (Freeman et al., 2001). High springtime flows appear important in striped bass recruitment (Rulifson and Manooch, 1990). Seasonal floods inundate floodplains, areas of high ecosystem productivity and areas essential for fish spawning and rearing (Junk et al., 1989). Loss of river floodplain connectivity from river regulation and dredging reduces ecosystem productivity (Light, 1995). Inter-annual variability in flow regime is widely believed to be important in maintaining species diversity (Grossman et al., 1998).

2. Improve water quality, particularly dissolved oxygen levels and temperature, below J. Strom Thurmond Dam.

Cold-water release associated with hypolimnetic discharge often results in a conversion from a warm-water to a cold-water fish assemblage (Scott et al., 1996) and can reduce mussel growth and inhibit reproduction (Heinricher and Layzer, 1999). J. Strom Thurmond Dam, like most large hydropower dams, has hypolimnetic release. Cold, deoxygenated water flows into the shoals. However, aeration occurs as the water falls over the shoals and thus, conditions probably recover downstream. Evidence for this is supported by some DO measurements taken in the shoals during the summer months (ENTRIX, 2002b; GDNR, 1998). However, some uncertainty remains regarding the point at which temperature recovers downstream. This thermal impact merits further investigation. Mitigation may be needed if effects on the ecosystem are determined.

3. Discontinue any maintenance activities on the Savannah to Augusta navigation project and allow the Savannah River to establish a new hydraulic equilibrium.

Structural modification to the Savannah River system has undoubtedly altered river, floodplain, and estuary communities (see summaries in Meyer et al., 2003). These habitats are also affected by the regulation of flow by J. Strom Thurmond Dam. The shoals, for example, are periodically dewatered during periods when upstream power generation at Thurmond Dam ceases and the Augusta Diversion Dam continues to divert water from the shoals (Meyer et al., 2003). The frequency and magnitude of floodplain inundation has been reduced because of channel dredging and straightening (i.e., a lower streambed results in lower water levels) and fewer, lower flood events resulting from river regulation (Hale and Jackson, 2003). However, the degree of floodplain inundation under various flow regimes is not well understood. Such information would be helpful in making management decisions.

4. Restore natural periodicity and magnitude of floodplain connectivity and inundation by modifying operation of J. Strom Thurmond Dam and/or restoring channel-floodplain connectivity by other means.

There is a loss of river-floodplain connectivity and inundation in the lower Savannah River (Hale and Jackson, 2003; Meyer et al., 2003). Channel straightening has probably contributed to a loss of river-floodplain connectivity and inundation by eliminating some inundation pathways (e.g. tributaries, distributaries, and other points of low stream bank elevation). This transition has probably resulted in the succession of forested wetlands to drier habitat types (EuDaly, 1999), reduced nutrient processing and availability (Junk et al., 1989), and an altered fish community (Duncan et al., 2003).

Multiple means may be necessary to restore natural periodicity and extent of floodplain connectivity and inundation. Compared to historic conditions, for example, higher flows are necessary to inundate the floodplain because of the lower streambed. Increased floodplain inundation may be achieved by releasing more water from J. Strom Thurmond Dam, but flooding problems in the City of Augusta arise when flows exceed 37,500 cfs (NOAA, 2003). Thus, a combination of structural river restoration (e.g. restoring flow to old river bends) and higher flow releases may be necessary to improve floodplain conditions and ecosystem function.

Water depths at controlling sills along the floodplain must be considered because larger fish need deeper water than smaller fish to access the floodplain. Similar to the Savannah River, the Apalachicola River is a regulated river with an entrenched riverbed, resulting in lower water levels and reduced floodplain inundation (Light et al., 1995). Light et al. related flow not only to the amount of floodplain inundated, but also the amount of floodplain accessible to various sized fishes. Under low flow conditions, for example, small fish have access to twice as much floodplain habitat as large fish. Such information would be valuable in making dam management decisions to meet various ecosystem needs.

Benefits to restoring floodplain inundation are not limited to aquatic species. The endangered wood stork *Mycteria americana*, for example, nests in the top of floodplain trees. Floodplain inundation impedes predator access to nest sites. In years when the floodplain is relatively dry, increased nest predation results in extremely reduced nest success (USFWS, 2002).

5. Restore flow to Savannah River cutoff bends when and where fish and wildlife and/or other benefits can be demonstrated.

River bends are biologically significant. The rare Atlantic sturgeon *Acipenser oxyrinchus* spawns in strong current over hard substrates such as rock, rubble, shale, and sand (Smith and Clugston, 1997; Kynard and Horgan, 2002; Smith, 1985). Spawning localities in the Savannah River may be similar to that of the endangered shortnose sturgeon *A. brevirostrum*, which also spawns over hard substrates at river bends (Kynard, 1997).

Tributaries, distributaries, and low points along the river bank are often found along river bends and function as pathways through which water flows onto the floodplain. An examination of 1:182,000 scale topographic maps of the Savannah River indicated that nearly half of the cutoff bends contained tributaries that could serve as inundation pathways to the floodplain. Thus, restoring flow to river bends may not only benefit sturgeon spawning and shallow water habitat availability, but it may also facilitate floodplain inundation and the fish and wildlife that use those habitats.

A restoration project at cut #3 was completed in 1996. A large partial diversion structure improved flows into Bear Creek. The mouth of Mill Creek which had been closed by an old logging road was also restored. The effectiveness of this restoration project has not yet been investigated, although water quality monitoring is being conducted. Information on the effectiveness of these past restoration initiatives would be useful to determine restoration potential for any of the other 37 river cutoffs. Additionally, cutoffs must be considered on a site-by-site basis because potential benefits and impacts vary between sites. For example, since channel straightening commenced in the 1950's, cutoffs have accumulated sediments. Although flow restoration may transport accumulated sediments out of the cutoffs and improve riverbed conditions, sediment accumulation may be severe in some cases and potential benefits may be small.

6. Evaluate the ecological significance of shallow-water habitats in the lower Savannah River and evaluate the effects of flow regime on these habitats.

Shallow, depositional areas in the bends of large, Coastal Plain rivers are biologically significant. Shallow-water habitats in the Alabama River, for example, are important foraging, refuge, and possibly rearing habitats for fishes (unpbl. data M.C. Freeman and E.R. Irwin). The availability, persistence, and fish use of these areas in the Savannah River are unexplored and merit further investigation.

7. Reduce saltwater intrusion in freshwater habitats, restore tidal freshwater marsh, and restore striped bass habitat.

Saltwater intrusion that resulted from harbor deepening has been implicated in the 1980's striped bass population crash (Will et al., 2002) and the loss of freshwater wetlands (EuDaly, 1999). The Savannah National Wildlife Refuge historically contained about 6,000 acres of tidal freshwater wetland, but a combination of spoil deposition and salinity intrusion has reduced freshwater wetlands to about 2800 acres (EuDaly, 1999). Freshwater marshes are dependent upon freshwater inflow, and dam management strategies that restore or maintain existing freshwater habitats should be considered.

FLOW RECOMMENDATIONS FROM THE SAVANNAH RIVER WORKSHOP

Flow recommendations were developed at the Savannah River Ecosystem Flows Workshop in April, 2003, sponsored by The Nature Conservancy and the U.S. Army Corps of Engineers. Scientific expertise was ensured by the participation of scientists from various disciplines in state and federal agencies (including the Service) and the University of Georgia (Appendix C). To ensure that scientifically informed recommendations were developed, an annotated bibliography and a detailed summary report of studies, conditions, and issues was prepared by scientists from the University of Georgia and made available to participants prior to the workshop (Meyer et al., 2003). Multiple opportunities to evaluate flow recommendations and the reports were made during and after the workshop to ensure a thorough, scientific evaluation.

Development of ecosystem flow recommendations was a three-phase process that involved multiple breakout groups with experts in each group. Because the purpose was to identify ecosystem flow needs, no constraints were considered (e.g. operational flexibility at J. Strom Thurmond Dam or the potential to flood Augusta).

Three groups were formed during the first phase; the shoals group, floodplain group, and the estuary group. Each group was tasked with developing base flow, high pulse, and flood flow recommendations for dry, average, and wet years. Average years were defined as flows occurring 50 percent of the years, while dry and wet years represented flows below the 25^{th} percentile and above the 75^{th} percentile, respectively. Results from each group were presented to the entire group and input was solicited and incorporated (Appendix D). These recommendations were used to develop a unified low flow, high pulse, and a flood flow prescription for the entire river. Again, results were presented and input was solicited and incorporated (Figures 20-23). It should be noted that these figures recommend flows in the river, not releases from Thurmond Dam. The results of this phase are as follows:

- Base Flows: Participants felt it necessary to minimize hourly and daily flow fluctuations related to hydropower peaking and mimic pre- dam rate-of-change in flow. Base flow recommendations are outlined in Table 1.

