Appendix F

Aquifer Pumping Test Calculation

Technical Task Cover Sheet

Discipline: Hydrogeology

Project:
UMTRA Ground Water

Site:
Green River, Utah

Subject:
Green River Aquifer Test Data Analyses

Sources of Data:

Bouwer, H. and R.C. Rice, 1976, "A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells," *Water Resources Research*, v. 12, p. 423-428.

Bouwer, H., "The Bouwer and Rice slug test – an update," *Ground Water*, 27(3), 304, 1989.

Black, J H, 1978, "The use of the slug test in groundwater investigations," *Water Services*, March, p. 174-178.

Environmental Simulations, Inc., 1999. "Guide to Using Aquifer Win32," Version 2.17.

Hvorslev, M.J., 1951, "Time lag and soil permeability in ground water observations," U.S. Army Corps of Engineers Waterway Experimentation Station, Bulletin 36.

Kruseman, G.P., and DeRidder, N.A., 1991. *Analysis and Evaluation of Pumping Test Data, International Institute for Land Reclamation and Improvement*, 2nd Edition, Wageningen, The Netherlands.

Moench, A.F.,1984, "Double-porosity models for a fissured groundwater reservoir with fracture skin," *Water Resources Research*, vol. 20, no. 7, pp. 831-846.

Theis, C.V., 1935. "The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground water storage," *Am. Geophys. Union Trans.*, Vol. 16, pp. 519-524.

USDOE, 1995, *Aquifer Test Analysis of Well 173*, Calculation Set No. GRN01/8-95/14-03/00.

Task Order No. ST02-109 File Index No. GWGRN 13.2

Proj. No. UGW-511-0009-10-000 Calc. No. U0174200 Supersedes Calc. No. NA

Calculated by	Date	Checked by	Date	Approved by	Date	DOE Concurrence (if required)	Date

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1.0 Introduction

Aquifer and slug tests were completed at the Green River Uranium Mill Tailings Remedial Action (UMTRA) Project site to collect the hydrogeologic data necessary to characterize the Browns Wash alluvial aquifer and the middle sandstone unit of the Cedar Mountain Formation. These data were collected to provide a range of the transmissivity and hydraulic conductivity of both the alluvial and Cedar Mountain middle sandstone aquifers, and the specific storage of the middle sandstone aquifer.

The alluvial aquifer consists of a mixture of silt, sand, gravel, and small cobbles, and ranges in thickness from 0 to 35 feet (ft). Saturated thickness during the testing period (July 2002) ranged from 0 to 3 ft, with the maximum thickness near Browns Wash.

The middle sandstone unit of the Cedar Mountain Formation consists predominately of coarse-grained sandstone with minor amounts of siltstone and conglomerate, and ranges in thickness from 15 to 30 ft in the vicinity of the site. Wells installed in this formation that were used for this investigation are generally screened from approximately 75 to 90 ft below ground surface (bgs). This unit is confined with a saturated thickness of approximately 19 ft.

2.0 Previous Testing

An aquifer test at well 0173 designed to evaluate the sustainable yield of the middle sandstone unit of the Cedar Mountain Formation was completed in October 1993. During this time the well was pumped for 72 hours at a rate of approximately 4 gallons per minute (gpm). The initial analyses of the data were completed using confined and leaky aquifer methods (Calculation Set No. GRN01-11-93-14-09-00). Subsequent analysis of the same data set (Calculation Set No. GRN01-08-95-14-03-00) estimated aquifer parameters using unconfined and confined dual porosity methods that provided a better fit between the collected data and type curves.

3.0 Test Procedures

3.1 Alluvial Aquifer

To determine the hydraulic parameters of the alluvial aquifer, both aquifer and slug tests were completed at well 0191 (Figure 1). This well was chosen because it was the only alluvial well with a sufficient saturated thickness (approximately 2 ft).

Water level responses to pumping were measured only in well 0191 as there were no observation wells located nearby. Slug tests were also performed at this location by quickly removing the water contained in the well and measuring the response. A duplicate slug test was also conducted for comparison with the initial slug test. Water level responses were measured using pressure transducers and manually with electronic sounders.

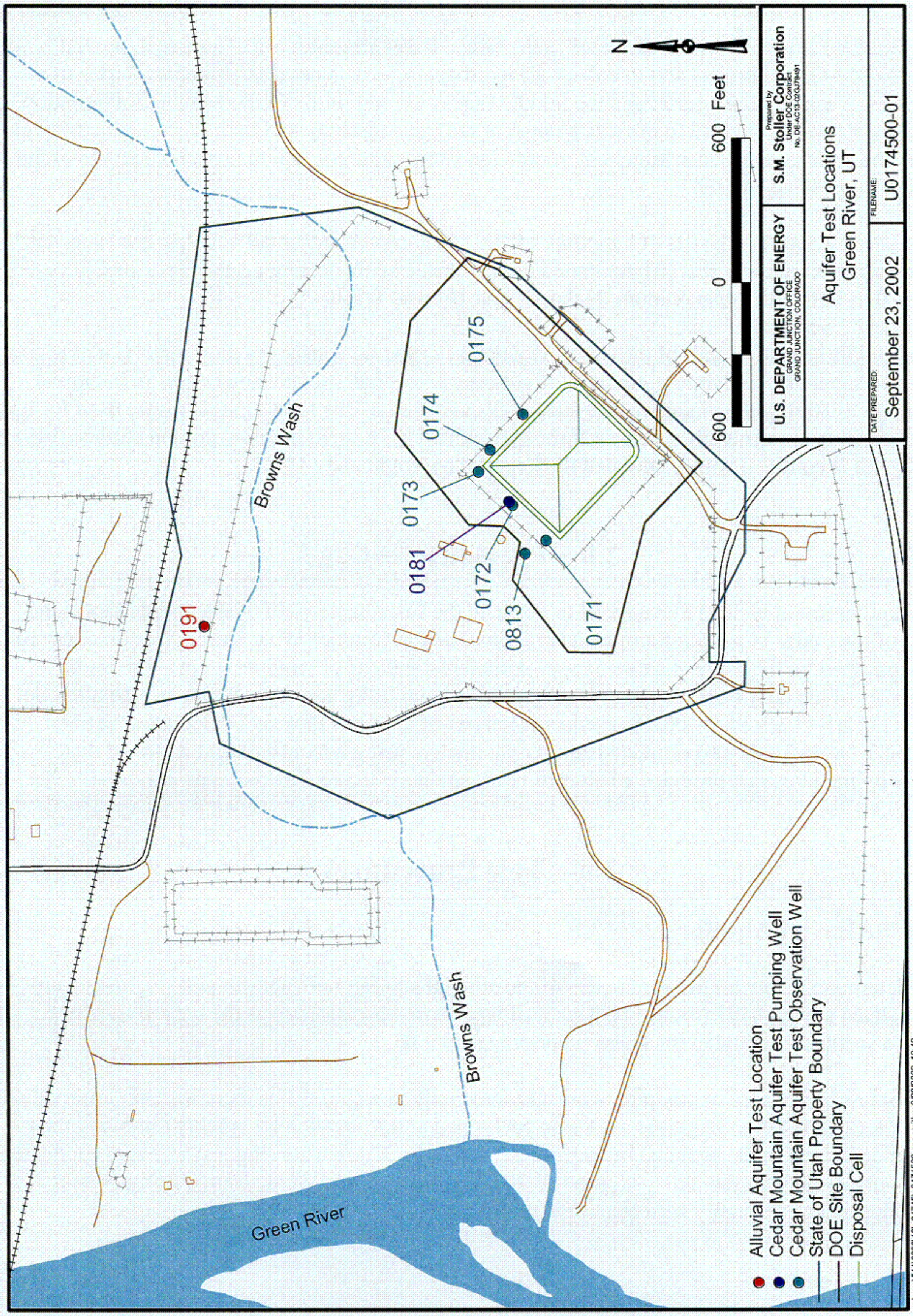

Figure 1. Aquifer Test Locations

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Drawdown and residual drawdown data collected during the aquifer and slug tests were analyzed using the software package AquiferWin32 (Environmental Simulations, Inc., Version 2.17). This package allows the user to analyze the data with a number of different analytical methods. Data collected during the slug tests were analyzed using the Bouwer and Rice (1976), Hvorslev (1951), and Black (1978) Methods. Residual drawdown data collected during the short-term aquifer test from well 0191 were analyzed using the Theis (1935) Recovery Method.

3.2 Cedar Mountain Formation Middle Sandstone Unit

An aquifer test designed to characterize the Cedar Mountain Formation Middle Sandstone Unit was conducted using newly installed well 0181, located 18.7 ft northeast of well 0172. In addition to monitoring water level response in wells 0181 and 0172, water level data were collected from wells 0171, 0173, and 0174. Water levels in wells 0175 and 0813 were measured to monitor background fluctuations (Figure 1).

This test was initially designed to run for 72 hours; however, well 0181 did not sustain the pump rate dictated by the step-drawdown test at this well. As a result, both a 3-hour (Test 1) and a 52-hour (Test 2) aquifer test were performed at this location.

All water level responses were measured using pressure transducers and manually with electronic sounders. Ground water generated from each test was discharged a minimum of 100 ft from the pumping well and observation wells. Table 1 lists the well construction details for the pumping and observation wells associated with these tests.

Table 1. Well Construction Details for the Cedar Mountain Middle Sandstone Unit Aquifer Test

	Well						
	0181	0171	0172	0173	0174	0175	0813
Distance from pumping well 0181 (ft)	na	220	18.7	175	230	360	220
Elevation (ft msl) of top of middle sandstone unit	4,059	4,072	4,063	4,051	4,065	4,084	4,072
Elevation (ft msl) of bottom of middle sandstone unit	4,047	4,051	4,045	4,038	4,056	4,052	4,045
Top of screen elevation (ft msl)	4,061	4,061	4,054	4,046	4,067	4,062	4,056
Bottom of screen elevation (ft msl)	4,046	4,051	4,044	4,036	4,057	4,052	4,036

Drawdown and residual drawdown data collected during the aquifer tests were analyzed using AquiferWin32. Drawdown data collected were analyzed using the Moench (1984) Method for fractured aquifers, while residual drawdown data were analyzed using the Theis (1935) Recovery Method.

4.0 Results

4.1 Alluvial Aquifer Tests—Well 0191

The short-term aquifer test at well 0191 was completed on July 11, 2002, using a pumping rate ranging from 0.9 to 1.3 gpm. After 3.5 hours of pumping, the pump was shut off and residual drawdown data were collected from the well. The water level returned to static level within 15 minutes. Two slug tests were then conducted. The pump was set to its maximum discharge rate (~5 gpm) to evacuate the well as quickly as possible. After less than 30 seconds of pumping, water in the well was completely removed and the recovery monitored. Once the water level returned to static level, a duplicate slug test was conducted.

A number of assumptions were made in order to analyze the residual drawdown data collected during the short-term aquifer test. These include:

- The well is pumped at a constant rate. (Flow rates fluctuated between 0.9 and 1.3 gpm during the pumping phase).
- The pumping well is of infinitesimal diameter, and fully penetrates the aquifer.
- The aquifer is unconfined (This assumption is only applicable to late-time drawdown data).
- Discharge from the well is derived exclusively from aquifer storage.

Assumptions were also made in order to complete the analysis of the data collected during the slug tests. These include:

- The volume of water discharged from the well occurs instantaneously at time t = 0. (The pump used to remove the water from the well is set at a substantially high flow rate to instantly remove the water.)
- The discharging well is of finite diameter and fully penetrates the aquifer.
- The length of the well screen is significantly larger than the diameter of the well. (The diameter of well 0191 is 0.33 ft, while the well screen is 5 ft long.)

Table 2 presents analysis results from tests conducted at well 0191 in the alluvial aquifer. The recovery test data from the short-term aquifer test provides an estimate of aquifer transmissivity, while the slug test analyses provide hydraulic conductivity estimates.

Table 2. Analysis Results from the Alluvial Aquifer Short-Term Aquifer Test and Slug Tests

Test Number	Aquifer Test Analysis		Slug Test Analysis		
	Theis Recovery		Bouwer and Rice	Hvorslev	Black
	T (ft^2/day)	K (ft/day)	K (ft/day)	K (ft/day)	K (ft/day)
0191 Aq Test 1	86.7	43 4	na	na	na
0191 Slug Test 1	na	na	24 5	27 4	25.5
0191 Slug Test 2	na	na	22 4	29 6	25.1

Notes: na = not applicable
K = Hydraulic Conductivity (based on a saturated thickness of 2 ft)
T = Transmissivity

Using a saturated thickness of 2 ft, the hydraulic conductivity derived from the short-term aquifer test is 43.4 ft/day. An aquifer test will typically influence a larger area of the aquifer compared to a slug test, and may provide a more representative hydraulic conductivity estimate. The plots associated with the aquifer and slug tests are in Appendix A.

It is possible that the weathered Mancos Shale underlying the alluvium influences hydraulic conductivity estimates for the alluvium. According to the boring log, the contact between the alluvium and underlying bedrock was encountered at a depth of approximately 15 ft bgs. The static ground water level during the test was encountered at approximately the same depth, suggesting that for well 0191 the tests may have been representative of hydraulic conductivity of both units.

Table 3 provides estimated sustainable flow rates for other wells completed in the alluvial aquifer based on well development data. As the table shows, the sustainable pumping rate associated with well 0191 is almost two orders of magnitude higher compared to the other three wells completed in the alluvium, further suggesting the sustainable flow rate associated with well 0191 is not indicative of the entire alluvial aquifer.

Table 3. Sustainable Pumping Rates for Wells Completed Within the Alluvial Aquifer Based on Well Development Data

Well No.	Sustainable pumping rate (gpm)
0191	~ 1.0
0189	0.035
0188	0.004
0194	0 0016

Note: Alluvial wells 0186, 0190, and 0193 were dry during the timeframe that development was completed

4.2 Cedar Mountain Formation Middle Sandstone Unit Aquifer Tests—Well 0181

A step-drawdown test was completed at well 0181 on July 8, 2002, using flow rates of 1 and 2 gpm. The response to pumping indicated the well could not sustain a flow rate of 2 gpm. In order to maximize drawdown in the pumping and observation wells, an aquifer test was started at well 0181 on July 9, 2002. The constant pumping rate was 1.5 gpm. After 3 hours of pumping, it was apparent that the well could not sustain this rate over the desired 72-hour time period. Consequently, the pump was shut off and recovery data were collected from the pumping well only since none of the observation wells significantly responded to the short pumping period. On July 10, a second 52-hour test was performed using a rate 1 gpm.

Drawdown measured in well 0181 and at each observation well at the conclusion of Test 2 is presented in Table 4. Observation well locations are shown on Figure 1.