Table 1. Savannah River Workshop unified base flow recommendations.

Month	Base Dry Year	Base Average Year	Base Wet Year
Jan	7500	9500	12000
Feb	7500	11000	13500
Mar	7500	12000	13500
Apr	7500	10000	13500
May	7500	9500	13500
Jun	6200	8000	8500
Jul	6200	7500	8500
Aug	5500	7500	8500
Sep	5500	7500	8500
Oct	5500	7500	9000
Nov	6200	7500	9000
Dec	6200	7500	9000

- **High pulse-Dry years**: Participants felt it was critical to provide flows between 16,000 - 18,000 cfs for 3 days in early March and again for 3 days in early April. If dry conditions extended beyond three years, the early April flows should be extended to a two-week period, to support striped bass spawning.

- **High Pulse- Average years**: Between January and April, the group suggested flows of 20,000-40,000 cfs. Participants stressed that the number should not be an average (for example 30,000 cfs each year), but that the magnitudes should vary within and between years. Flows in this range should occur for 2-3 days, once each month. Between May and October, the group suggested flows of between 8,000-12,000 cfs. These levels should be achieved 2-3 days each month, but with a frequency of not more than once every ten days.

- **High Pulse- Wet years**: Between the months of January through April, the group suggested a total of 5 pulses of at least 20,000 – 40,000 cfs. They further specified that one pulse, of two weeks duration, should occur in March. A second pulse, also of 2 weeks duration, should occur in early April. The other 3 pulses should be randomly distributed throughout this time period and last a minimum of 2 days.

- **Flood Flow Prescription**: a two-week flow of 50,000-70,000 cfs (at the Augusta gauge) to occur on average once every three years between January 1 and April 30 during wet or average years, with three consecutive non-flood years periodically provided during April.

Figure 20. Unified flow prescription for dry years on the Savannah River. Graph courtesy of B. Richter, The Nature Conservancy.

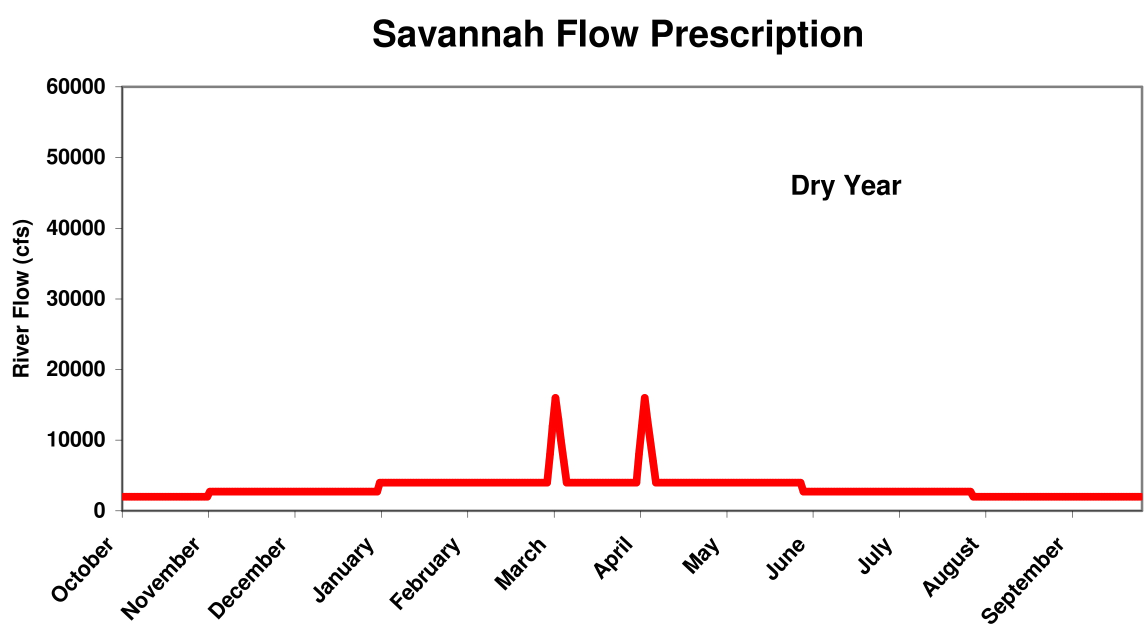


Figure 21. Unified flow prescription for average years on the Savannah River. Graph courtesy of B. Richter, The Nature Conservancy.

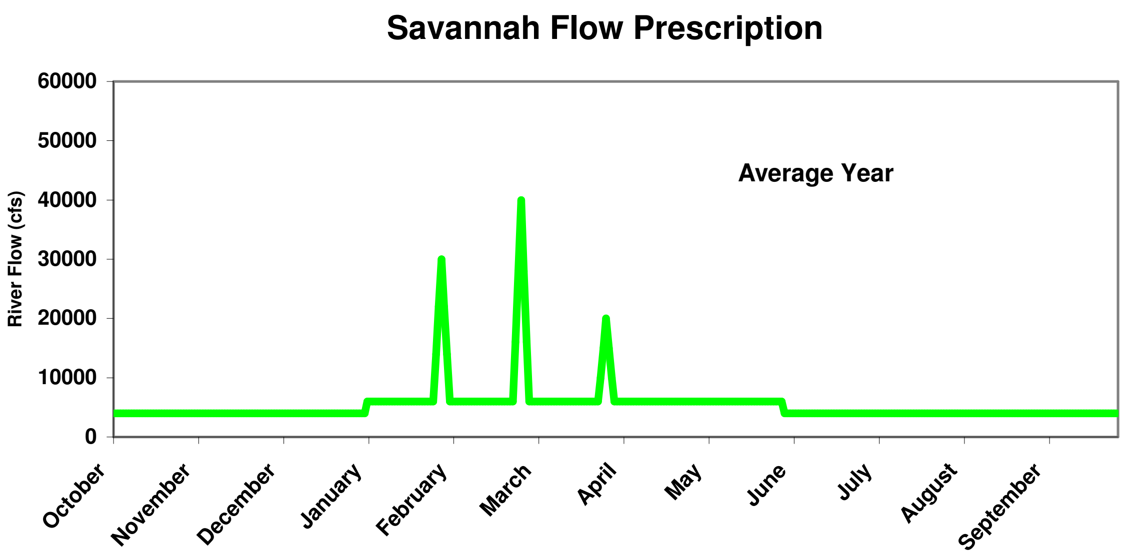


Figure 22. Unified flow prescription for wet years on the Savannah River. Graph courtesy of B. Richter, The Nature Conservancy.

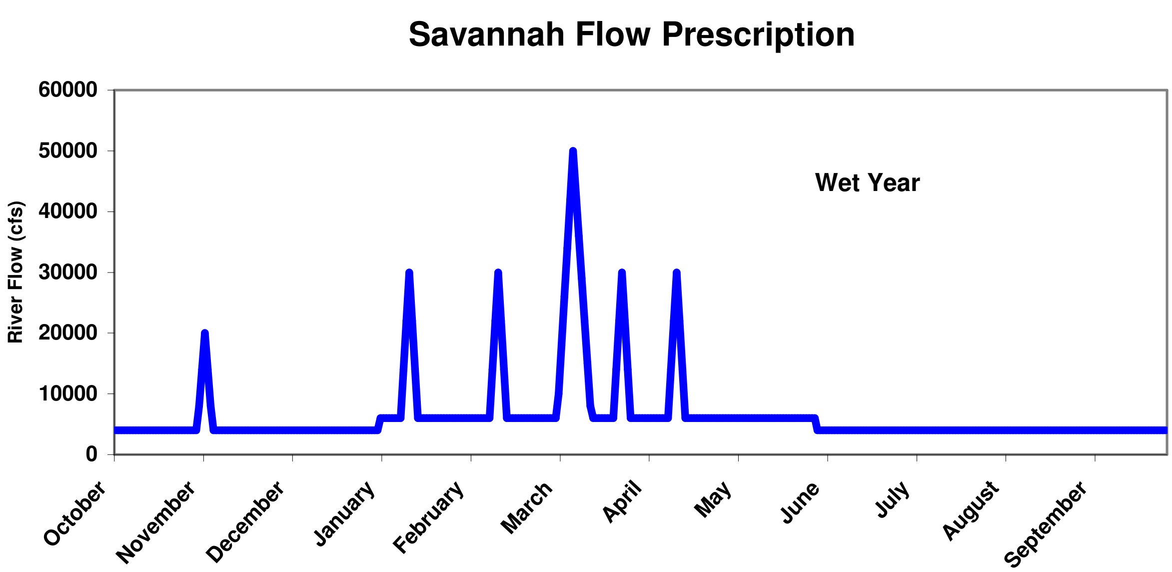
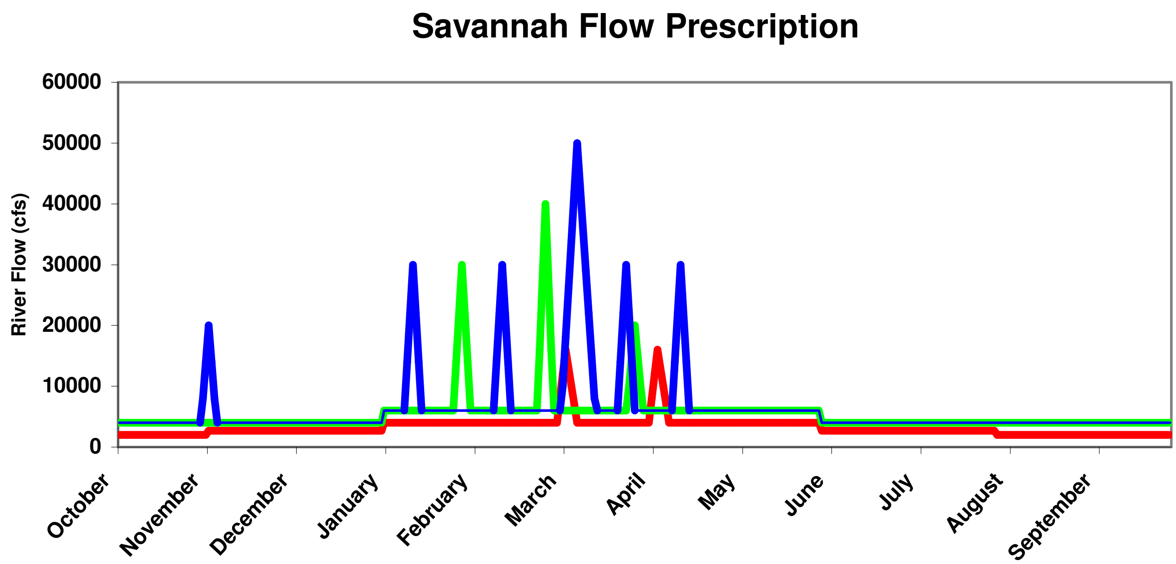


Figure 23. Unified flow prescription for dry (red), average (green), and wet (blue) years on the Savannah River. Graph courtesy of B. Richter, The Nature Conservancy.



SERVICE FLOW RECOMMENDATIONS

Figures 20-23 provide an overview prescription for the entire river system and are based on combining recommendations from the different work groups (i.e., shoals, floodplain, and estuary work groups). Use of the unified flow prescription to model reservoir operation is complicated by several factors. First, several different gauges throughout the river must be used to evaluate flows in the shoals, adjacent to the floodplain, and into the estuary. Second, the shoals group intentionally did not incorporate water diverted from the shoals by the Augusta Canal into their recommendations. Last, water returned to the river by the Augusta Canal plus water required in the shoals yields higher down-river base flows, which may be a detriment to shallow water habitats and forested wetlands during the growing season. Thus, the following Service recommendations are provided for the three different reaches of the river to enhance use of the recommendations in future modeling studies needed to analyze reservoir operation.

Water withdrawals at the Augusta Diversion Dam for the Augusta Canal may be major constraint on providing a feasible prescription. The Augusta Canal diverts flow from the shoals at a nearly constant rate of 3500 cfs (pers. comm. A. Hill, USFWS). Thus, an additional 3500 cfs must be added to the following shoal flow recommendations to determine discharge from J. Strom Thurmond Dam. The 3,500 cfs exceeds or almost equals the recommended flow at Augusta Shoals in dry years (2,000-4000 cfs). That water is returned to the river downstream of the shoals increasing the downstream base flow.

We reduced the workshop recommended flows in the shoals in May in order to reduce May flows downstream in the floodplain. The floodplain group had concerns that recurrent high May flows would reduce floodplain drainage and inhibit tree growth and regeneration in forested wetlands. We believe the resources will be best balanced by reducing May flows in the shoals in dry and average years. Conversely, if flows could be occasionally reduced in the canal, then it would be possible to reduce flows downstream without compromising habitats in either the shoals, floodplain, or shallow water habitats in the lower river mainstem.

The following recommendations are based on an assumption of 3,500 cfs withdrawal at the Augusta Diversion Dam. If additional flow diversion is allowed into the Augusta Canal under the Federal Energy Regulatory Commission relicensing, then providing needed flow in the Augusta shoals will be more difficult.

The Service recommendations for flows in the Savannah River are provided in Tables 2-4. Average years were defined as flows occurring 50 percent of the years, while dry and wet years represented flows below the 25th percentile and above the 75th percentile, respectively.

A pulse flow of 16,000 cfs is necessary to provide passage for striped bass, shad, shortnose sturgeon and Atlantic sturgeon over the New Savannah Bluff Lock and Dam (NSBL&D), located downstream of both the Augusta Canal discharge and the USGS Augusta gauge (Figure 1). The following shoal pulse flow recommendations will achieve downstream flow requirement for fish passage because of the 3,500 cfs returned to the river from the Augusta Canal.

Pulse flow recommendations provide a range of flows that need to be provided in multiple dry or average years. For dry and average years, all pulse flows are recommended to occur over at least five days with a rapid rise and a gradual recession (see description below). The original unified flow recommendations were for a high pulse of three days in duration. Further examination of the Indicators of Hydrologic Alteration (IHA) analysis (supplied by B. Richter, The Nature Conservancy) subsequent to the workshop indicated that most high pulses were over 5 days in duration at the Augusta gauge prior to mainstem impoundment. Extending the period to 5 days will accommodate the rise rate specified below. For wet years, pulse flows for January, February and late October are recommended to occur over at least five days with a rapid rise and a gradual recession. For wet years, pulse flows for March and April are recommended to occur over 14 days with the peak flow provided in the table to occur during the middle of the 14 day period.

Rise rate should be similar to that of conditions that existed prior to mainstem impoundment. The IHA analysis indicated that the flood rise rate was variable, but most often between 10,000 and 20,000 cfs/day in upriver areas. The Service recommends that the rise rate should fall within this range at the Savannah River at Augusta gauge. The pre-dam rise and fall rate was often slower and the duration of the pulse was frequently longer at the Clyo gauge. This slower rate probably results from the channel morphology and the extensive floodplain storage capacity. Thus, basin geomorphology will likely moderate recommended rise rates and lengthen pulse duration at Clyo, conditions that will resemble pre-dam pulses.

Estuary (Clyo) recommendations were derived primarily by using the flow recommended by the estuary group. In cases where the floodplain (upstream) flow recommendations were higher than those of the estuary group, the floodplain recommendations were used.

Table 2. Service recommended flows in the Savannah River, Augusta Shoals.

Month	BaseDry	BaseAvg	BaseWet	PulseDry	PulseAvg	PulseWet	Flood
Jan	4000	6000	8500		16500-36500	26500	
Feb	4000	7500	10000		16500-36500	26500	
Mar	4000	8500	10000	12500-14500	16500-36500	26500	
Apr	4000	6500	10000	12500-14500	16500-36500	26500	
May	2700	4500	10000				
Jun	2700	4500	5000				
Jul	2700	4000	5000				
Aug	2000	4000	5000				
Sep	2000	4000	5000				
Oct	2000	4000	5500			16500	
Nov	2700	4000	5500				
Dec	2700	4000	5500				

Table 3. Service recommended flows in the Savannah River Floodplain, Burtons Ferry Gauge.

Month	BaseDry	BaseAvg	BaseWet	PulseDry	PulseAvg	PulseWet	Flood
Jan	7500	9500	12000		20000-40000	30000	
Feb	7500	11000	13500		20000-40000	30000	50000
Mar	7500	12000	13500	16000-18000	20000-40000	30000	
Apr	7500	10000	13500	16000-18000	20000-40000	30000	
May	6200	8000	13500				
Jun	6200	8000	8500				
Jul	6200	7500	8500				
Aug	5500	7500	8500				
Sep	5500	7500	8500				
Oct	5500	7500	9000			20000	
Nov	6200	7500	9000				
Dec	6200	7500	9000				

Table 4. Service recommended flows in the Savannah River Estuary, Clyo Gauge.