Table 4. Drawdown Measured in Response to Pumping From Well 0181

	Well						
	0181	0171	0172	0173	0174	0175	0813
Distance from pumping well 0181 (ft)	na	220	18.7	175	230	360	220
Drawdown after pumping well 0181 for 52 hours at 1 gpm	19 1	0 13	0 69	0.44	0 45	0 0	0.16

As this table indicates, drawdown in wells 0171, 0173, 0174, 0175, and 0813 was less than 0.5 ft. Data collected from a background well indicated that barometric pressure changes caused water level fluctuations of approximately 0.2 ft during the test (Section 5.0). Consequently, the drawdown data collected from the observation wells were not analyzed.

Drawdown data from observation well 0172 resulted in a plot representative of either a delayed yield response or a dual porosity medium (i.e., fracture flow). Field conditions observed in the sandstone suggested the response was caused by dual porosity phenomena.

A number of simplifying assumptions were made so that drawdown data in well 0181 could be used to estimate the aquifer parameters. These assumptions include:

- The well is pumped at a constant rate. (The pump discharge during the 52-hour test ranged from 0.95 to 1.04 gpm, which is assumed to be sufficiently small to have no impact on the test analysis.)
- The pumping well fully penetrates the aquifer. (Based on the boring log for well 0181, the sandstone unit is 12.5 ft thick and occurs from 79 to 91.5 ft bgs. This entire unit is contained within the screened interval. Although this well is considered fully penetrating, the actual saturated thickness is subject to interpretation. For the analysis, a saturated thickness of 19 ft was used, which is the average thickness of the sandstone unit in wells 0171, 0172, 0173, 0174, 0175, 0181, and 0813.)
- The aquifer is fully confined. (Depth to water measurements are approximately 60 ft bgs, while the screened interval ranges from 77 to 92 ft bgs. The difference between elevations of the water bearing zone and the measured water level suggests the sandstone unit is confined. In addition, the water level response to barometric pressure changes in background wells also suggests that the aquifer is confined.)
- The discharge from the well is derived exclusively from aquifer storage. (The low specific storage estimated from this test is consistent with this assumption.)
- The sandstone aquifer can be represented by a fractured, dual porosity system consisting of low-permeability, primary porosity blocks and high-permeability, secondary porosity fissures. (Analysis of the data collected during this test indicates the dual-porosity model is representative of the aquifer.)
- The aquifer matrix consists of slab or spherical blocks. (Some required inputs for the Moench Method were not measured during this field investigation; therefore, these inputs were based on previous test analyses. These inputs included the matrix configuration [slab as opposed to spherical blocks], well bore skin [set equal to 0], fracture skin [set between 0.9 and 3.1] and fracture block thickness [set equal to 5 ft].)

Table 5 presents results from analysis of the data collected during the two tests. Residual drawdown data measured in well 0181 from both tests were analyzed to estimate aquifer transmissivity. Drawdown measured at observation well 0172 was too small to warrant analysis. Plots associated with the tests are contained in Appendix B.

Table 5. Analysis Results for the Cedar Mountain Formation Middle Sandstone Unit Aquifer Tests

Well / Test No.	Fracture Parameters		Aquifer Matrix Parameters		Theis Recovery	
	K (ft/day)	Ss (ft^{-1})	K (ft/day)	Ss (ft^{-1})	T (ft^2/day)	K (ft/day)
0181 / 1	na	na	na	na	2.6	0.14
0181 / 2	na	na	na	na	3.1	0.16
0172 / 2	2.4	6.9×10^{-4}	9.0×10^{-2}	3.5×10^{-2}	58.9	3.1

Notes: na = not applicable
K = Hydraulic Conductivity (based on saturated thickness of 19 ft)
Ss = Specific Storage
T = Transmissivity

Hydraulic conductivity estimates for aquifer fractures fall within the range estimated from the previous (October 1993) test (0.4 to 13 ft/day). Estimates of fracture specific storage were larger than the high end of the range (9.2×10^{-8} to 5.5×10^{-6} ft^{-1}) derived for this parameter in the previous test. The aquifer matrix hydraulic conductivity and specific storage estimates were both above the high end of the range calculated by the previous tests (1×10^{-4} to 3.3×10^{-3} ft/day and 1.8×10^{-5} to 2.0×10^{-4} ft^{-1}, respectively).

Analysis of the residual drawdown data from the pumping well in both tests produces similar transmissivity estimates (from 2.6 to 3.1 ft^2/day). However, the result of the residual drawdown data analysis for observation well 0172 indicates the transmissivity is 58.9 ft^2/day. The analysis of residual drawdown data produces an estimate of the combined hydraulic conductivity of fractures and matrix, and does not distinguish between fracture and aquifer matrix parameters. On the basis of all estimates of aquifer transmissivity, and using a saturated thickness of 19 ft, the hydraulic conductivity of the middle sandstone unit ranges from 0.14 to 3.1 ft/day.

5.0 Background Monitoring

Water level data collected from well 0813 were used to measure the background fluctuations of the potentiometric surface during the test. This data set is presented as Figure 2, which also presents the barometric pressure fluctuations. As the plot shows, the background ground water level fluctuates approximately 0.2 ft in response to the changes in the barometric pressure.

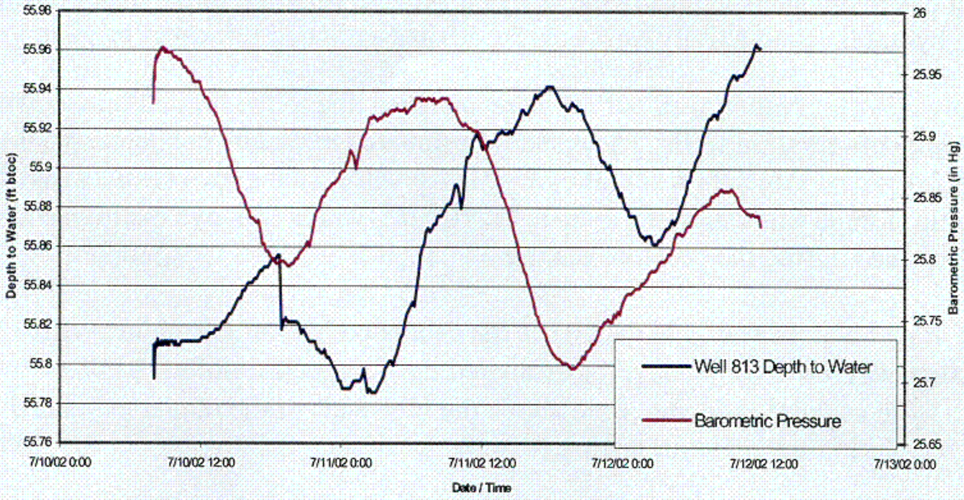

Figure 2. Temporal Changes in Barometric Pressure Changes and Well 0813 Water Levels

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6.0 Conclusions / Discussion

6.1 Alluvial Aquifer

The following conclusions can be made based on the data collected from the alluvial aquifer hydrogeologic investigation at the Green River site:

- The saturated thickness of the alluvial aquifer was possibly limited as result of the drought conditions during the investigation.

- Residual drawdown data collected during the short-term aquifer test suggests the transmissivity of the alluvial aquifer is 86.7 ft^2/day. Using a saturated thickness of 2 ft, the estimated hydraulic conductivity is 43.4 ft/day.

- Analysis of slug test data from well 0191 indicates the hydraulic conductivity of the alluvium ranges from 22.4 to 29.6 ft/day.

- The hydraulic conductivity estimate based on drawdown data from well 0191 is the largest of all hydraulic conductivity estimates for the alluvial aquifer. During development of other wells screened within the alluvial aquifer, it was estimated that these wells have sustainable pumping rates ranging from 0.0016 to 0.035 gpm. The weathered Mancos Shale unit underlying the alluvium at well 0191 may be the main contributor of ground water flow into the well. Approximately 2 ft of the screened interval for this well is within this weathered zone.

6.2 Cedar Mountain Formation Middle Sandstone Unit Aquifer

The following summary and conclusions are derived from data collected during the Cedar Mountain Formation aquifer hydrogeologic investigation at the Green River site:

- The field conditions and the plot of the drawdown data collected from observation well 0172 suggested the response to pumping from well 0181 was caused by dual porosity phenomena. As a result, all data were analyzed using the Moench Method for a fractured, dual porosity medium, with hydraulic conductivity estimates based on a saturated thickness of 19 ft.

- Data from only one observation well (0172) were analyzed due to the limited drawdown measured in other observation wells. The resulting estimated hydraulic conductivity of the fractures was 2.4 ft/day, which is within the range established during the previous test. The fracture specific storage was estimated to be 6.9×10^{-4} ft^{-1}, which is above the high end of the range established during the previous testing.

- Based on the drawdown measured in well 0172 the estimated hydraulic conductivity of the sandstone matrix was 9.0×10^{-2} ft/day; the estimated matrix specific storage was 3.5×10^{-2} ft^{-1}. Both of these estimates were above the high ends of the ranges estimated for these parameters during the previous testing.

- The estimated hydraulic conductivity of the fractures was significantly larger than the estimated hydraulic conductivity of the matrix, whereas the estimated specific storage of the matrix was significantly larger than the estimated specific storage of the fractures. Such a response is typically encountered in an aquifer associated with fractured, dual porosity media.

- Analyses of recovery data indicated the combined hydraulic conductivity of the fractures and matrix ranged from 0.14 to 3.1 ft/day.

- The sustainable pumping rate for well 0181 is 1 gpm, whereas a pumping rate of 4 gpm was sustained in well 0173 during the previous test completed in October 1993. This difference in the flow rates may explain the difference between analysis results from the two tests. It is possible the fracture system in the vicinity of well 0173 is more extensive and/or more conductive than the fracture system associated with well 0181.

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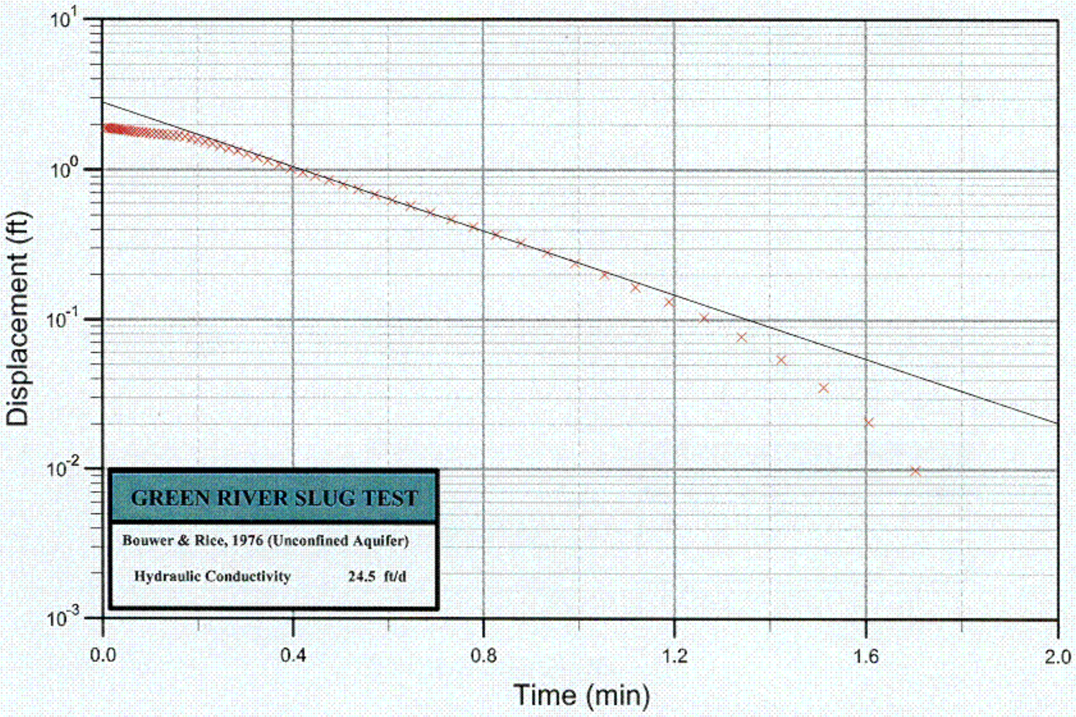
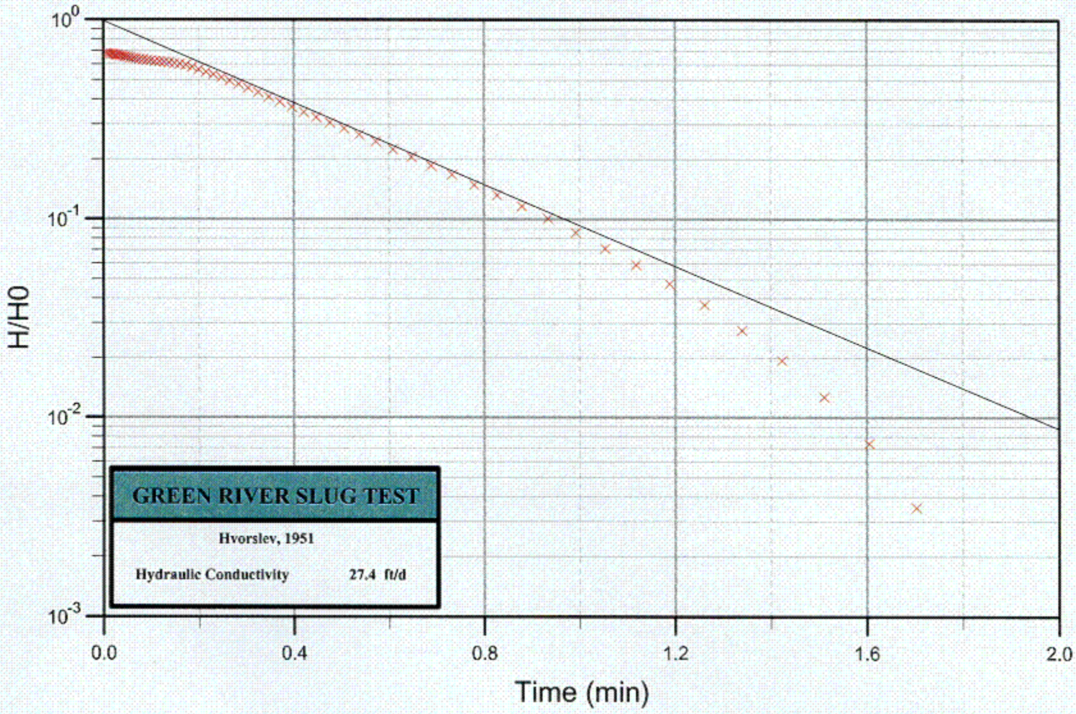
Appendix A