Month	BaseDry	BaseAvg	BaseWet	PulseDry	PulseAvg	PulseWet	Flood
Jan	8000	9500	12000		20000-40000	30000	
Feb	8000	11000	13500		20000-40000	30000	50000
Mar	8000	12000	13500	16000-18000	20000-40000	30000	
Apr	8000	10000	13500	16000-18000	20000-40000	30000	
May	6200	8000	13500				
Jun	6200	8000	9000				
Jul	6200	8000	9000				
Aug	6000	8000	9000				
Sep	6000	8000	9000				
Oct	6000	8000	9000			20000	
Nov	6200	8000	9000				
Dec	6200	8000	9000				

ECOLOGICAL BENEFITS

A detailed description of the recommendations and rationale are included in Appendix D. Below is a summary of the ecological benefits from implementing the flow prescription.

Low flow recommendations

The Savannah River Instream Flow Study (ENTRIX, 2002) assisted in the development of low flow recommendations for the shoals. Flow recommendations considered fish passage into and within shoal habitats, weighted useable area for various fish guilds, species, and life stages (including both resident and anadromous fishes), and juvenile outmigration. Additionally, deer are known to enter the shoals and graze on the state listed shoal spider lily *Hymenocalis coronaria* during low flow periods. The amount of flow necessary to prevent deer access to the lilies was considered in the recommendation.

In the floodplain, base flows must be low enough as not to impede floodplain drainage during the growing season (Apr-Oct). The workshop floodplain group recommended a three-year sequence of low flows floodplain seedling establishment. However this recommendation was in conflict with the estuary recommendations where base flows are needed to offset salinity intrusion. The May flows provided in our recommendations were reduced to address the need for lower flows during the growing season. Base flows should also be low enough in Jun-Oct to provide shallow water habitat for small-bodied fishes. Higher base flows during wet years help ensure good egg and larval drift for pelagic spawning fishes.

Low flow recommendations in the estuary were based, in part, on recent low flow periods and known biological responses, including reduced tidal freshwater marsh area and stressed plant communities. The spatial distribution of salinity gradients, freshwater marsh, and fish access to the marsh were considered in determining the low flow recommendation. Low flow recommendations in average years are likely higher than natural base flows and should have a restorative influence on select portions of the system such as freshwater tidal marshes and processes that are sensitive to high salinity. Potential ecological benefits associated with wet year low flow recommendations included "more extensive seed dispersal across the freshwater tidal marsh, increased invertebrate productivity, greater nutrient cycling, enhanced conditions for select species (e.g. striped bass, American eel, sturgeon, southern flounder, striped mullet) and life stages (e.g., striped bass spawning), and a "push-back" of the salt water gradient to support different fish assemblages across space (Appendix D)."

High pulse recommendations

High flow pulse recommendations in the shoals considered fish passage into and within the shoals (including across New Savannah Bluff Lock and Dam), striped bass *Morone saxatilis* egg suspension and transport, and flows that trigger anadromous fish migration in the spring and fall (for likely fall spawning season for sturgeon *Acipenser* spp.). High pulses may remove silt accumulations that may be affecting habitat conditions in the shoals and gravel bars. Finally, it was noted that these recommendations were predicated on the continued operation of the New Savannah Bluff Lock and Dam. The group noted that alternative strategies for fish passage should be explored and if achievable, the prescription could be revised.

Springtime high pulses are needed to allow fish access to the floodplain, nutrient and carbon exchange between the river and floodplain, woody debris export to the channel, larval fish transport, predator-free bird nesting habitat (e.g. prothonotary warbler *Protonotaria citrea*, wood stork *Mycteria americana*, and other Ciconiforms) and seed transport. A sequence of low flow years are important for seedling establishment. High pulses in the dormant season inhibit germination of upland vegetation species. Pulses in the summer and early fall are needed to exchange water with oxbows. Rapid up and down fluctuations that reduce survivorship of juvenile fishes should be avoided.

High flow pulse recommendations in the estuary considered the importance to maintaining the health of the estuarine system as well as mitigating the impacts of harbor deepening. Periodic pulses of freshwater are known to act as effective controls of oyster and blue crab parasites. High flow pulses reduce salinity in the tidal freshwater marsh and are necessary in the beginning of the growing season (April) for nutrient input and increased seed dispersal. The recommended flows and the two-week duration were defined to enhance conditions for striped bass spawning (suspension and transport of eggs) in the estuary.

Flood flow recommendations

Ecological benefits of floods in the shoals are uncertain, and consequently, no flood flow recommendations were developed for the shoals. The river/floodplain group identified geomorphic processes as the primary function of flood flows. Although sediment input and transport above the City of Augusta has been reduced because of dam construction, flood flows can redistribute sediments input downstream and sediments accumulated in cutoff bends.

Flood flows in the estuary support a number of ecological functions. The estuary group identified sediment replenishment, nutrient and productivity boost for near-shore marine fishes, species mixing, turbidity protection for young fish, freshwater, sediment, and nutrient replenishment of the freshwater tidal marsh, and improved habitat and forage for bird species as potential benefits of flood flows.

DESCRIPTION OF POTENTIAL ENVIRONMENTAL IMPACTS

Several environmental concerns are acknowledged should the above flow recommendations be implemented at J. Strom Thurmond Dam. First, some of the floodplain group believe that base flow recommendations may be too high, thus preventing floodplain drainage in some areas and potentially impacting tree growth and regeneration. Research to address this question would be of great value in refining recommended flows (see appendix A). Another concern was that dry year low flows could result in dissolved oxygen problems during the summer in the shoals. Monitoring during summer low flow periods is recommended to address this concern.

Flood flows have the potential to transport bed sediments downstream without replacement from an upstream source, ultimately resulting in streambed armoring. However, the likely affected area, between Thurmond Dam and the NSBL&D impoundment) may already be sediment deprived. It was the general consensus at the workshop that the potential flood benefits to ecological processes outweigh the costs of sediment loss. However, monitoring of shoal spider lily *Hymenocalis coronaria,* which is probably dependent on some sediments, is recommended.

Flood stage at Augusta, however, is 21 feet, or about 37,500 cfs. At this flow, "extensive areas of New Savannah Bluff Lock and Dam Park become flooded including park roads and bridges. Lowlands and farmlands immediately adjacent to the river become flooded at stages above 21 ft" (NOAA, 2003). The only impact noted at 32.6 ft is "the Sandbar Ferry Road Bridge becomes submerged." At 33 ft, "extensive damage occurs in the Augusta metropolitan area… Water [is] as much as 15 feet deep in adjacent farmland and 8 to 10 feet deep in the lowest areas of Augusta. The Sandbar Ferry Road [is] submerged (NOAA, 2003)."

Thus, limited impacts are observed at 21 ft and extreme impacts are observed at 33 ft. An alternative to releasing recommended flood flows that cause extensive damage could be to release high flows that cause limited, or no, damage, i.e., stage less than

32 ft. Another alternative may be to release high but non-damaging flows during periods of, or prior to, widespread downriver rainfall events. Cumulative effects of rainfall and high water release may inundate the floodplain more than either event by themselves.

Flood discharge in the lower study area is less than at Augusta, being 15,000 cfs at Clyo, and 20,500 cfs at Burton's Ferry (NOAA, 2003). However, because of the broad undeveloped floodplain, only minor impacts to man-made structures are noted in the lower parts of the study area at any flow. Downstream of Augusta, farmland, livestock and small roads may be affected at the higher flows.

CRITICAL RESEARCH NEEDS AND FUTURE FWCA ACTIVITIES

Although flow recommendations from the April, 2003 workshop were based on scientific expertise in a variety of fields, critical research needs were identified and ranked in order of importance (Appendix A). Addressing critical research needs would assist agencies in implementing more informed management decisions related to the operation of J. Strom Thurmond Dam. Results would be used to prepare Fish and Wildlife Coordination Act Reports that evaluate fish and wildlife habitats and ecological processes associated with the Savannah River.

RECOMMENDATIONS

The Fish and Wildlife Service makes the following recommendations to the USACE regarding lower Savannah River projects.

1. Implement the Service Savannah River flow prescription outlined in this report. Consult the U.S. Fish and Wildlife Service regarding flood flows after an assessment of potential impacts to the City of Augusta has been made for various high flow scenarios.

2. Address critical research needs identified in the April, 2003 workshop (Appendix A) and modify the flow prescription based on results of the research and further coordination with resource agencies.

3. Evaluate biological and hydrological effects pre- and post-flow regime change.

4. Improve water quality, particularly dissolved oxygen levels and temperature, below J. Strom Thurmond Dam.

5. Discontinue any maintenance activities on the Savannah to Augusta navigation project. Seek deauthorization of this navigation project.

6. In conjunction with state and federal fish and wildlife agencies, the Army Corps of Engineers, and other scientists, evaluate cutoff bend restoration sites based on potential benefits to fish, wildlife, and floodplain connectivity.

7. Restore flow to Savannah River cutoff bends when and where fish and wildlife and/or other benefits can be demonstrated. Evaluate restoration effectiveness.

8. Examine the ecological significance of shallow-water habitats in the lower Savannah River and evaluate the effects of flow regime on these habitats.

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APPENDICIES

APPENDIX A. Critical research needs for informed management of the lower Savannah River.

Savannah River Ecosystem Flow Workshop, April 1-3, 2003
Critical Research Needs

Shoals

- Real time streamflow gauging in Shoals along with temperature: allows for the development of a streamflow-temperature model
- Fish, plant, invertebrate distribution and composition (and movement tied to flows over time)
- Physical dynamics during low and high flow extremes: informs sediment transport and deposition study
- Spider Lily flow needs
- Robust redhorse spawning habitat
- Atlantic sturgeon spawning and passage information along with shortnose sturgeon passage data in relation to flow
- Striped bass passage and thermal requirements as well as egg drift requirements for movement past New Savannah Bluff Lock and Dam

Floodplain

- Cross-sectional and/or spatial topography at fine resolution
- Vegetation community distributions
- In-channel survey of physical structure (woody debris, sand and gravel bars, etc)
- Location of gravel patches below New Savannah Bluff LD and flow-habitat relationships
- Oxbows & sloughs – at what flows will water be exchanged with river, and how do these exchanges affect water quality
- Duration of inundation in floodplain after flood events
- Modify existing USGS streamgauges to include temperature, turbidity, dissolved oxygen
- Revisit COE cut-off bend study

Estuary

- Relate flow at Clyo to salinity distribution in estuary
- Fish community distributions, inter-tidal marsh conditions during high flow periods (similar to what has been done for drought period)
- Relate salinity conditions to inter-tidal/floodable habitat
- How does flow affect spawning and recruitment success for estuary-dependent (incl. diadromous) fish species
- Relationship between flow and dissolved oxygen
- Analyze fish community data with a focus on flow impacts

Research needs are ranked in order of importance
List was provided by K. Lutz, The Nature Conservancy.

APPENDIX B. Unified low flow, high pulse, and flood flow recommendations.

The following summaries were provided by K. Lutz, The Nature Conservancy.

Savannah River Ecosystem Flow Workshop, April 1-3, 2003
Unified Low Flow Group

The recommendations provided in the attached spreadsheet are for releases from Thurmond Dam. Translating habitat-based recommendations to release recommendations required a set of assumptions. These assumptions are as follows:

- 3,500 cfs that would otherwise flow through the Shoals area will be removed by the Augusta diversion canal. This diversion estimate is based on the most recent data provided to the USFWS. Due to the fact that the gauge on the canal is faulty, these numbers are not currently verifiable. Improvement of flow gaging on the canal and for flow in the Shoals is a priority.

- The assumption was made that this entire diversion was returned to the Savannah River downstream of Augusta.

- Estuarine inflow recommendations were made for the Clyo gauge. To translate these recommendations to Thurmond dam releases, 1,000 cfs was subtracted from these recommended inflow numbers. Clearly a more refined adjustment to these numbers would be preferable.

Recommendation Definition Process

The process of determining low flow recommendations in the workgroup involved first listing the recommendation for each habitat-based group for each month and water year type. Then these recommendation were translated into Thurmond dam release recommendations based on the assumptions listed above. This step was followed by a discussion of how well the recommendations compared with each other. Finally, a minimum recommended flow level was selected- often by taking the lowest acceptable value that satisfied the previously defined recommendations of all three habitat-based groups. The numerical recommendation(s) that acted as the "ecological driver(s)" of the overall low flow recommendation is in italics in the attached spreadsheet. If the translation of habitat-based recommendations are refined based on a better understanding of the issues outlined in the assumptions above, this driver information will be important. Note that the habitat-based recommendations listed in the attached spreadsheet have all been translated to Thurmond releases and are in cubic feet per second (cfs). Average years were defined as occurring 50% of years, while dry and wet years represented below the 25th percentile and above the 75th percentile, respectively.

Additional Notes

The floodplain group representatives noted the need to optimize dry periods to promote tree growth in the floodplain by suppressing growing season flood for a few years following a dry year. However, this was an issue for the estuary group due to concerns about saline buildup. Mitigation through winter flushing flows is necessary. Another concerns for the floodplain group was that the low flow recommendations were too high and might impact the channel habitat in the floodplain portion of the river. This concern centered around the availability of shallow water habitat for juvenile fish species, particularly in the months of June-October. A key question for floodplain group was at what base flow do we inhibit floodplain drainage in the growing season (April-October). There is a need to ensure the drainage occurs so that normal growth can proceed. Finally, there was a concern that dry year low flow numbers, in the Shoals in particularly, might result in dissolved oxygen problems as the assimilative capacity of the stream would be tested in summer.

Savannah River Ecosystem Flow Meeting, April 1-3, 2003
High Pulse Unified Flow Prescription

Participants began their discussion by layering the three hydrographs to visually examine areas of consensus and areas where recommendations differed. The group was pleased by the degree of general agreement among the shoals, estuary and floodplain groups.

Average years were defined as occurring 50% of years, while dry and wet years represented below the 25th percentile and above the 75th percentile, respectively.

Dry Years

The needs of anadromous fish were key in arriving at a unified prescription for dry years. Participants felt it was critical to provide flows between 16,000 - 18,000 cfs for 3 days in early March and again for 3 days in early April. Flows of this magnitude were slightly higher than those recommended by either the floodplain or estuary group, and slightly lower than the shoals group. Again, lacking specific elevation data, the floodplain group was uncertain about percent floodplain inundation at these levels, but thought with the limited number of days requested, they could support this recommendation.

If dry conditions extended beyond three years, the April flows should be extended to a two-week period, to support striped bass spawning. While flows of this magnitude might be detrimental to cypress and tupelo in the short term, we considered the needs of anadromous fish to be a higher priority then seedling survival during extended drought periods.

The rate of change for these flows was considered inconsequential.

Finally, it was noted that these recommendations were predicated on the continued operation of the New Savannah Bluff Lock and Dam. The group noted that alternative strategies for fish passage should be explored and if achievable, the prescription could be revised.

Average Years

Recommendations for average years by the shoals and floodplain groups were identical. The estuary groups recommendations were lower and covered a shorter time frame. Ultimately, however, the groups agreed that there were two critical time periods for fish and floodplain plant communities, each with a specific flow recommendation. Between January and April, the group suggested flows of 20,000-40,000 cfs. Participants stressed that the number should not be an average (for example 30,000 cfs each year), but that the magnitudes should vary within and between years. Flows in this range should occur for 2-3 days, once each month.

The rate of change for this prescription should reflect a rapid rise and a gradual decline.

Between May and October, the group suggested flows of between 8,000-12,000 cfs. These levels should be achieved 2-3 days each month, but with a frequency of not more than once every ten days.

Wet Years
Again the shoals, floodplain and estuary requirements were remarkably similar, with only minor variations in the duration of pulses. Between the months of January through April, the group suggested a total of 5 pulses of at least 20,000 - 40,000. They further specified that one pulse, of two weeks duration, should occur in March. A second pulse, also of 2 weeks duration, should occur in early April. The other 3 pulses should be randomly distributed throughout this time period and last a minimum of 2 days.

Savannah River Ecosystem Flow Workshop, April 1-3, 2003
Unified Flood Flow Group

The Unified Flood Flow Group was comprised of representatives from each of the three systems groups (shoals, river/floodplain, and estuary). As the shoals group did not develop a prescription for flood flows, the task became one of meshing the flood flow recommendations from the river/floodplain and estuary groups.

The original recommendations from these two groups were in fact quite similar. The river floodplain group had called for one flood to occur on average every two years at a magnitude of 50,000-70,000 cfs and to last for a duration of two weeks. These floods were prescribed to occur during wet years anytime from January 1 through April 30. The flood flow prescription from the estuary group consisted of one flood on average every five years at a magnitude of at least 50,000 cfs, to last for a duration of four weeks. These prescribed floods were to occur during average or wet years anytime between February 1 and April 30. The differences between these two prescriptions that were resolved by the Unified Flood Group included the recurrence interval of the flood (once every two years versus once every five years), the duration (two weeks versus four weeks), and the timing of the flood (January-April versus February-April).