Browns Wash (Alluvial Aquifer) Slug and Aquifer Test Plots

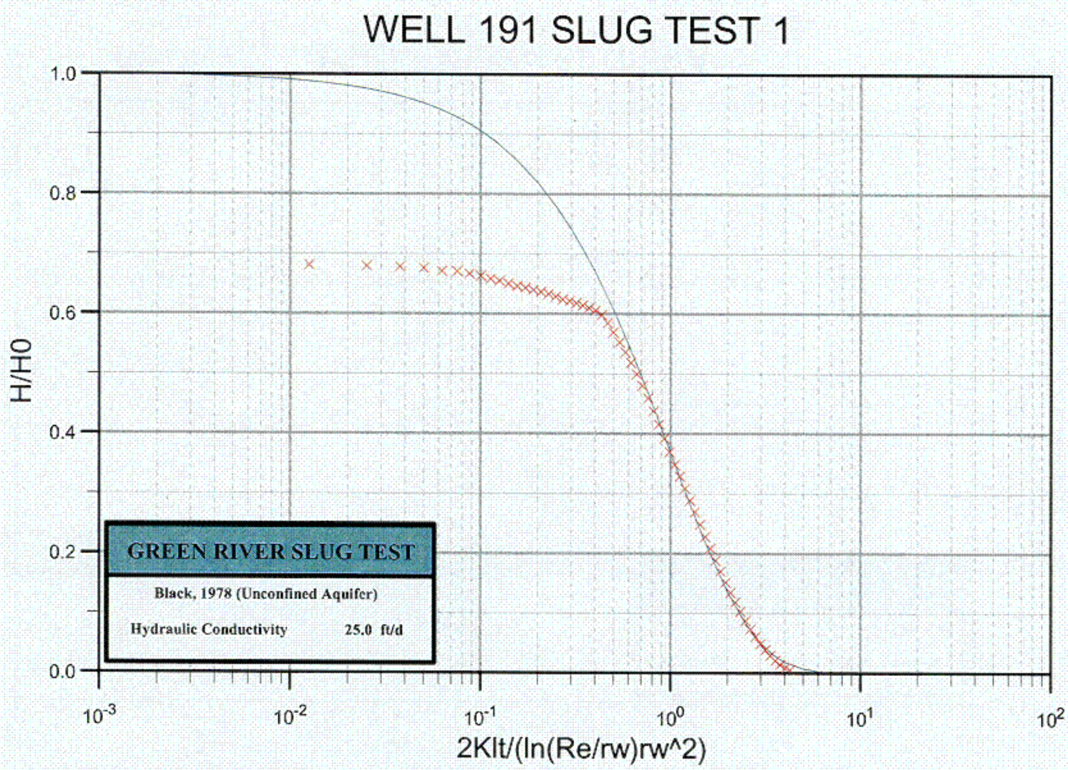
WELL 191 SLUG TEST 1



WELL 191 SLUG TEST 1



CO3


WELL 191 SLUG TEST 1
H/H0
2Klt/(ln(Re/rw)rw^2)
GREEN RIVER SLUG TEST
Black, 1978 (Unconfined Aquifer)
Hydraulic Conductivity 25.0 ft/d

C04

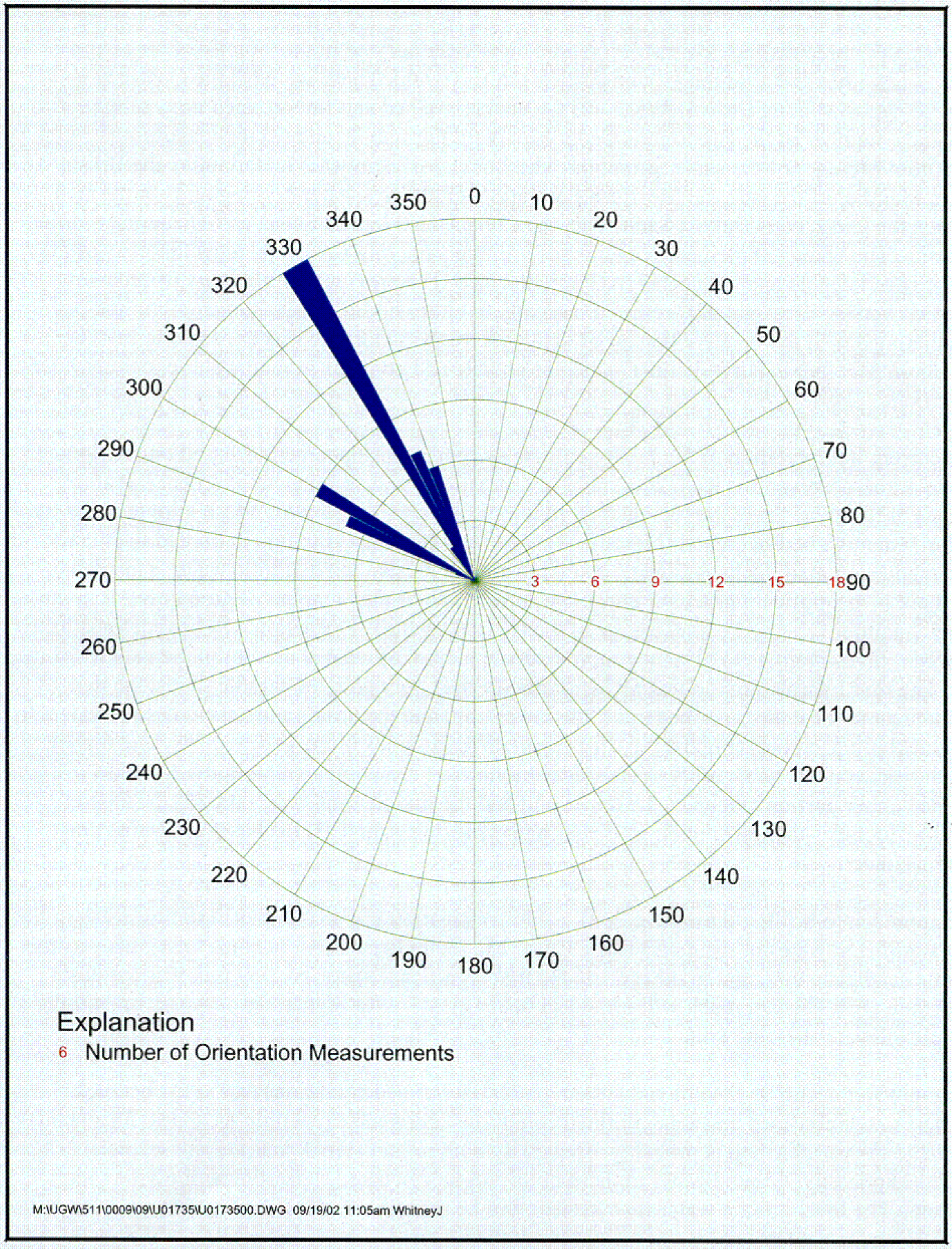


Figure 5–6. Orientation of Fracturing and Joints at the Green River Site

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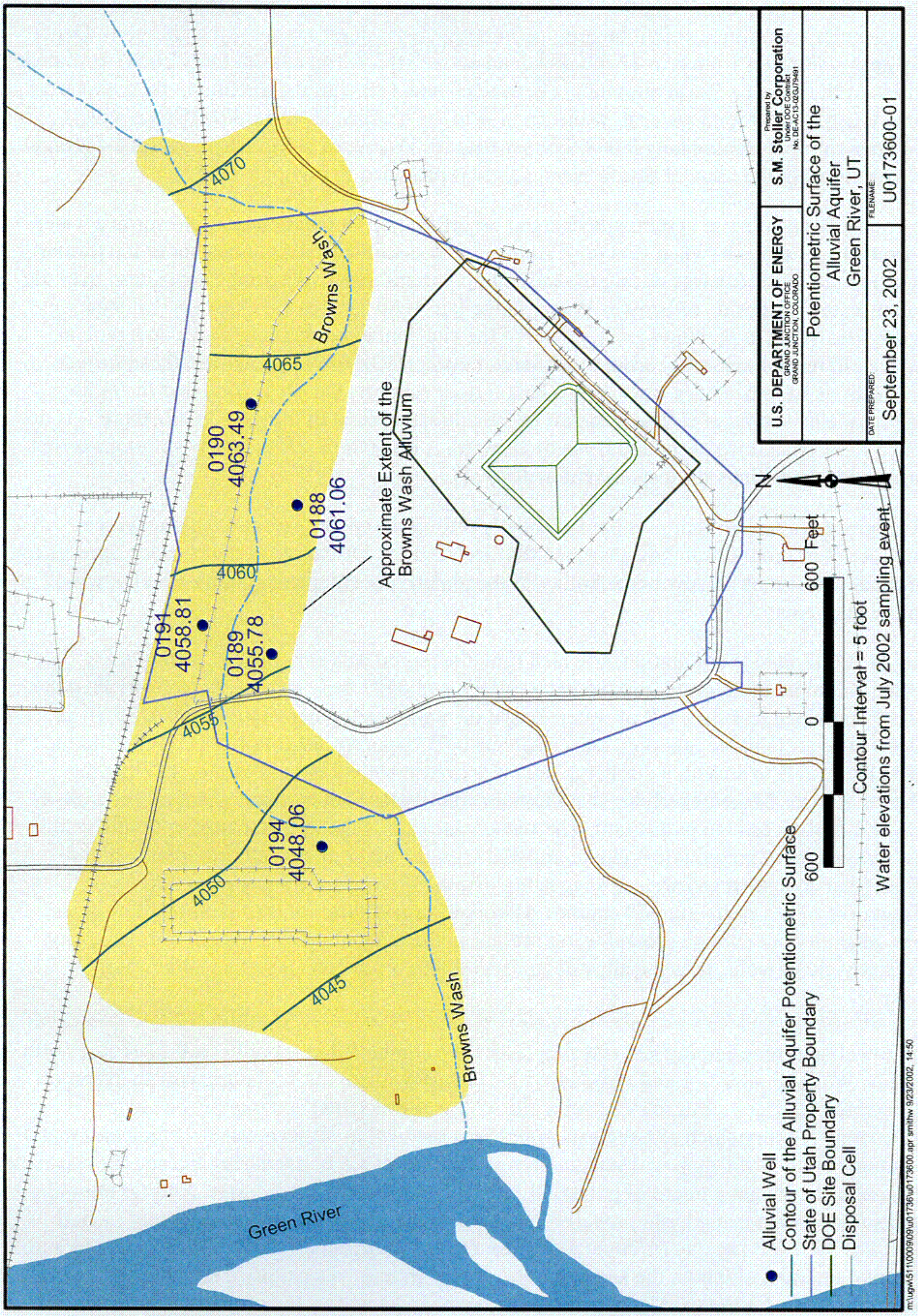

Figure 5–7. Potentiometric Surface of the Alluvial Aquifer at the Green River Site