The timing of the flood was quickly resolved as the representatives from the estuary group saw no problems with including January as part of the flood window. One caveot brought by the river/floodplain group was that there needs to periodically be at least three consecutive years without floods during April to allow for successful establishment of bottomland vegetation. The different durations of flooding were also determined to not truly be in conflict as flood flows typically dampen out and lengthen between the river/floodplain and the estuary; that is, it was expect that a two week flood on the river would be a three to four week flood in the estuary. Consequently, much of the discussion focused on the question of flood frequency and adjusting the difference between one every five years (estuary group) and once every 2 years (river/floodplain group). The definitions of "dry", "average", and "wet" years were first re-visited, with a re-iteration that each category contains an even one-third of all years. After additional discussion of the ecological requirements for both systems, a unified recommendation was made for floods to occur at a frequency of once every three years (on average over an extended period such as a decade). Further, the group identified no problems with these floods occurring during either wet or average years, which should provide operational flexibility to meet the prescription. With the differences resolved, ***the group agreed on a Unified Flood Flow prescription that consists of a two-week flow of 50,000-70,000 cfs (at the Augusta gauge) to occur on average once every three years between January 1 and April 30 during wet or average years, with three consecutive non-flood years periodically provided during April.***

APPENDIX C. Savannah River ecosystem flows workshop attendees.

Name		Affiliation
Merryl	Alber	University of GA
David	Allen	SC Department of Natural Resources
Colin	Apse	The Nature Conservancy
A.W. (Bud)	Badr	SC Department of Natural Resources
Bill	Bailey	U.S. Army Corps of Engineers
Darold	Batzer	University of GA
Ed	Bettross	GA Department of Natural Resources
Braye	Boardman	The Nature Conservancy
Prescott	Brownell	National Marine Fisheries Service
Dick	Christie	SC Department of Natural Resources
Mark	Collins	SC Department of Natural Resources
Paul	Conrads	U.S. Geological Survey
Robert	Cooper	University of GA
Emily	Cope	SC Department of Natural Resources
Leroy	Crosby	U.S. Army Corps of Engineers
Mary	Davis	The Nature Conservancy
Will	Duncan	University of GA
Gene	Eidson	Southeastern Natural Sciences Academy
Ed	Eudaly	U.S. Fish and Wildlife Service
Mary	Freeman	University of GA
Jim	Greenfield	EPA
Cody	Hale	University of GA
Joe	Hamilton	The Nature Conservancy
Deborah	Harris	U.S. Fish and Wildlife Service
David	Hawkins	GADNR - Environmental Protection Division
John	Hickey	U.S. Army Corps of Engineers
Amanda	Hill	U. S. Fish and Wildlife Service
Joe	Hoke	U.S. Army Corps of Engineers
Ted	Illston	The Nature Conservancy
Jeff	Isely	USGS-Coop Unit
Rhett	Jackson	University of GA
Gerritt	Jobsis	SC Coastal Conservation League
Danny	Johnson	SC Department of Natural Resources
Eric	Krueger	The Nature Conservancy
Kim	Lutz	The Nature Conservancy
Judy	Meyer	University of GA
Monica	Palta	University of GA
Elizabeth	Richardson	University of GA
Brian	Richter	The Nature Conservancy
Becky	Sharitz	University of GA
Joan	Sheldon	University of GA
Ellen	Tejan	The Nature Conservancy
Matt	Thomas	GA Department of Natural Resources
Vic	Van Sant	GA Department of Natural Resources
Andy	Warner	The Nature Conservancy
Richard	Weyers	University of GA
Spud	Woodward	GADNR-Coastal Resources Division

APPENDIX D. Ecosystem flow recommendations for shoal, floodplain, and estuary breakout groups.

The following summary of recommendations from shoal, floodplain, and estuary breakout groups was supplied by K. Lutz, The Nature Conservancy.

Savannah River Ecosystem Flows Workshop April 1-3, 2003
Recommendations from the Shoals Breakout Group

Assumptions

These recommendations are for the flows in the shoals themselves. When calculating releases from J. Strom Thurmond (JST) dam, the flows transferred to the canal need to be added.

We used preliminary recommendations of the state and federal agencies to help form the recommendations in the shoals, however, since the state and federal recommendations were constrained by current operational procedures, those estimates were likely low for ecosystem protection.

Definition of Reach

The Shoals are defined as that 4.5 miles stream segment upstream of Augusta, GA and downstream of the Augusta Canal Diversion Dam

Low Flow Recommendations

Dry Years

Recommendation:
Jan- May: 4,000-6,000 cfs; 4,000 base flow with variability above.
Jun-Jul: at least 2700 cfs
Aug-Oct: at least 2,000 cfs
Nov-Dec: at least 2,700 cfs

Justification: Spawning season flows elevated above 4,000 cfs to benefit shad and robust redhorse spawning and passage. These flows may be low for Atlantic sturgeon, but as a long-lived species, good years need not occur every year. These flows should also benefit the shallow-fast guild based on the ENTRIX study. The shallow slow guild will not benefit, but habitat for this guild is better downstream.
DATA GAP: Passage and spawning requirement for Atlantic Sturgeon

June-July flows at least 2700 cfs to protect spider lily (see above).
August-October flows designed to mimic summer lows in a natural flow regime.
November-December flows designed to mimic natural flow regime, ensure that there is more gradual increase towards spawning flows, and allow for out-migration of juveniles.

Average Years

General recommendation: Minimize subdaily and subweekly fluctuations related to peaking hydropower generation. Attempt to have rate-of-change in flow in the shoals that mimic pre-JST dam rates. Manage for mussel specific flow needs by managing for host fish due to the lack of data to base decisions upon. Snails require light penetration to the shoals (for algal growth) and inundation in order to have habitat needs met. Our goal was to meet these needs through all recommendations.

Recommendation:
January through May: 6,000-10,000 cubic feet per second (cfs). 6,000 cfs should be used as the base flow recommendation, but variability up to 10,000 cfs is desired (assuming natural rate-of change and frequency)

June through December: 4,000- 5,000 cfs. 4,000 as the base flow recommendation with small variation above is desirable.

Justification: Jan-May is spawning season for anadromous fish and fish in the deep-fast guild that currently access (or may access in the future) the shoals for spawning. Figure 21 in UGA report and ENTRIX report shows that Weighted Usable Area continues to increase at flows above 6,000 cfs for American shad (spawning and larval) and striped bass. It also should provide adequate habitat for robust redhorse.

Expert opinion was that sturgeon need sustained flows of at least 5,000 cfs for 2 1/2 months. 45 days for spawning in Feb-March and an additional 30 days of sustained flows to prevent drying of substrate/eggs. Shallow slow and shallow fast guilds would have less WUA available under this average year regime, yet the group believed that these habitat needs were better taken care of further downstream. They will benefit from the dry year regime in the shoals.

June and July flows need to be sustained above 2700 cfs to limit deer grazing on the spider lily (which are not known to enter shoals when river edges are wetted). Flows above 2700 cfs throughout the non-spawning season are necessary to provide upstream and downstream fish passage through the shoal area. 4,000-5,000 cfs was selected for June through December based on the pre-dam baseflow conditions during those months, because it provides constant habitat for resident fish species, and because it allows for juvenile outmigration.

Recommendations were not made based on mussels due to evidence of low abundance and diversity in the shoals area. Nonetheless, these base flows, coupled with more natural rate-of-change in flows, should benefit mussels by providing habitat stability.

DATA GAP: Need cross sections to confirm flow required to protect spider lily population through inundation.

Wet Years

Recommendation:
January-May: 6,000-10,000 cfs
June- Dec: 4,000-5,000 cfs

Justification: Same benefits and numbers as in an average year. High pulses are more important addition in wet years than increased base flow. In addition, ENTRIX study did not go over 8,000 cfs in its modeling so benefits to fish in terms of PMWUA were not determined. However, we can assume that flows above 10,000 cfs may have negative impacts on habitat for deep fast and shallow fast guilds.

4,000-5,000 cfs in October-November may allow fall spawning of sturgeon. This behavior has been documented on other regional rivers, but has not been verified on the Savannah (DATA GAP).

DATA NEEDS: Temperature-discharge relationship. Without such a relationship there may be temperature impacts on fish and mussel species from higher releases that are not accounted for in these recommendations.

Sedimentation dynamics. An understanding of pre-dam sediment dynamics is desired, but what is more critical is a model of what flows result in significant scouring of the channel that might impact spawning habitat for fish as well as mussel habitat.

High Pulse Recommendations

General recommendation: Overall, high pulses are less necessary to the shoals than are persistence of adequate base flows. Recommendations attempt to get velocities of 1 ft/sec for striped bass reproduction (entrainment of eggs), however downstream flow-velocity relationships needed to ensure Morone eggs are kept in suspension as they move downstream (particularly through the New Savannah BL&D impoundment) (DATA GAP).

Although there was a general assumption that high pulses could benefit the shoals, the mechanics of how the ecosystem would benefit from these high pulses was not known (DATA GAP). However, based on data from other systems, high pulses can be expected to be important triggers for migration, especially on the descending limb of the pulse.

High pulses during the summer months are assumed to have a negative effect on shoals species due to the cold temperatures that may disrupt life cycles of fish and mussel species.

Dry Years

Recommendation:
January- April: 1-2 pulses of approximately 20,000 cfs during these four month in total. Duration of each of these pulses should be 1-2 days.

Justification: Based on pre-dam flow pulses. Need at least 16,000 cfs to provide fish passage for herring over New Savannah Bluff Dam to the shoals. Passage needs for other species needs to be confirmed (DATA GAP). Once passage over NSBLD is provided (through dam removal or a fish ladder) these pulses will enhance migration of anadromous fish. The 1-2 day pulse provides a diversity of durations (in relation to wet and average years) while being adequate for Morone egg suspension.

Average Years

Recommendation:
January-April: Pulses of 20,000-40,000 cfs each month for a duration of 2 to 3 days per month.
Pulses during the summer (July-September) may have negative impact due to the potential effects of cold, hypolimnetic water on resident fish species and mussel reproduction and growth.
Pulses during the rest of the year not necessary for shoals, but are more likely to be beneficial than not.

Justification:
Pattern and magnitude based on natural flow regime (similar to pre-dam pulses). These high pulses should benefit anadromous fish as triggers to migration (as seen in literature). Some evidence that striped bass have higher reproductive success after January pulse flows in the Roanoke. Although the shoals have been sediment starved since regulation of the river, high pulses may provide benefits related to moving silt accumulations downstream that may be affecting habitat conditions, including existing gravel bars. Finally, Morone spp. recruitment should generally benefit from January-April high flows since eggs will be more likely to stay suspended in the water column as they move downstream.

DATA GAP: Research is necessary to better understand negative/positive impacts on spider lilys from high and low pulses. Cindy Smith completed a report of flow impacts on the lily and concluded that high flows were beneficial in reducing terrestrial vegetation encroachment on spider lily habitat. More research is needed to examine other potential impacts throughout the range of flow conditions that might be experienced. This research may be most important during blooming season, May-June, where a negative impact is hypothesized.

Wet Years

Recommendation:
January-April: monthly pulses of 20,000 to 40,000 cfs. January-February duration of 2-3 days. March to April duration of at least 14 days.

October-November: 1 pulse of 20,000 of 2-3 days.

Justification

Natural flow regime creates the basis for the pulse magnitude and timing. Duration of pulses during March and April match longer duration flows seen during pre-dam conditions as well as occasional spring pulses seen in the post-dam period. These long duration pulses may also provide more opportunity for passage to the shoals (whether New Savannah Bluff dam is there or not). The 14 day long pulse was set to captures a greater opportunity for migration, spawning, and egg suspension of fish that may not all be at the same point in their life cycle.

The fall pulse is for sturgeon migration and spawning flows (assuming there may be a fall spawning season).

DATA GAPS: No temperature data for the shoals- particularly flow-temperature relations and how the temperature profile changes from the beginning of the shoals to the end. However, there may be temperature data available through Mike Alexander who is leading the Stephens Creek Dam DO study. We need an accurate USGS gauge for the shoals.

Flood Flow Recommendations

All Years

Workgroup determined there was no need for floods since the ecological benefits of higher flows could be provided by high pulses. Due to the lack of sediment input to the shoals area due to the dam, there was a concern that extremely high flows could lead to channel scouring and that decrease critical habitat (e.g. gravels) in the shoals area. However, it was noted that woody debris and nutrient transport might be increased by occasional floods. More research on the costs and benefits of floods to the shoals area should be a research topic (DATA GAP).

Final Data Gaps:

Many of the recommendations are based on the needs of anadromous fish. The local native fish assemblage, since it is not well understood, was not fully taken into consideration with these recommendations. Once a survey of fish species composition and distribution in the shoals has been completed, the recommendations should be reexamined based on that information.

Extremes low flow and high flows were not included in our recommendations due to concerns about negative impacts on the shoals' physical and ecological system. Concerns about excessive scouring of the channel at high flows should be examined through a physical study of the system. Assumptions about the negative impacts of extremely low flows were made based on loss of habitat concerns and water quality issues (temp and DO). These assumptions should be examined through a physical study of the system at extremely low flows (less than approximately 500 cfs).

Savannah River Ecosystem Flows Workshop, April 1-3, 2003
Recommendation from the Floodplain Breakout Group

Guiding Assumptions

The floodplain group was challenged in making recommendations as they lacked detailed elevation data for the floodplain, and also lacked detailed information on the location of gravel and sandbars. Some members of the group, however, had anecdotal information regarding the relationship between river stages and inundation of landmarks and geographic features such as trails, boat ramps and oxbows. This anecdotal information, coupled with the limited numbers of cross-sections available, was used to make assumptions about percent inundation of the floodplain. Thee assumptions should be revisited as detailed floodplain data is gathered.

Description of Reach
This reach begins at downstream from the Augusta shoals (river mile) and extends to the beginning of the estuary (river mile).

Low Flow Recommendations

General recommendation: Facilitate processes influenced by base flow conditions.

These include:

- Germination and establishment of tupelo-bald cypress (bottomland swamp) and bottomland hardwood forest species
- Growth of adult trees
- Pelagically spawning fishes: egg and larval drift
- Juvenile fish survival
- Spawning habitat in gravel shoals
- Adequate adult fish habitat during low flow periods

Note that 30d min flow post dam is about 60% higher than pre-dam.
90 d min flow post dam is about 25% higher than pre-dam.

(Ecosystem limitations may occur as a result of higher later spring and early summer flows; pulses during low flows, or lack of years with prolonged low flows)

Dry Years

Recommendation: Need about 3-yr sequence of about 3000 cfs * base flow, April - October; should occur every 10-20 yrs.

Justification: Needed for seedling establishment. Note - don't want to exacerbate desiccation of floodplain; water quality if of concern (need to meet assimilative capacity); COE drought plan – 3600 cfs during low flows.

*Don't really know what low flow level allows appropriate germination sites on the floodplain.

Average years

Recommendation: 5000 cfs April – October

Justification**:** During growing season, April- October, need base flows low enough to not impede floodplain drainage, and June-October, base flows should be low enough to provide shallow water habitat for small-bodied fishes. Note: NEED to know flow-habitat relations on gravel bars to recommend appropriate base flows. David Allen, SCDNR – gravel bars submerged when flow is at about 4ft on Augusta gauge, which equate to about 5000-6000 cfs.

Wet years

Recommendation**:** 8000 cfs for prolonged periods during March –May at least once a decade.

Justification: ensure good larval drift for pelagic spawners.

- Need to know base flow effects on temperature
- Need to know at what levels base flow impedes drainage of the floodplain

High Pulse Recommendations

These are episodic events, occurring multiple times each year

General recommendation: Pulses should facilitate -

- Seed dispersal
- Flow into oxbows
- Floodplain access for fishes for spawning, foraging
- Nutrient and water replenishment to floodplain soils
- Fish passage past NSBLD
- Woody debris export to channel from floodplain
- Good nesting habitat for birds, prevention of predator access
- Preventing access/knocking back feral pigs
- Macroinvertebrate habitat on floodplain

Dry years

Recommendations**:** From mid-March through growing season, no pulses (>= 13,000 cfs) for 3 yrs in a row, once every 10-20 yrs.

Justification: Need a sequence of low flow years for tree recruitment. Several years needed for seedling establishment; expect tree mortality if "establishment years" are followed by an extremely wet year.

Average years

Recommendation: (1) January to April, need pulses of 20,000 – 40,000 cfs at least once a month, lasting 2-3 days. Rate of change: rapid rise and gradual recession over 2-3 day period. Need substantial inter-annual variation in pulse magnitude. Could be as low as 13,000 cfs if NSBLD were removed.

(2) May-September: need pulses of 8,000 – 12,000 cfs, no more frequently than about once every 10 days on average.

Justification: Jan-April pulses needed to allow migratory fishes passage at NSBLD; allow fish floodplain access (e.g., blueback herring spawn on floodplain); provide nutrient, carbon exchange between river and floodplain; woody debris export to channel from floodplain; larval fish transport; provide predator-free bird nesting habitat (e.g. prothonotary warbler); seed transport. Note that mast producers, e.g. oaks, may produce every 5-6 years. Inter-annual variability essential to providing a diversity of habitats on the floodplain for trees, fishes, macro-inverts and birds. Conditions that promote a diversity of tree spp will also maximize biodiversity of macro-arthropods, birds.