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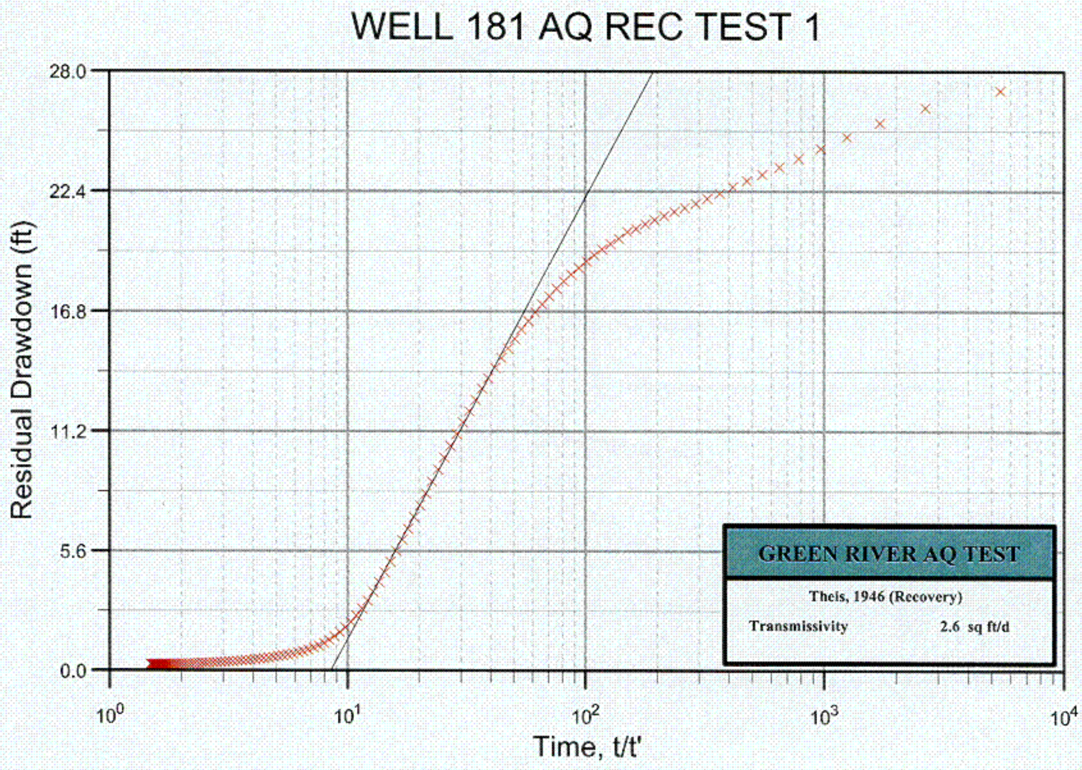
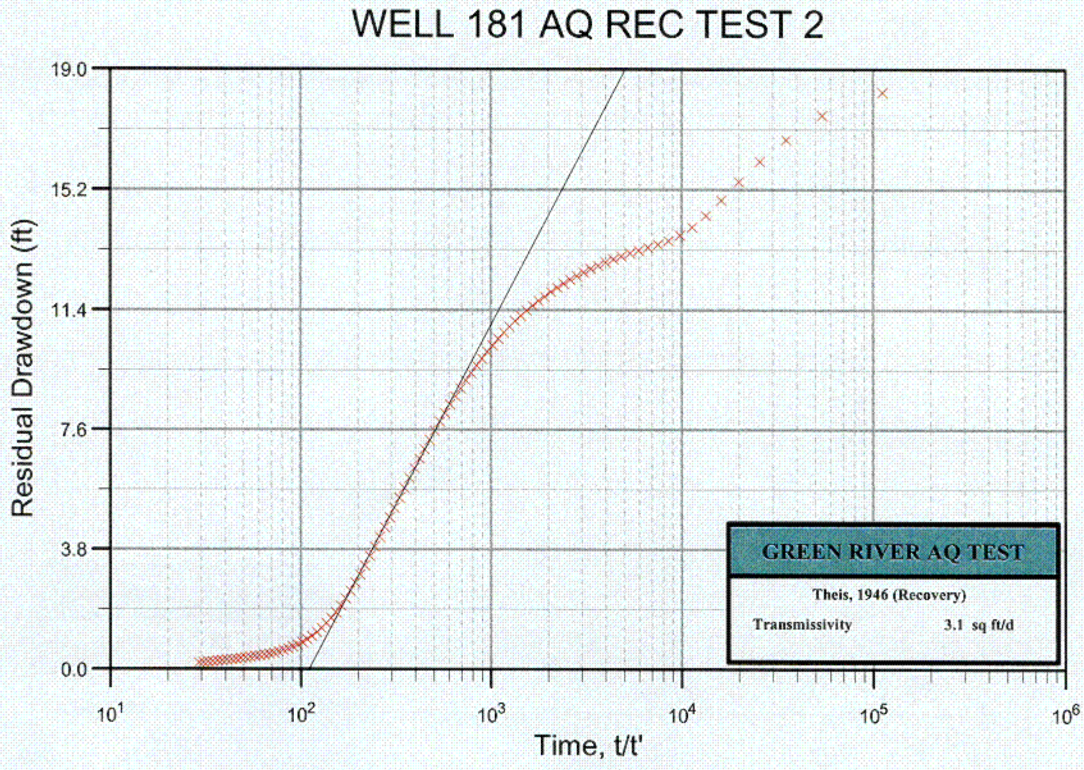
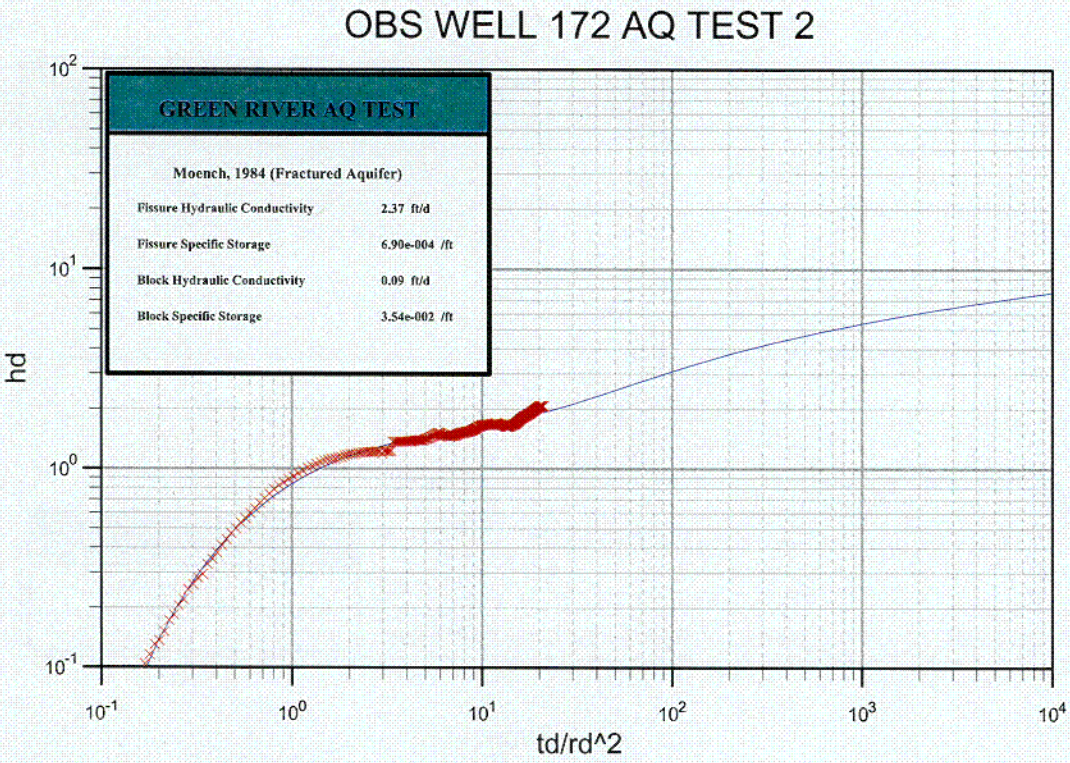
Appendix B

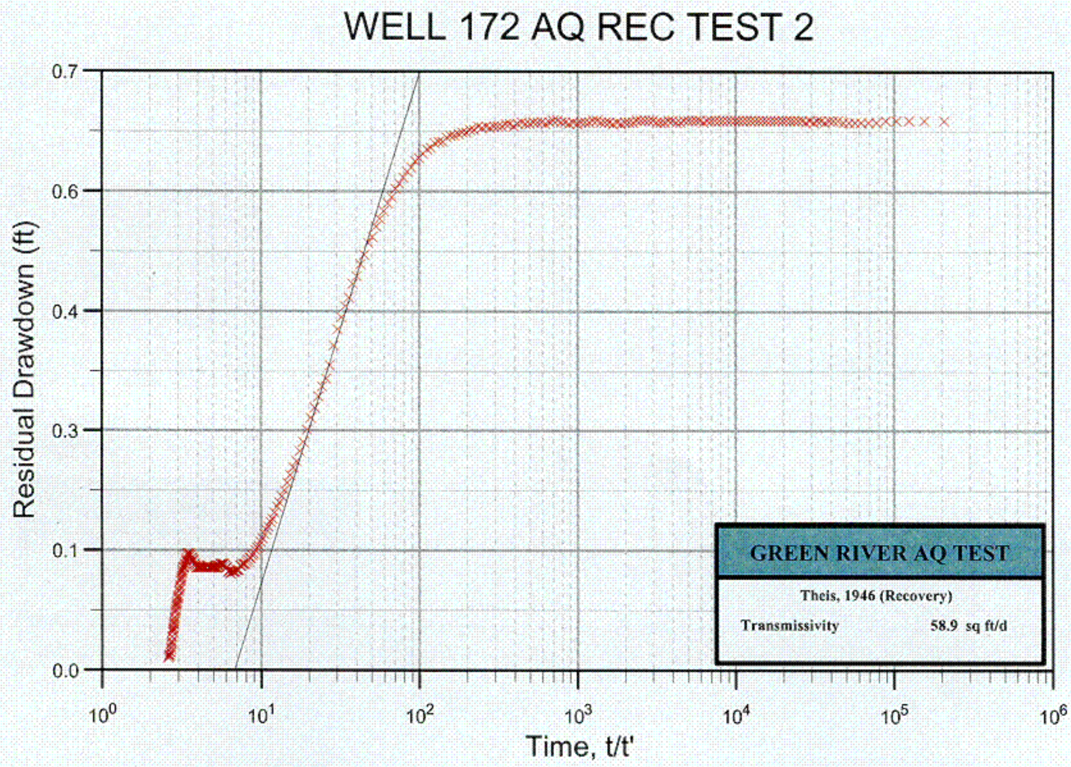
Cedar Mountain Formation (Middle Sandstone Unit)
Aquifer Test Plots


WELL 181 AQ REC TEST 1
Residual Drawdown (ft)
28.0
22.4
16.8
11.2
5.6
0.0
Time, t/t'
10^0
10^1
10^2
10^3
10^4
GREEN RIVER AQ TEST
Theis, 1946 (Recovery)
Transmissivity 2.6 sq ft/d


WELL 181 AQ REC TEST 2
Residual Drawdown (ft)
19.0
15.2
11.4
7.6
3.8
0.0
Time, t/t'
10^1
10^2
10^3
10^4
10^5
10^6
GREEN RIVER AQ TEST
Theis, 1946 (Recovery)
Transmissivity 3.1 sq ft/d

C07


OBS WELL 172 AQ TEST 2
GREEN RIVER AQ TEST
Moench, 1984 (Fractured Aquifer)
Fissure Hydraulic Conductivity 2.37 ft/d
Fissure Specific Storage 6.90e-004 /ft
Block Hydraulic Conductivity 0.09 ft/d
Block Specific Storage 3.54e-002 /ft
hd
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
td/rd^2


WELL 172 AQ REC TEST 2
Residual Drawdown (ft)
0.7
0.6
0.4
0.3
0.1
0.0
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
Time, t/t'
GREEN RIVER AQ TEST
Theis, 1946 (Recovery)
Transmissivity 58.9 sq ft/d

C08

Appendix G

Ecological Risk Assessment

1.0 Ecological Risk Assessment

This Appendix supplements and provides details to Section 6.2.2 of the document. Some information within the text of the document has also been included in this Appendix to accurately reflect context. As shown in Figure 1, the framework of the ecological risk assessment (ERA) contains three main components: (1) problem formulation, (2) analysis, and (3) risk characterization. The overall goal of the problem formulation is to "set the stage" for the analysis and risk characterization phases of the process. In the problem formulation, the need for a risk assessment is identified and the scope of the problem is defined. Available data are evaluated to identify potential stressors (in this case, the potential stressors are ecological constituents of potential concern [E-COPCs] associated with the ground water at the Green River processing site), key ecological receptors, and potential exposure pathways linking the receptors to the stressors. This information is used to develop a site conceptual model and risk hypotheses. Finally, assessment and measurement endpoints are defined for the specific determination of risk to these receptors and the environmental resources they represent. These endpoints are directly tied to overall management goals for the site.

The analysis phase of the ERA includes two concurrent steps—the exposure assessment and the effects characterization. In the exposure assessment, the potential for each receptor to be exposed to each stressor is evaluated and, where possible, quantified. The effects characterization describes the potential for the stressor to adversely affect the receptors that are exposed to it. Because the stressors at the Green River site are chemical in nature, the principal effects to ecological receptors will be toxicological; however, they may also include physical effects, such as those related to radiation.

The risk characterization phase evaluates (either qualitatively or quantitatively) the combined results of the exposure assessment and effects characterization to determine the potential for risk to the receptors due to their exposure to the stressors. A critical aspect of the risk characterization is the analysis of uncertainties associated with predictions of potential risk. Typically, uncertainties result from data gaps, which necessitate the incorporation of assumptions into the analysis and risk characterization phases. In general, these assumptions are conservatively biased toward results that will lead to overestimations rather than underestimations of risk. The uncertainty analysis provides an analysis of these assumptions in terms of their potential for introducing significant bias in the risk estimation.

As described in the U.S. Environmental Protection Agency (EPA) guidance (EPA 1998), ERA is an iterative process in which the evaluation of potential risks to ecological receptors is refined as additional data are collected to fill data gaps and reduce uncertainties. At the conclusion of each iteration (or "tier") in the process, decisions are made as to whether sufficient data have been collected and analyzed to proceed with risk management actions (if required), or whether additional data should be collected. Such a tiered approach to the process was initiated at the Green River site in 1995 by the performance of the screening-level baseline risk assessment (BLRA) (DOE 1995).

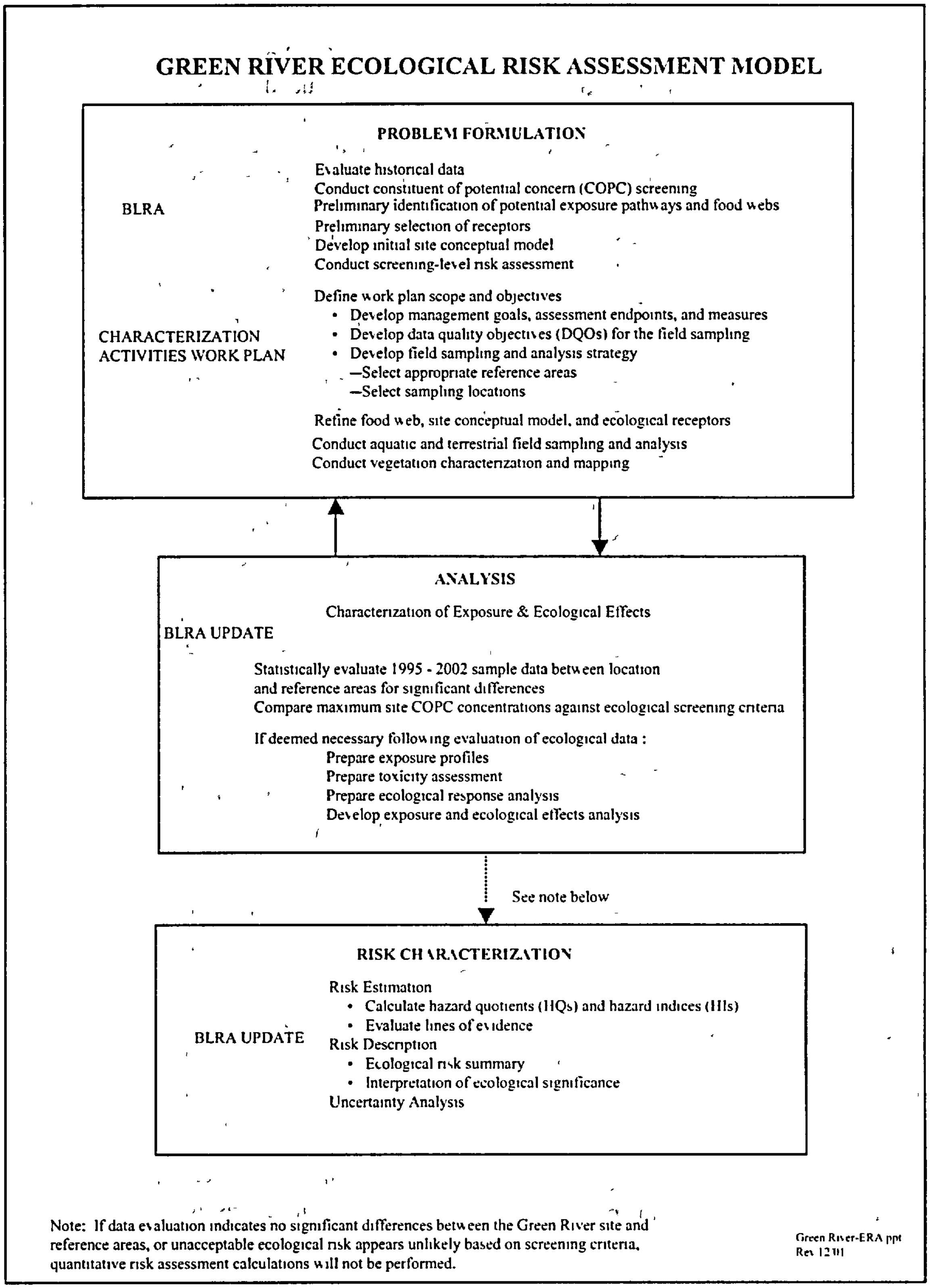


Figure 1. Ecological Risk Model for the Green River Site

Subsequently, additional data was collected from key environmental media. The ERA incorporates these new data as a refinement and update of the screening-level assessment presented in the BLRA. Additional sampling of ground water and surface water (from Browns Wash and the Green River) and sediments for chemical analysis was conducted between 1994 and 2002.