May-September pulses needed to exchange water with oxbows, but want to avoid rapid up and down fluctuations that reduce survivorship of juvenile fishes.

Need to know floodplain inundation – flow relations. Need to know how much water is needed to inundate differing riverine floodplain habitats. Need these to be inundated for 14 d during growing season every one in two years on average.

Wet years

Recommendation: December - March, need 5-8 pulses of 30,000 - 40,000 cfs about once every four years; of at least 1week duration each.

Justification**:** Needed to allow migratory fishes passage at NSBLD; allow fish floodplain access (e.g., blueback herring spawn on floodplain); provide nutrient, carbon exchange between river and floodplain; woody debris export to channel from floodplain; seed transport; larval fish transport; provide predator-free bird nesting habitat (e.g. prothonotary warbler). Multiple pulses, provide good floodplain access for fishes
Dormant season floods increase soil moisture, can inhibit germination of upland spp.
25,000 cfs at Augusta &32,000 cfs at Clyo – substantial floodplain inundation.

Flood Flow Recommendations

Floods – historically 2-yr event was about 90,000 cfs; occurred Dec- March, Aug – Sept.

General recommendation: Flood should -
Maintain channel
Kill invasives
Transport organic matter
Provide fish access
Facilitate denitrification, improve water clarity,

Facilitate aquatic macroinvertebrate production
Recharge groundwater
Fill oxbows/sloughs
Seed dispersal
Floodplain erosion/sedimentation
Maintain jurisdictional wetland conditions

Less frequent events (less than 2-10 yr events) important for shaping floodplain topography – occurs in very large floods over which we have little control.

Average years

Recommendation: January – April, need 1-2 peaks of 50,000 - 70,000 cfs; every 1 in 2 yrs on average.

Justification: Regulation has eliminated peaks **and** reduced sediment supply; restoring pre-dam flood regime will degrade channel. If restore the cutoffs, and sediment is entering channel downstream from Augusta, would need peaks to redistribute sediments. Rhett guesses 50,000 – 75,000 cfs might be a good flow to balance need for geomorphic effects with reduced sediment input. ALSO – consider that pre-European sediment loading would have been lower.

Savannah Ecosystem Flow Workshop, April 1-3, 2003
Recommendations from the Estuary Breakout Group

Guiding Assumptions
The recommendations from the Estuary Group for ecosystem flows were predicated on a number of assumptions and conditions. First, recommendations are based on records from and presented for the river at the USGS Clyo gauge. Second, recommendations are considered appropriate ***only*** for the current (2003) harbor configuration. Due to the extensive modification of the harbor (deepening from approximately 12 feet to 42 feet for navigation), the group explicitly identified the natural (pre-dam) flow regime as not appropriate for consideration for ecosystem protection/restoration. Nor should the ecosystem flow recommendations developed by the Estuary Group be considered applicable if additional harbor deepening is conducted.

Description of Reach
For the purposes of these flow recommendations, the estuary has been defined with an upper limit of Ebenezer Landing (approximate river kilometer 65) down to the mouth of the river.

Low Flow Recommendations

Dry Years
The prescription consists of 8,000-cfs, January through April, and 6,000-cfs in all other months. This was based on two historical drought periods. First, the recent drought period (1997-2001) led to a sustained low flow of between 4,000 and 5,000-cfs and

negative effects were observed in the estuary. The primary impact noted was to the tidal freshwater marsh (e.g., diminished area and stressed plant community). Secondary concerns were associated with the salinity gradient (0.5 PSU in particular) versus the spatial distribution of critical freshwater tidal marsh habitat for fish; that is, an extensive up-river shift of higher salinity zones could effectively cut-off fish access to marsh habitat. Therefore, the group' s initial low flow target for dry years was to keep flow levels above 4,000 to 5,000-cfs. This was revised upward to the target presented above based on conditions and biological response observed during an earlier drought period in the 1980' s. This 6,000-cfs level was deemed acceptable and set as a lower limit for sustained low flows during dry years. The January to April 8,000-cfs flow was established to mimic a seasonal rise in low flow levels that is characteristic of the Savannah even during the driest of years.

Final day adjustment to these recommendations included adding a condition to maintain instantaneous flows at not less that 5,000-cfs at any time of the year.

Average Years

Recommendations of monthly low flows during average precipitation years are presented in the table below and were based on the median monthly flows for the gauged record at Clyo, 1968-1997. This gauged record reflects regulated conditions. Seasonal variations in the gauged monthly medians were included in the recommended regime to emphasize the natural shape of Savannah River flows. By using medians in lieu of a more specific representation of base flow, these recommendations are likely higher that natural base flows and should have a restorative influence on select portions of the system such as freshwater tidal marshes and processes that are sensitive to high salinity.

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept
8,100	9,400	9,400	12,000	15,500	16,300	13,600	9,500	9,200	8,500	8,600	8,300

Final day recommendations included modifying these targets to a set median monthly baseflow level of 8,000-cfs. This lack of variation in the low flow recommendations was considered acceptable, as the high pulse targets presented in the unified flow prescription should effectively generate ecologically important fluctuations across the months. A condition was also added to the recommendation to maintain the instantaneous flow at not less than 6,000-cfs.

Wet Years

Wet year recommendations for monthly minimum flows were 10,000-cfs from May through December and 20,000-cfs from January through April, based roughly on average 75% nonexceedance flows at Clyo, (years?). The ecological benefits in the estuary associated with these wet year low flows include a more extensive seed dispersal across the freshwater tidal marsh, increased invertebrate productivity, greater nutrient cycling, enhanced conditions for select species (e.g., striped bass, American eel, sturgeon, southern flounder, striped mullet) and life stages (e.g., striped bass spawning), and a "push-back" of the salt water gradient to support different fish assemblages across space as compared to dry and average years.

Final day recommendations included modifying these targets to a set median monthly baseflow level of 10,000-cfs. The removal of the February-April 20,000-cfs is expected to be recovered by the larger and greater number of high pulse targets presented in the unified flow prescription. A condition was also added to the recommendation to maintain the flow at not less than 6,000-cfs.

High Pulse Recommendations

All Years

The recommendations for high pulses were limited to one per year and were defined as having peaks of 12,000-cfs, 16,000-cfs, and 30,000-cfs for dry, average, and wet years, respectively. Each of these pulses was defined as having a 2-week duration and confined to the March 15 to May 15 time period, with the month of April noted as the preferred window. These flow recommendations were made considering both the roles that high pulses naturally play in maintaining the health of the estuarine system as well as their role in mitigating the impacts of harbor deepening. Also, additional pulses -- especially during the summer months -- were not defined by the Estuary Group, as it was recognized that characteristic summer/fall storms often occur on the coastal plain below Thurmond Dam thereby generating high pulses outside management control.

Ecological benefits associated with the recommended high pulses include a "freshening" of the tidal freshwater marsh that encompasses freshwater inputs at the beginning of the growing season (April), nutrient inputs, and increased seed dispersal. The recommended level and two-week duration of high pulses also were defined to enhance conditions for striped bass spawning (suspension and transport of eggs). Further, periodic pulses of freshwater are known to act as effective controls of oyster and blue crab parasites. Specifically, oyster drill is intolerant of salinity levels below 8-10 ppt, whereas oysters themselves are tolerant of these conditions especially in cooler temperatures and for periods up to two weeks. The Estuary Group was not in a position to quantify the flows that result in a salinity of 8-10 ppt at critical oyster bed locations (river mouth up to U.S. Route 17). However, it was noted that the Georgia Port Authority is developing a hydrodynamic model (due in August 2003) that will allow this to be done. The recommendations presented here should be modified once this modeling is complete so that flow requirements for parasite control in oysters and blue crab can be explicitly incorporated.

One concern was raised regarding the delivery of high pulses to the estuary in the absence of the extensive wetland system that was historically present in the Savannah. Without these wetlands, sharp pulses manifest themselves abruptly in the estuary resulting in a "shocking" of the system due to rapid salinity fluctuations. This can be avoided by controlling the rise/fall rate of constructed high pulses from Thurmond Dam.

Flood Flow Recommendations

All Years

A single flood flow peaking at least at 50,000-cfs was recommended for one in five years (20% of the years over an extended duration such as one to two decades). Floods should not occur during dry years. The recommended time period for these flood flows was between February and the end of April, with a duration of four weeks. These flood flow events perform a number of ecologically important functions in the estuary, including sediment replenishment; nutrient and productivity boost for near-shore marine fishes; species mixing; turbidity protection for young fish; freshwater, sediment, and nutrient replenishment of the freshwater tidal marsh; and improved habitat and forage for bird species.