2.0 Problem Formulation

The problem formulation phase in this risk assessment is represented in part by the information presented in the BLRA (DOE 1995). The BLRA was based on analytical data collected at the Green River site prior to 1995. These data were reviewed to determine if concentrations of analytes in ground water, surface water, and sediment may pose a potential ecological risk. Information on the geologic setting, ground water hydrology, geochemistry, and habitats of the site were incorporated in the BLRA evaluation. Principal results of the BLRA included an initial screening of chemical analytes as E-COPCs and an assessment of potential risk to biota, including livestock and irrigated crops. The assessment of potential risk, however, was primarily qualitative. The BLRA provided, in part, a basis for the preparation of this work plan. Since the completion of the BLRA, additional ground water and surface water samples were collected. These new analytical data are included in this update.

Potentially Affected Habitats and Population

The Green River processing site is highly disturbed from past use and subsequent remediation activities. These disturbed areas were revegetated with selected seed, although vegetation has not been significantly reestablished (DOE 1995). Areas adjacent to the millsite are a mix of agricultural, ranching, and limited industrial activity. Due to the site's arid environment and proximity to the city of Green River, flora and fauna species diversity is somewhat limited. The exceptions are the riparian zones along Browns Wash and the Green River to the north and west of the site, respectively. Along Browns Wash and the Green River, the habitat is a mix of riparian species dominated by tamarisk, cottonwoods, and willow. The arid areas are characterized as a salt desert scrub community dominated by shadscale, saltbush, greasewood, and rabbitbrush (DOE 1988). Although Browns Wash was evaluated in the BLRA as a potential surface water medium, it is an ephemeral stream with very limited capability for supporting an aquatic ecosystem. The exception is the mouth of Browns Wash where it empties into the Green River. This area could be considered a backwater of the Green River because of the presence of water most of the year. Its ecological significance, if any, was not discussed in the BLRA.

Few species of wildlife have been observed at the site because of the proximity to Interstate Highway 70 and other human activities. The environmental assessment (EA) lists 34 species of mammals, 18 species of raptors, 51 species of nongame birds, 23 species of reptiles, seven species of amphibians and 14 species of fish that could occur in the vicinity of the site (DOE 1988). There is no reason to believe that the species diversity has changed since the time the EA was written.

The EA also identified six endangered wildlife species protected under the Endangered Species Act as potentially occurring in the vicinity of the site. The species are the peregrine falcon (*Falco peregrinus*), bald eagle (*Haliaeetus leucociphalus*), black-footed ferret (*Mustela nigripes*), Colorado pikeminnow (*Ptychocheilus lucius*), bonytail chub (*Gila elegans*), and humpback chub (*Gila cypha*). The razorback sucker was mentioned briefly, but dismissed as not potentially occurring in the Green River area. Of the remaining species, the peregrine falcon has since been delisted, and the black-footed ferret, humpback, and bonytail chubs are not believed to currently inhabit the site area. Therefore, the Colorado pikeminnow and bald eagle are the only endangered species that will be considered further in this assessment.

Summary of the 1995 Ecological Risk Assessment Results

As a starting point for identifying E-COPCs for the 1995 BLRA, the data used were from locations where some ground water constituents were either detected in concentrations statistically elevated above the background (upgradient) concentrations or were detected in at least one sample and insufficient data were available for a statistical comparison in that medium. Analytical data from surface water and sediment samples from Browns Wash and the Green River were also evaluated for E-COPCs based on comparisons of maximum detected concentrations to background (upstream) data, when available. The BLRA initially identified 20 ground-water-based constituents (Table 1) as possible E-COPCs for further screening and evaluation. Table 2 summarizes those E-COPCs that exceeded media standards or risk guidelines.

Table 1. Possible E-COPCs Based on the BLRA

Constituents for Which Water Quality Criteria or Guidelines were Available	Constituents for Which Water Quality Criteria or Guidelines were Not Available
Aluminum	Ammonium
Arsenic	Calcium
Cadmium	Magnesium
Chloride	Potassium
Iron	Radium-226
Manganese	Sodium
Molybdenum	Sulfate
Nickel	Vanadium
Nitrate	
Selenium	
Uranium	
Zinc	

Table 2. Summary of Ecological COPCs in Ground Water, Surface Water, and Sediments that Exceeded Water Quality Criteria or Risk Guidelines

Constituents Above Background in Ground Water[a]	Constituents Exceeding Criteria/Guidelines in Green River Surface Water/Sediments[b]		Constituents Exceeding Criteria/Guidelines in Browns Wash Surface Water/Sediments[b]	
	Water	Sediments	Water	Sediments
Aluminum	No	NS	No	No
Ammonium	No	NS	NA	No
Arsenic	No	NS	No	No
Cadmium	No	NS	Yes	Yes
Calcium	No	NS	NA	No
Chloride	No	NS	Yes	No
Iron	No	NS	Yes	No
Magnesium	No	NS	NA	No
Manganese	No	NS	Yes	No
Molybdenum	No	NS	No	No
Nickel	No	NS	No	No
Nitrate	No	NS	Yes	No
Potassium	No	NS	NA	No
Radium-226	No	NS	NA	No
Selenium	No	NS	Yes	Yes
Sodium	No	NS	NA	No
Sulfate	No	NS	Yes	No
Uranium	No	NS	Yes	Yes
Vanadium	No	NS	NA	No
Zinc	No	NS	No	No

[a]Ground water constituents with concentrations that exceeded background Cedar Mountain Formation ground water was used as background.
[b]Ground water constituents with concentrations that exceeded background concentrations (upgradient of the site) in surface water, sediment, or the median are indicated by a **Yes** or **No**
NA = Not assessed due to lack of criteria or guidelines.
NS = Not sampled or results not included in the BLRA.
(DOE 1995)

Browns Wash

Location 0711 was used as the background surface water location and was sampled in 1982, 1989, and 1993 during periods of runoff associated with rainstorms. However, the BLRA points out that using location 0711 as a true background location is questionable because water was not present at this location in other years due to the ephemeral nature of the wash. Therefore, ground water in the Cedar Mountain Formation was used as background for surface water. Downgradient locations 0709, 0710, 0718, and 0526 were sampled intermittently between 1982 and 1993 in areas of exposed bedrock when standing pools of water were present. On the basis of the data evaluated, the BLRA states that "based on chemical concentrations in surface water at these locations, it is likely that at least some of the surface water contamination...originates from ground water at the site." The BLRA also states that the elevated concentrations could be attributed to storm water runoff or contaminated soils/sediments. However, based on a review of weather data, storm water is eliminated to some extent as the possible source of contamination.

Concentrations of the 20 ground water-based constituents were compared to federal or state water quality criteria or guidelines. Eight of the 20 constituents had no criteria or guidelines available. Of the eight, sulfate was retained for evaluation because limited data existed showing that livestock could be adversely affected by elevated concentrations.

In Browns Wash, concentrations of five constituents (aluminum, arsenic, molybdenum, nickel, zinc) did not exceed surface water guidelines or criteria. Eight constituents, including sulfate, had concentrations that exceeded guidelines or criteria.

Sediment samples were collected from six locations in Browns Wash (Table 2) during a single sampling event in 1993. Sampling locations 0711 (background sandy substrate), 0526, 0709, and 0710 were dry; samples taken from locations 0717 and 0718 were wet. No true sediment background location was identified due to the ephemeral nature of Browns Wash. Additional sampling was completed at locations 0718 and 0720 in 1994 and 1995. It is unclear to what extent the 1994 and 1995 sampling was considered in the BLRA. It appears most of the conclusions drawn were based on the 1993 sampling event. No information is provided in the BLRA as to what constituents were analyzed in sediments, or which had criteria or guidelines available. However, cadmium, selenium, and uranium were identified as E-COPCs in Browns Wash sediments. Cadmium was selected because the concentration exceeded the lowest observed effect level at one location (0718) and is known to bioaccumulate in plants. Selenium was also retained due to its ability to bioconcentrate. Uranium was selected due to the possibility that it could be transported up the food chain. Section 7.4.1 of the BLRA (DOE 1995) provides detailed rationale as to why these constituents were selected.

Green River

Surface water samples were collected at two locations between 1984 and 1992 and again in 2002. Location 0801 served as the background (upstream) and 0802 as the location downstream of Browns Wash. Location 0846 was established (2002) at the confluence of Browns Wash with the Green River. Table 3.6 of the BLRA (DOE 1995) details the 36 constituents and frequency for surface water sampling in the Green River. Sampling indicated that millsite constituents were undetectable in the Green River and, therefore, were not retained as E-COPCs. Sediments were sampled during a single sampling event in 1994, prior to completion of the BLRA.

3.0 BLRA Risk Summary

The BLRA further evaluated the E-COPCs to determine the significance or degree of risk. Table 3 summarizes the final list of E-COPCs (by media) described in the BLRA.

Cadmium was retained as an E-COPC in sediments due to the potential to bioaccumulate. However, it was only detected in one alluvial well and has not been detected in surface water since 1990. Although chloride concentration was elevated in ground water and surface water (standing pools), the significance and degree of effect was considered minimal due to the ephemeral nature of Browns Wash. Iron concentration was elevated in ground water, but iron was eliminated due to its low potential to contaminate surface water and sediments. Manganese

Table 3. BLRA Final List of E-COPCs

Constituent	Ground Water	Surface Water	Sediments	Comment
Cadmium	No	No	Yes	Bioaccumulates, and exceeded LOAEL at location 0718
Chloride	Yes	Yes	ND	Chloride exceeds water quality standards at more than one standing pool surface location in Browns Wash.
Iron	Yes	No	ND	Exceeds aquatic water quality standards in Cedar Mountain Formation
Manganese	Yes	No	ND	Exceeds aquatic water quality standards in Cedar Mountain Formation
Nitrate	Yes	Yes	ND	High concentration in aquifer and in standing pools when present.
Selenium	Yes	Yes	Yes	Bioconcentrates. Elevated in pools in Browns Wash when water was present.
Uranium	No	No	Yes	Could be transported up the food chain through vegetation to livestock/wildlife

LOAEL = lowest-observed-adverse-effect level
ND = not detected

was included on the basis of its elevated concentrations in ground water and potential for risk if terrestrial or aquatic organisms were exposed to ground water. Nitrate concentration was elevated in ground water and surface water and could pose risk to terrestrial or aquatic organisms. Selenium concentrations indicated risk to terrestrial and aquatic receptors in all three media. Uranium was included due to the potential for plant uptake in sediments and transportation up the food chain; however, risk was not determined in the BLRA.

Although limited media-specific benchmark values and receptor-specific toxicity information were available, the results of the screening ERA presented in the BLRA indicated that the potential for overall risk to ecological receptors at the Green River site is probably low.

For purposes of current risk assessment, ground water (Table 4) and surface water collected subsequent to completion of the BLRA are used to reevaluate the list of E-COPCs and to further assess these constituents for potential ecological risk at the Green River site. This update to the BLRA focuses on data collected from 1995 through 2002. For purposes of this assessment, soils and air are not considered contaminated media due to completion of surface remediation prior to the BLRA.

An important aspect of risk assessment is determining the locations considered most relevant to ecological risk. The BLRA discussed ecological risks associated with ground water if it were brought to the surface (i.e., stock pond). The BLRA also discussed risks associated with the Green River and Browns Wash surface water. However, it focused considerable attention on Browns Wash as an ecological community due to its proximity to ground water and its potential to serve as a point of exposure for aquatic receptors. Because of the ephemeral nature of Browns Wash and its limited potential to support an aquatic community, the upper reaches of the wash will not be evaluated as an aquatic community for purposes of this update. However, the pooled area at the mouth of the wash, where it empties into the Green River, is considered a viable aquatic community and will be assessed as such. Therefore, the only relevant surface water data

Table 4. Summary of Preliminary Ecological COPCs in Ground Water (Uppermost Aquifer) at the Green River Site Based on Sampling Data from 1995 through 2002

Constituent	Maximum Concentration in Ground Water				E-COPC? (Site)	Reason
Nonradionuclide Inorganic Analytes (mg/L)						
	Sample Dates	Concentration	Location	FOD		
Aluminum	95	0 22	0172	1/26	No	Based on FOD and historically low concentrations
Ammonium[a]	**95**	**0.67**	**0174**	**15/24**	**Yes**	**Exceeds background range**
Arsenic[a]	**95/96/98-02**	**0.186**	**0813**	**22/156**	**Yes**	**Exceeds background range**
Cadmium	95/98-02	0.0033	0172	1/146	No	Based on FOD and historically low concentrations.
Calcium	95-02	521	0176	162/162	No	Essential nutrient
Chloride[a]	**95-02**	**1290**	**0583**	**162/162**	**Yes**	**Exceeds background range**
Iron[a]	**95/96**	**4.6**	**0813**	**9/17**	**Yes**	**Exceeds background range and is elevated above BLRA concentrations**
Magnesium	95-02	419	0176	152/152	No	Essential nutrient
Manganese[a]	**95-02**	**0.936**	**0813**	**111/152**	**Yes**	**Exceeds background range**
Molybdenum[a]	**95-02**	**0.08**	**0177**	**59/162**	**Yes**	**Exceeds background range**
Nickel	95	ND	---	0/24	No	Not detected
Nitrate[a]	**95-02**	**1650**	**0172**	**65/211**	**Yes**	**Exceeds background range**
Potassium	95-02	42 2	0176	162/162	No	Essential nutrient
Selenium[a]	**95-02**	**0.849**	**0176**	**76/211**	**Yes**	**Exceeds background range**
Sodium	95-02	3740	0172	162/162	No	Essential nutrient
Sulfate[a]	**95-02**	**8510**	**0172**	**200/200**	**Yes**	**Exceeds background range**
Uranium[a]	**95-02**	**0.198**	**0179**	**130/211**	**Yes**	**Exceeds background range**
Vanadium	95-02	ND	---	0/152	No	Not detected
Zinc	95	ND	---	0/12	No	Not detected
Radionuclides (pCi/L)						
Radium-226[a]	**95/97-01**	**2.65**	**0813**	**97/116**	**Yes**	**Exceeds background range**

[a]Constituent was retained as a ground water E-COPC
FOD = frequency of detection
ND = not detected

in Browns Wash is that collected at locations 0526, 0846, and 0847. These sampling locations are within or at the mouth of Browns Wash, which could be considered a backwater to the Green River. Both surface water locations in the Green River (0801 and 0802) will be retained for purposes of this assessment.

Further review of sediment data indicates that the value of these data in assessing potential risks to benthic organisms in Browns Wash is questionable. Prior to the BLRA, it was suspected that ground water may have been surfacing in the form of seeps into Browns Wash. However, attempts to collect sediment data in the past have typically resulted in collecting samples from dry locations where there are no benthic organisms. Recent (2001 and 2002) inspections of the site also found no evidence of seeps, and ground water, therefore, has limited potential to influence Browns Wash sediments. With the exception of location 0526, sediment sampling data at other Browns Wash locations will not be assessed due to limited potential for ecological risk. In the Green River, relevance of sediment data for locations 0801 and 0802 will be evaluated.

An analyte was identified as an E-COPC if its maximum detected concentration exceeded historical background concentrations (the corresponding upgradient data set). This is due to the lack of current background data. Constituents that are considered to be essential nutrients (calcium, magnesium, potassium, and sodium) are excluded as E-COPCs. Sulfate and chloride are anions of low potential toxicity in biota. However, because chloride has a State of Utah water quality standard for the Green River, and toxicity data exist for sulfate, they have been retained for consideration as E-COPCs. Despite the relatively low toxicities of these anions and cations, it is recognized that at high concentrations in water they can contribute to adverse ecological effects due to high osmotic potentials, and some can affect the use of water by wildlife and livestock by imparting strong tastes to the water. These types of effects, however, are not addressed in this risk assessment.

Aluminum and cadmium were eliminated based on low frequency of detection (FOD). Nickel, vanadium, and zinc also were eliminated because they have not been detected since completion of the BLRA. Therefore, 11 constituents are retained for further assessment. To determine if downgradient concentrations of these COPCs may present risk or may be influencing the lower sections of Browns Wash (in the vicinity of surface locations 0526 and 0846), the concentrations of these constituents were compared to those at downgradient ground water locations 0583 and 0810. On the basis of comparison, it appears that downgradient ground water in the uppermost aquifer is not being affected by nitrate and selenium and is only slightly affected (if at all) by arsenic, manganese, molybdenum, and uranium. However sulfate and radium-226 concentrations at locations 0583 and 0810 do show mill-related influence. Ammonium and iron were not sampled at these locations from 1995–2002. Surface water data from locations 0526, 0801, 0802, 0846, and 0847 were considered most relevant for purposes of this ERA update.

A constituent was considered an E-COPC if its maximum detected concentration exceeded the maximum concentration from the upstream (background) Green River location (0801). It is assumed that aluminum, ammonium, iron, and zinc were not sampled after 1994 due to low concentrations, low FOD, or they were not detected in subsequent ground water and surface water sampling. Of the 10 remaining constituents, arsenic, molybdenum, selenium, and vanadium were not detected in 2000–2001 sampling at location 0526. Chloride, manganese, nitrate, and uranium concentrations are below background (location 0801) and are well below the applicable surface water standards or guidelines. Sulfate concentration is below the secondary drinking water standard (250 milligrams per liter [mg/L]) and well below the threshold for toxicity to livestock (1,500–2,000 mg/L). Radium-226 concentration is below the Utah water quality standard and is not considered a risk in surface water. Therefore, there appears to be no risk to surface water as a result of mill-related constituents.

Because no additional sediment sampling has taken place at the Green River site since the 1993 samples that were reported in the BLRA (DOE 1995), the data used to evaluate E-COPCs for sediment are unchanged from those of the BLRA. The concentrations from sample location 0526 are considered most relevant. As stated in the BLRA summary above, three constituents (cadmium, selenium, and uranium) were detected in the sediments of the site at concentrations that could pose potential ecological risk. Due to the lack of data after 1995 it is recommended that chloride, iron, manganese, and sulfate also be included for further analysis in sediments. These analytes constitute the sediment E-COPCs for purposes of the draft site observational work plan.

In July 2002, additional surface water samples were collected from two locations near the mouth of Browns Wash. Sampling location 0846 was at the confluence of Browns Wash and the Green River and sampling location 0847 was approximately 300 feet upstream of the confluence on Browns Wash. These locations represent the wetland and aquatic habitats of the mouth of Browns Wash, where the channel of the wash creates a backwater inlet along the Green River. This inlet is potentially important habitat for fish, possibly including the Colorado pikeminnow. Concurrently with these samples, a surface water sample was collected at the upstream (background) location on the Green River (location 0801).

Maximum concentrations of the nonradiological analytes measured at the two locations at the mouth of Browns Wash were compared to the measured concentrations from the Green River background location. Twelve of the 16 analytes at the mouth of Browns Wash exceeded the background location concentration for at least one of the two locations, indicating the possibility that they are influenced by the millsite. Two of these, however, (cadmium and strontium) were close enough to the background concentration that they considered not significantly elevated above background. In the case of strontium, the sample exceeding background was from the confluence, while the upstream sample was less than background. Four of the analytes were essential nutrients (calcium, magnesium, potassium, and sodium). The remaining seven analytes (Table 5) were identified and E-COPCs for this wetland area and are further evaluated for potential risk to aquatic, wetland, and terrestrial receptors.

Table 5. Nonradiological Constituents Retained for Risk Evaluation in the Surface Water at the Mouth of Browns Wash Based on Sampling Data from July 2002

Constituent	Concentration in Surface Water (mg/L)		E-COPC?	Reason
	Maximum of Locations 0846 and 0847[a]	Green River Background Location[b]		
Arsenic	**0.0014**	0.00093	Yes	Exceeds background range
Cadmium	**0.00057**	0 00056	No	Considered not significantly greater than background
Calcium	**47.9**	47 2	No	Essential nutrient
Chloride	**33.5**	30.9	Yes	Exceeds background range
Fluoride	0 218	0 219	No	Within background range
Magnesium	**26.2**	25.9	No	Essential nutrient
Manganese	**0.0398**	0 0034	Yes	Exceeds background range
Molybdenum	**0.0055**	0.0040	Yes	Exceeds background range
Nitrate	**0.203**	0.0506	Yes	Exceeds background range
Potassium	3.38	3 40	No	Essential nutrient
Selenium	**0.0011**	0 00077	Yes	Exceeds background range
Sodium	**75.7**	71.4	No	Essential nutrient
Strontium	**0.618**	0 603	No	Considered not significantly greater than background[c]
Sulfate	**193**	181	Yes	Exceeds background range
Uranium	0.0029	0 0029	No	Within background range
Vanadium	0.0024	0 0024	No	Within background range

[a]Location 0846 is at the confluence of Browns Wash and the Green River, location 0847 is approximately 300 feet upstream of the confluence on Browns Wash.
[b]The Green River background location is at location 0801.
[c]The maximum concentration for strontium was from the confluence with the Green River. Because this concentration exceeded the background concentration by only 3 percent, and the concentration in the sample from 300 feet upstream of the confluence on Browns Wash (0.532 mg/L) was significantly less than the background concentration, it was determined that strontium at the mouth of Browns Wash is not significantly greater than background.
Bold text indicates value exceeds the background concentration.

4.0 Ecological Conceptual Site Model

The conceptual model for an ERA is developed from information about stressors, predicted exposure pathways, and the potential effects of exposure on ecological receptors. Conceptual models consist of two principal components (EPA 1998):

- A set of risk hypotheses that provide descriptions of predicted relationships among stressor, exposure, and assessment endpoint response, along with the rationale for their selection.

- A diagram that illustrates the relationships presented in the risk hypotheses.

A complete exposure pathway is the mechanism by which a contaminant in an environmental medium (i.e., the source) can contact an ecological receptor. A complete exposure pathway includes:

- Contaminant source.
- Release mechanism that allows contaminants to become mobile or accessible.
- Transport mechanism that moves contaminants away from the release.
- Ecological receptor.
- Route of exposure (e.g., dermal or direct contact, inhalation, or ingestion).

Because the stressors at the Green River site are chemical contaminants, the risk hypotheses are considered to be stressor-initiated.

As part of the initial problem formulation in the BLRA, a generalized site conceptual model (Figure 2) was developed for the Green River site. That model has since been revised to address current and potential exposure pathways based on all the available data. The movement of contaminated ground water from the mill tailings area is believed to have come from the former tailings pile just south of Browns Wash. However, there is currently no evidence that this has continued to occur after 1994. For this reason, risk hypotheses are developed for surface water assuming that ground water does not influence surface water in Browns Wash. In addition, there has been no evidence that ground water is influencing the Green River. This uncertainty will be addressed in the ongoing investigation.

Risk Hypotheses Based on Current Exposure Scenarios

The following are the risk hypotheses proposed for the site where complete exposure pathways to ecological receptors may exist based on the current site conditions. Contaminants in the near-surface ground water of the site may be taken up by deep roots of phreatophytes. These contaminants may result in phytotoxic effects on the plant or they may be transported to plant tissues that are accessible to wildlife. If future sampling indicates that aquatic organisms in direct contact with these media may be affected or bioaccumulation up the food chain may occur, further assessment may be required. If a pathway exists, wildlife could be directly exposed to contaminants through the ingestion of this water and/or the food items exposed to the water and sediment and the incidental ingestion of the sediment.

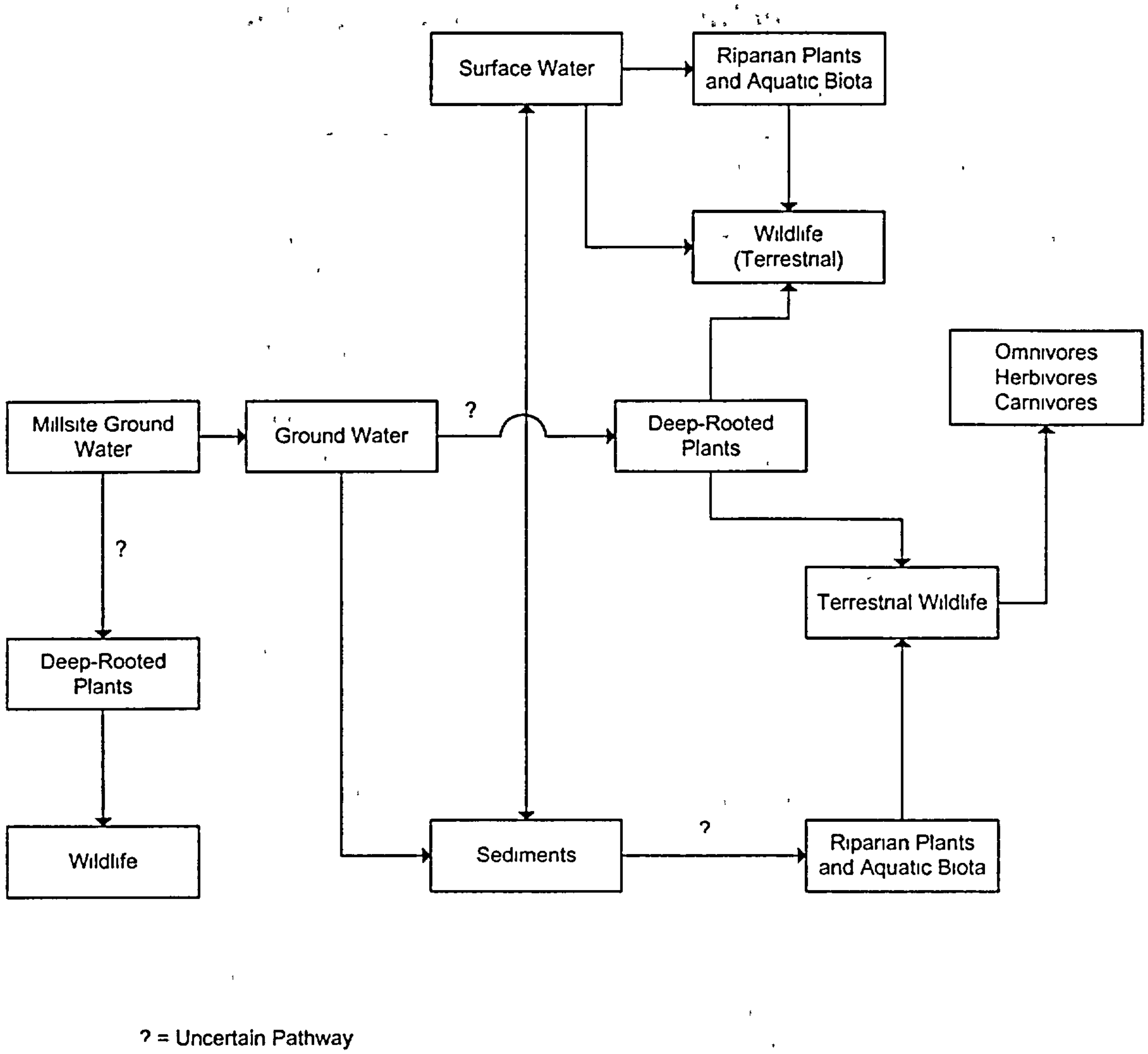


Figure 2. Green River Generalized Ecological Site Conceptual Model

Risk Hypotheses Based on Hypothetical Future Exposure Scenario

Without institutional controls, ground water could possibly be pumped and used for irrigation, surface ponds, livestock watering, or industry. This practice would create a source for potential ingestion of ground water, direct contact with terrestrial vegetation, and deposition of ground water on the soil. The soil would then represent an additional source medium for ingestion and direct contact.

Ecological Receptors

Ecological receptors that could potentially be exposed to E-COPCs were identified in the BLRA (DOE 1995) and include aquatic, mammalian, and avian species. The food web for this site (Figure 3) illustrates the potential dietary interactions among receptors associated with the site. The food web also depicts the major trophic interactions and shows nutrient flow through the

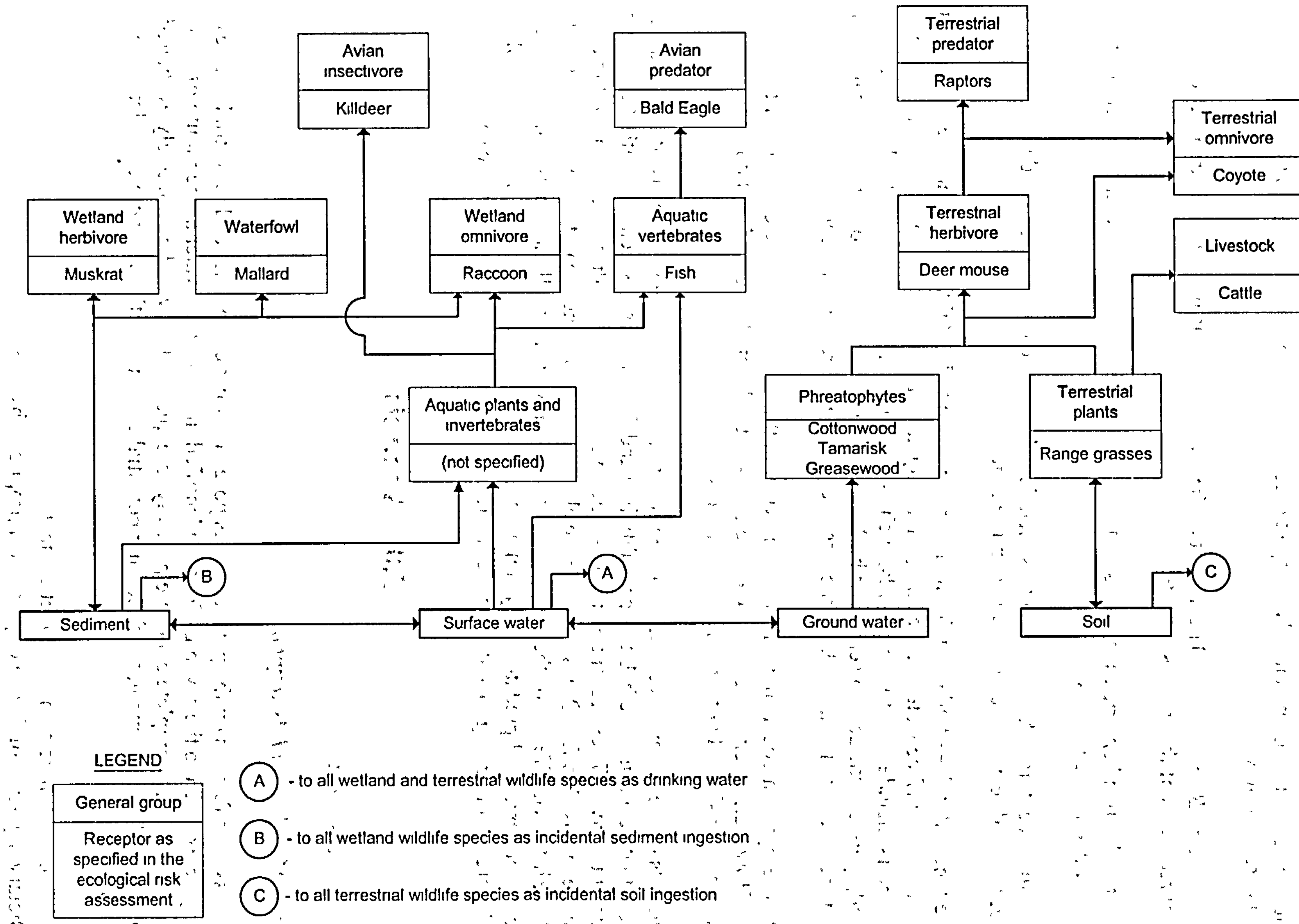


Figure 3. Generalized Food Web for Green River Ecological Receptors

trophic levels. This food web model was developed from the species lists and consideration of the exposure pathways. The food web diagram was used to portray potential pathways of E-COPCs from the ground water to biota at various trophic levels, with potential receptor species being identified as having potentially complete ecological exposure pathways. These potential receptors are as follows:

Green River and Browns Wash: The habitat of the river channel is primarily riparian. The potential receptors of these areas include:

- Plants—Wetland and riparian plants that grow along the channel course in direct contact with water and sediments.
- Aquatic receptors—Aquatic receptors include fish, aquatic invertebrates, and aquatic plants that live in direct contact with water and sediments.
- Wetland wildlife—Wetland wildlife may be exposed to E-COPCs along the river as a result of drinking surface water and feeding on the aquatic organisms and wetland plants. Potential receptors include insectivorous birds, such as swallows, flycatchers; shorebirds, such as sandpipers and killdeer; piscivorous birds, such as herons and the bald eagle; and mammals that are associated with wetland habitats, including muskrats and raccoons.

Potential receptors associated with the Green River at this site also include endangered fish species. However, no endangered species are exposed to elevated levels of contaminants and are therefore not considered potential receptors at this site.

The habitats of the Green River site area are primarily terrestrial; however, many of the wildlife receptors that occur in these habitats probably live and feed in close association with the aquatic habitats of the river. These receptors may use the river as a source of drinking water, and may thereby be exposed to E-COPCs, if they were elevated. Because the area of the millsite is highly disturbed, little wildlife use of these areas is expected. However, small mammals and birds use the areas, and terrestrial predators may sometimes hunt these animals. Larger species probably cross the area while going to and from the river, and may forage in the area on occasion.

5.0 Analysis

Exposure Assessment

Exposure Modeling and Assumptions

This assessment focuses on the potential risks posed to aquatic, wetland, and terrestrial species that may be exposed to the seven E-COPCs identified in the surface water at the mouth of Browns Wash. Only complete exposure pathways are quantitatively and qualitatively evaluated in an ERA. In this assessment, the following potential exposure pathways were considered for evaluation:

- Surface water ingestion and direct contact
- Dietary ingestion of forage or prey, as appropriate, by receptor

The contaminants associated with the site are inorganics. Estimations of potential exposures to key ecological receptors are based on the dominant pathways from these media for the specific receptor. Exposures in wetland plants and aquatic organisms are based on direct contact with the surface water in which they live and, in the cases of aquatic animals, also include the ingestion of food associated with this medium. In all of these cases (plants and animals), potential exposure to an E-COPC is based on the concentration of that E-COPC in the surface water.

Exposures in wildlife involve multiple potential pathways that may include ingestion of food, water, and soil/sediment; direct contact and dermal absorption; and inhalation. In this assessment, the inhalation and dermal absorption pathways are assumed to be minor pathways with respect to the combined exposures based on ingestion. Most wildlife of the area have very little and infrequent direct dermal contact with potentially contaminated media due to their protective covers of feathers or fur and their habits and behaviors, such as preening and grooming, and (in the cases of most birds) living principally in trees and shrubs. The E-COPCs are not highly volatile. Therefore, their occurrence in the air is minimal. Exposures in wildlife through inhalation was considered a minor exposure pathway relative to sediment ingestion. Although both dermal absorption and inhalation will contribute to the overall exposure in these receptors, these contributions are assumed to be included within the conservatisms incorporated in the estimation of exposures through the ingestion pathways. Sediment is not identified as a medium of concern, and therefore, sediment-based pathways are not evaluated.

In the estimation of ingestion-related exposure for the wildlife receptors, the E-COPCs are assumed to be 100 percent bioavailable, and the receptors are assumed to be exposed only at the selected exposure point concentration, regardless of home range size or seasonal use patterns. The exposure through multiple ingestion pathways is modeled using the methods described in EPA's *Wildlife Exposure Factors Handbook* (EPA 1993).

The basic model for estimating the daily intake of an E-COPC per kilogram of body weight (i.e., the estimated daily dose of the E-COPC) through these ingestion pathways is

$$D_x = \frac{\sum_{k=1}^{m} (C_k \cdot F_k \cdot I_k) + C_w \cdot F_w \quad I_w}{W}$$

where

D_x is the estimated daily dose (milligrams per kilogram per day [mg/kg-day]) of E-COPC x,
C_k is the concentration of E-COPC x in the k^th^ food type (mg/kg dry weight),
F_k is the fraction of the k^{th} food type that comes from the site,
I_k is the ingestion rate of the k^{th} food type (kg dry weight/day),
m is the number of food items in the receptor's diet,
C_w is the concentration of E-COPC x in water (mg/L),
F_w is the fraction of the ingested water that comes from the site,
I_w is the ingestion rate of water (liters per day [L/day]), and
W is the body weight of the receptor (kg wet weight).

F_k, F_s, and F_w are commonly assumed to be the area use factor (the area of the site divided by the home range of the receptor or 1, whichever is smaller) but may also be modified by a seasonal use factor (number of days at the site divided by 365 days per year) if the home range is used for only part of the year. For estimating risk in this assessment, both area use and seasonal use are conservatively assumed to be 100 percent; therefore, F_k, F_s, and F_w are assumed to be 1.

For the purposes of estimating exposure in wildlife, the E-COPC concentrations in plants were principally based on the empirically-derived uptake models (nonlinear or linear) as recommended by Oak Ridge National Laboratory (Bechtel Jacobs Company 1998a). Because these models are based on uptake from soil, the soil-water partitioning coefficient (K_d) is used to estimate the E-COPC concentration in the soil from the water concentration. The nonlinear form of the uptake model is

$$C_{plant} = B_0 \cdot (K_d \cdot C_w)^{B_1}$$

where

C_{plant} is the concentration of the E-COPC in the plant (mg/kg dry weight),
K_d is the soil-water partition coefficient
C_w is the water concentration of the E-COPC (mg/L), and
B_0 and B_1 are empirically derived model parameters for the E-COPC.

In the linear form of this model, B_1 is assumed to be exactly 1 and B_0 becomes a soil-to-plant transfer factor, where

$$C_{plant} = B_0 \quad K_d \cdot C_w$$

In cases where parameters were not available in the Oak Ridge National Laboratory uptake model documents, soil-to-plant transfer factors from other literature sources (e.g., Baes and others 1984) were used in this linear model.

For aquatic prey species (invertebrates and fish), linear uptake models based on bioaccumulation factors (BAFs) were used to estimate concentrations of E-COPCs in tissues. These models are of the form:

$$C_{organism} = BAF \cdot C_{water}$$

where:

$C_{organism}$ is the concentration of the E-COPC in the invertebrate or fish prey species (mg/kg dry weight),
C_{water} is the concentration of the E-COPC in the water (mg/L), and
BAF is the bioaccumulation factor for the E-COPC.

BAFs account for all exposure pathways (dermal absorption, uptake through respiratory organs, and ingestion). In contrast, bioconcentration factors (BCFs) account for uptake through pathways other than ingestion. However, for most inorganic constituents, uptake through ingestion is insignificant, and BAFs are considered to be equal to BCFs. Therefore, BCFs are used as BAFs in this assessment when the latter values are not available. Whenever possible, however, BAFs and BCFs specific to either invertebrates or fish were used to model the concentrations in these respective prey types. Data specific to chloride, nitrate, and sulfate uptake could not be found; however, concentrations of these constituents in the prey species were assumed to equal its concentration in the surrounding media. Table 6 presents the uptake model parameters (B_0, B_1, BAF, and/or BCF values) used in modeling the concentrations of E-COPCs through the food chain at the mouth of Browns Wash.

Table 6. Uptake Model Parameters and Bioaccumulation Factors for Ecological Contaminants of Potential Concern

E-COPC	Plant Uptake Model Parameters		Bioaccumulation Factors	
	B_0	B_1	Invertebrates	Fish
Arsenic	0.136[a]	0.564[a]	73.0[b]	17.0[c]
Chloride	70[d]	1.0[e]	1.0[f]	1.0[f]
Manganese	3.0[g]	1.0[e]	65[h]	17.8[h]
Molybdenum	0 8[i]	1.0[e]	10[j]	10[i]
Nitrate	1.0[f]	1.0[f]	1.0[f]	1.0[f]
Selenium	0.508[a]	1.10[a]	269[k]	129[b]
Sulfate	1.0[f]	1.0[f]	1.0[f]	1.0[f]

[a]From Bechtel Jacobs Company (1998a)
[b]From NMED (2000)
[c]From Sample and others (1996)
[d]From Baes and others (1984)
[e]The uptake model is linear; therefore, B_1 = 1.0
[f]Default value.
[g]From NCRP (1989).
[h]From EPA (2001)
[i]From IAEA (1994).
[j]Invertebrate bioaccumulation factor based on fish bioaccumulation factor.
[k]Geometric mean of selenite bioaccumulation factors for water fleas based on 14-day exposure from EPA (2001).

Key Indicator Receptors

The receptors used to evaluate potential risks were selected on the basis of their potential presence in the habitats of the site, their potential for exposure to E-COPCs in the media at the site, and their potential for conservatively representing potential exposures to a range of other receptors at the site. The indicator receptors are representative of key links in the food webs associated with these habitats.

These indicator receptors are as follows:

- Terrestrial habitats—deer mouse (herbivorous), mule deer, coyote, northern harrier
- Wetland habitats—wetland plants, muskrat, raccoon, mallard, spotted sandpiper, bald eagle
- Aquatic habitats—aquatic organisms

Terrestrial exposure pathways are found in limited areas of the floodplain and adjacent uplands. For the terrestrial wildlife, surface water is considered to be the primary source medium for E-COPC exposures, and therefore, evaluations of risks to all terrestrial receptors are based on the potential consumption of drinking water from the mouth of Browns Wash. The terrestrial wildlife receptors used represent both mammals and birds; the mammals are represented by a range of body sizes, from a deer mouse to a mule deer.

For the wetland habitats, emergent plants are considered to be the primary producers, and the muskrat and mallard are considered to be representative of herbivores that may consume such plants. The raccoon represents an omnivore in this habitat. The spotted sandpiper represents an insectivorous bird and the bald eagle a piscivorous bird. All animal prey of these wildlife receptors (the muskrat being the only one modeled as purely herbivorous) are assumed to be aquatic (invertebrates or fish). The species-specific parameters used to model exposures to these key indicator receptors (wildlife only) are presented in Table 7.

Table 7. Exposure Parameters for Wildlife Receptors

Receptor	Body weight (kg)[a]	Food ingestion rate (kg [dry wt.]/day)[b]	Water ingestion rate (L/day)[c]	Dietary Composition (percent)[d]
Deer mouse (*Peromyscus maniculatus*)	0 0239[e]	NA	0.00344	NA
Muskrat (*Ondatra zibethicus*)	1.135	0 0772[f]	0.111	Plant: 100
Raccoon (*Procyon lotor*)	5.74	0 289	0.477	Plant: 40 Invertebrate: 50 Fish: 10
Coyote (*Canis latrans*)	10[e]	NA	0.786	NA
Mule deer (*Odocoileus hemionus*)	65[e]	NA	4 24	NA
Northern harrier (*Circus cyaneus*)	0.180[g]	NA	0 0187	NA
Mallard (*Anas platyrhynchos*)	1.134	0.0592	0 0642	Plant: 90 Invertebrate 10
Spotted sandpiper (*Actitis macularia*)	0.0425	0 00503	0 0711	Invertebrate: 100
Bald eagle (*Haliaeetus leucocephalus*)	3.75	0.0863	0 135	Fish: 100

[a]From EPA (1993), except where noted.
[b]Based on allometric equations from Nagy (1987), as presented in EPA (1993), except where noted.
[c]Based on allometric equations from Calder and Braun (1983), as presented in EPA (1993), except where noted.
[d]Diets are generalized to emphasize specific trophic levels Dietary compositions of the raccoon and mallard are based on species-specific information presented in EPA (1993) and Martin and others (1951) and have generally been rounded to increments of 10 percent
[e]From Silva and Downing (1995).
[f]Based on species-specific food intake rate from EPA (1993), with assumed water content of food of 80 percent.
[g]From Dunning (1993).

Receptors in the aquatic habitats are not specified. Risk to these receptors is based on comparisons of the surface water E-COPC concentrations to broad-based benchmark values, such as ambient water quality criteria (AWQC), that are protective of a wide range of aquatic and benthic organisms. Fish are assumed to be included as potential aquatic receptors within this broad categorization. All wildlife receptors are modeled as potential receptors of E-COPCs in surface water through the consumption of that water at all sites where surface water is present as a medium of concern.

6.0 Effects Characterization

The potential for adverse effects to ecological receptors resulting from exposures to E-COPCs at the site was evaluated through a comparison of the potential exposure in the receptor to a toxicity-based benchmark of exposure representing the threshold of potential adverse effects.

For aquatic and benthic receptors and plants, the exposure to an E-COPC is characterized by the concentration of that E-COPC in the medium (water or sediment, respectively) with which the receptor is principally in direct contact. Therefore, the benchmarks by which the potential for adverse effects is evaluated are also based on media concentrations. For surface water, either AWQC (EPA 1999) or Utah Department of Environmental Quality Water Quality Standards (whichever was less) were used as the principal benchmarks for evaluating potential risk to aquatic life. When neither was available for an E-COPC, other values are used. The water quality benchmarks are summarized in Table 8.

Table 8. Surface Water Quality Benchmarks for Ecological Contaminants of Potential Concern for the Protection of Freshwater Aquatic Life

COPC	Water Quality Benchmarks (mg/L)		
	AWQC[a]	UDEQ WQS[b]	Other
Arsenic	0.15	0.19	--
Chloride	230	--	--
Manganese	--	--	0 08[c]
Molybdenum	--	--	0.24[c]
Nitrate (as N)	--	0.23[d]	--
Selenium	0.005	0 005	--
Sulfate	--		250[e]

[a]EPA ambient water quality criteria (EPA 1999)
[b]Utah Department of Environmental Quality Water Quality Standard for aquatic life (Rule R317.2)
[c]Tier II secondary chronic value from Suter and Tsao (1996).
[d]Standard for NO_3 as N for class 3A water at pH 8 5 and 25°C.
[e]EPA secondary maximum contaminant level (EPA 2000)
-- = No value available

For plants, toxicity benchmarks are based primarily on the information provided in Efroymson and others (1997). These benchmarks are based on lowest-observed-adverse-effect levels (LOAELs) using 20 percent reduction in growth as the endpoint. Solution-based (water) benchmarks were used. Although based on LOAELs, these benchmarks are considered conservative. The endpoint is sublethal and reductions in plant growth may have no significant effect on the reproductive potential or the continued existence of a plant population. The plant toxicity benchmarks are presented in Table 9.

Table 9. Plant Toxicity Benchmarks for Ecological Contaminants of Potential Concern

E-COPC	Plant Toxicity Benchmark for Water[a] (mg/L)
Arsenic	0 001
Chloride	--
Manganese	4.0
Molybdenum	0 5
Nitrate	--
Selenium	0.7
Sulfate	--

[a]From Efroymson and others (1997)
-- = No benchmark available.

For the wildlife receptors, no-observed-adverse-effect levels (NOAELs) for chronic oral exposure are used as benchmarks for toxic effects. The endpoints of particular interest in this assessment are those associated with reproductive health, development, and mortality. Therefore, NOAELs are defined as the maximum dosage tested that produced no effect that would be considered adverse to the receptor's survival, growth, or reproductive capacity. Because the NOAELs for the wildlife receptor species are based on NOAELs from test species, the latter are scaled to NOAELs specific to the wildlife receptor species using a power function of the ratio of body weights, as described by Sample and others (1996) and Sample and Arenal (1999). This scaling is based on the equation:

$$NOAEL_W = NOAEL_T \left(\frac{BW_T}{BW_W} \right)^s$$

where

- $NOAEL_W$ is the no-observed-adverse-effect level for the wildlife receptor species (mg/kg/day),
- $NOAEL_T$ is the no-observed-adverse-effect level for the test species (mg/kg/day),
- BW_T is the body weight of the test species (kg),
- BW_W is the body weight of the wildlife receptor species (kg), and
- s is the body weight scaling factor; (s = 0.06 for mammals and s = -0.2 for birds (Sample and Arenal 1999).

Toxicity studies were considered to be chronic if they are conducted over a period of 26 weeks (one-half year) or more. This period represents the period of seasonal use by migratory and hibernating species and is sufficient time for small animals to complete their reproductive cycles. Studies of lesser duration (i.e., 1 to 25 weeks) are considered subchronic, unless they specifically included reproductive effects as endpoints (Sample and others 1996). When only subchronic oral $NOAEL_T$ values were available, these are converted to chronic $NOAEL_T$ values by applying an uncertainty factor of 0.1 (Sample and others 1996).

When only a chronic LOAEL value was available for test data, an uncertainty factor of 0.1 was used to convert it to the chronic $NOAEL_T$. If only a subchronic LOAEL was available, then an uncertainty factor of 0.01 was used to estimate the chronic $NOAEL_T$. This uncertainty factor is the product of two uncertainty factors of 0.1, one to convert the subchronic value to a chronic value and the other to convert the LOAEL to an NOAEL. NOAELs were not determined if toxicity data could not be found for test species within the same class. Therefore, NOAELs for mammalian receptors are derived only from mammalian test species data and NOAELs for avian receptors are derived only from avian test species data. The toxicity data and receptor-specific NOAELs used in this assessment for mammalian and avian receptors are presented in Tables 10 and 11, respectively.

Table 10. Mammal Toxicity Benchmarks for Ecological Contaminants of Potential Concern

E-COPC	Mammalian Test Data[a]			Mammalian Receptor NOAELs (mg/kg/day)				
	Test Species	Body weight (kg)	NOAEL (mg/kg/day)	Deer mouse	Muskrat	Raccoon	Coyote	Mule deer
Arsenic	Rabbit	4 396	0 396	0 541	0 430	0 390	0 377	0.37
Chloride	---	---	---	---	---	---	---	---
Manganese	Rat	0 35	88 0	103	82.0	74.4	72 0	64 3
Molybdenum	Mouse	0.03	0 26	0 264	0 209	0 190	0.183	0 164
Nitrate	Guinea pig	0 86	507	629	499	452	438	391
Selenium	Rat	0 35	0 20	0 235	0 186	0 169	0 164	0 146
Sulfate	---	---	---	---	---	---	---	---

[a]From Sample and others (1996)
--- = Insufficient toxicity information

Table 11. Avian Toxicity Benchmarks for Ecological Contaminants of Potential Concern

E-COPC	Avian Test Data[a]			Avian Receptor NOAELs (mg/kg/day)			
	Test Species	Body weight (kg)	NOAEL (mg/kg/day)	Northern harrier	Mallard	Spotted sandpiper	Bald eagle
Arsenic	Mallard	1.0	5.14	3.65	5 27	2.73	6.70
Chloride	---	---	---	---	---	---	---
Manganese	Japanese quail	0.072	977	1,170	1,700	879	2,150
Molybdenum	Chicken	1.5	3.53	2.31	3.34	1.73	4.24
Nitrate	---	---	---	---	---	---	---
Selenium	Mallard	1.0	0.40	0.284	0.410	0.213	0.521
Sulfate	---	---	---	---	---	---	---

[a]From Sample and others (1996).
--- = Insufficient toxicity information

7.0 Risk Characterization

The potential for risk to ecological receptors is determined through hazard quotients (HQs). HQs are specific to a particular receptor for exposure to a particular E-COPC. An HQ is defined by:

$$HQ = \frac{\text{Exposure}}{\text{Benchmark}}$$

For aquatic and benthic organisms and plants, exposures are equivalent to media concentrations (surface water or sediment) with which the organism is in contact. For wetland wildlife, exposures are modeled from multiple pathways.

The value of the HQ is greater than 1.0 if the magnitude of the exposure is greater than the corresponding benchmark, and conversely, the HQ is less than or equal to 1.0 if the exposure is less than or equal to the benchmark. An HQ value less than or equal to 1.0 is interpreted as evidence of no potential risk to that receptor for that E-COPC. If the HQs for an E-COPC are less than unity for all receptors, that E-COPC is eliminated from further consideration as a potential ecological risk driver. However, because exposure for the screening of E-COPCs is conservatively estimated, an HQ value greater than unity is not interpreted as evidence of risk, but only as evidence that the potential for risk cannot be ruled out.

For the purposes of this evaluation, potential exposures were conservatively based on the maximum measured E-COPC in surface water at the mouth of Browns Wash. The following are summaries of the risk assessment results for specific receptor groups.

Risk to Ecological Receptors Associated with Surface Water at the Mouth of Browns Wash

Table 12 presents the HQs for aquatic organisms and wetland plants exposed to surface water at the mouth of Browns Wash. With one exception (plant exposure to arsenic), all of these HQs are less than 1. The single exception is only slightly above 1. Because these HQs are based on the maximum of the two samples collected at this site, with the other data point for arsenic (0.00088 mg/L) being less than the plant toxicity benchmark, the potential for risk to plants is considered negligible.

Table 12. Hazard Quotients for Aquatic Organisms and Wetland Plants at the Mouth of Browns Wash Based Upon Comparison of Surface Water Concentrations to Water Quality and Plant Toxicity Benchmarks[a]

E-COPC	Aquatic Organisms		Wetland Plants	
	Water Quality Benchmark (mg/L)	Hazard Quotient	Plant Toxicity Benchmark (mg/L)	Hazard Quotient
Arsenic	0.15	0.00933	0.001	**1.40**
Chloride	230	0.146	--	--
Manganese	0.08	0.498	4.0	0.00995
Molybdenum	0 24	0 0229	0.5	0.0110
Nitrate	0 23	0.199	--	--
Selenium	0 005	0.220	0.7	0 00157
Sulfate	250	0.772	--	--

[a]Hazard quotients based on maximum surface concentration

-- = No benchmark value available
Hazard quotient greater than 1 shown in **Bold**

Tables 13 and 14 present the HQs for exposures to wetland and terrestrial wildlife to surface water and associated prey organisms at the mouth of Browns Wash. None of the E-COPCs at this site are at concentrations that pose a potential risk to either wetland or terrestrial wildlife that may exposed to surface water at the site or to food organisms eaten from the site.

Table 13. Hazard Quotients for Wetland Wildlife at the Mouth of Browns Wash[a]

E-COPC	Muskrat	Raccoon	Mallard	Spotted Sandpiper	Bald Eagle
Arsenic	0 00386	0.00929	0 000316	0 00451	0 000335
Chloride	--	--	--	--	--
Manganese	0.00648	0 00321	0 000224	0.000356	0.0000309
Molybdenum	0.0312	0.0249	0.00142	0.00429	0.00124
Nitrate	0.0000675	0.0000667	--	--	--
Selenium	0 00108	0.0616	0.00408	0.165	0 0251
Sulfate	--	--	--	--	--

[a]Exposure based on surface-water-based pathways, including direct ingestion of water, and ingestion of plants, invertebrates, and fish with tissue concentrations estimated from water concentrations
-- = No toxicity benchmark available.

Table 14. Hazard Quotients for Terrestrial Wildlife at the Mouth of Browns Wash[a]

E-COPC	Deer Mouse	Coyote	Mule Deer	Northern Harrier
Arsenic	0 000372	0.000292	0.000271	0.0000399
Chloride	--	--	--	--
Manganese	0.0000554	0.0000435	0 0000404	0 00000352
Molybdenum	0.00300	0.00236	0.00219	0 000247
Nitrate	0 0000464	0 0000365	0.0000338	--
Selenium	0 000673	0 000529	0 000491	0 000403
Sulfate	--	--	--	--

[a]Exposure based on direct ingestion of water only.
-- = No toxicity benchmark available.

Potential Risk to Ecological Receptors Associated with Non-Radionuclides

Few, if any, complete exposure pathways potentially exist between ground water at the Green River site and ecological receptors. The most credible of these is the potential for contact with contaminated ground water by deep-rooted plants, such as phreatophytes (e.g., greasewood). Comparisons of the plant toxicity benchmarks shown in Table 9 to the maximum ground water concentrations from the two downgradient wells (0588 and 0810) show that only the maximum concentration of arsenic from location 0588 (0.0127 mg/L) exceeded the plant toxicity benchmark, resulting in an HQ of 12.7. However, arsenic was not detected at location 0810. (For completeness, it should be noted that the plant toxicity benchmark for uranium is 40 mg/L [Efroymson and others 1997], which is well above the maximum ground water concentrations for this element shown in Table 4.) Based on these comparisons it can be concluded that arsenic in ground water could pose a potential risk to deep-rooted plants that may contact it; however, this potential risk is limited in extent over the Green River site, and does not appear to extend as far as the mouth of Browns Wash to a significant degree.

Potential Risks to Ecological Receptors Associated with Radionuclides

In addition to the nonradiological analytes measured in surface water at the mouth of Browns Wash, radiological parameters were also measured, including gross alpha and gross beta activity, lead-210, radium-226, radium-228, and thorium-230. None of these analytes except gross beta activity were at detectable levels. The maximum gross beta activity (4.24 picocuries per liter [pCi/L]) is very low, and unlikely to be of potential concern to ecological receptors. Radium-226 has been detected in the past in both surface and ground water samples from the Green River site at concentrations as high as 3.0 pCi/L. However, this is well below the screening-level benchmark for aquatic biota (160 pCi/L) derived by Oak Ridge National Laboratory (Bechtel Jacobs Company 1998b), based on the methodology for estimating dose rates for aquatic biota (specifically large and small fish) developed by Blaylock, et al. (1993). Therefore. analysis of radionuclides in surface water and ground water samples from the site indicates no potential ecological risk.

Potential Risks to Sensitive Species

The Colorado pikeminnow is an endangered species that has the potential for occurring in the Green River near the site. The bald eagle is a threatened species that could also occur in this area. Both of these species would be associated with the aquatic habitats of the Green River, the bald eagle potentially using this habitat to catch prey (fish). Because the HQs for aquatic organisms and the bald eagle exposed to E-COPCs at the mouth of Browns Wash were all less than 1, neither of these sensitive species appear to be at risk from these potential exposures.

8.0 Ecological Risk Summary

This ERA has determined that there is little potential for site-related constituents to affect surface water or sediments. There is the possibility that ground water arsenic concentrations could affect deep-rooted plants if and exposure pathways exists. This assessment further concludes that there is limited, if any, potential for sensitive species to be adversely affected by site-related constituents.

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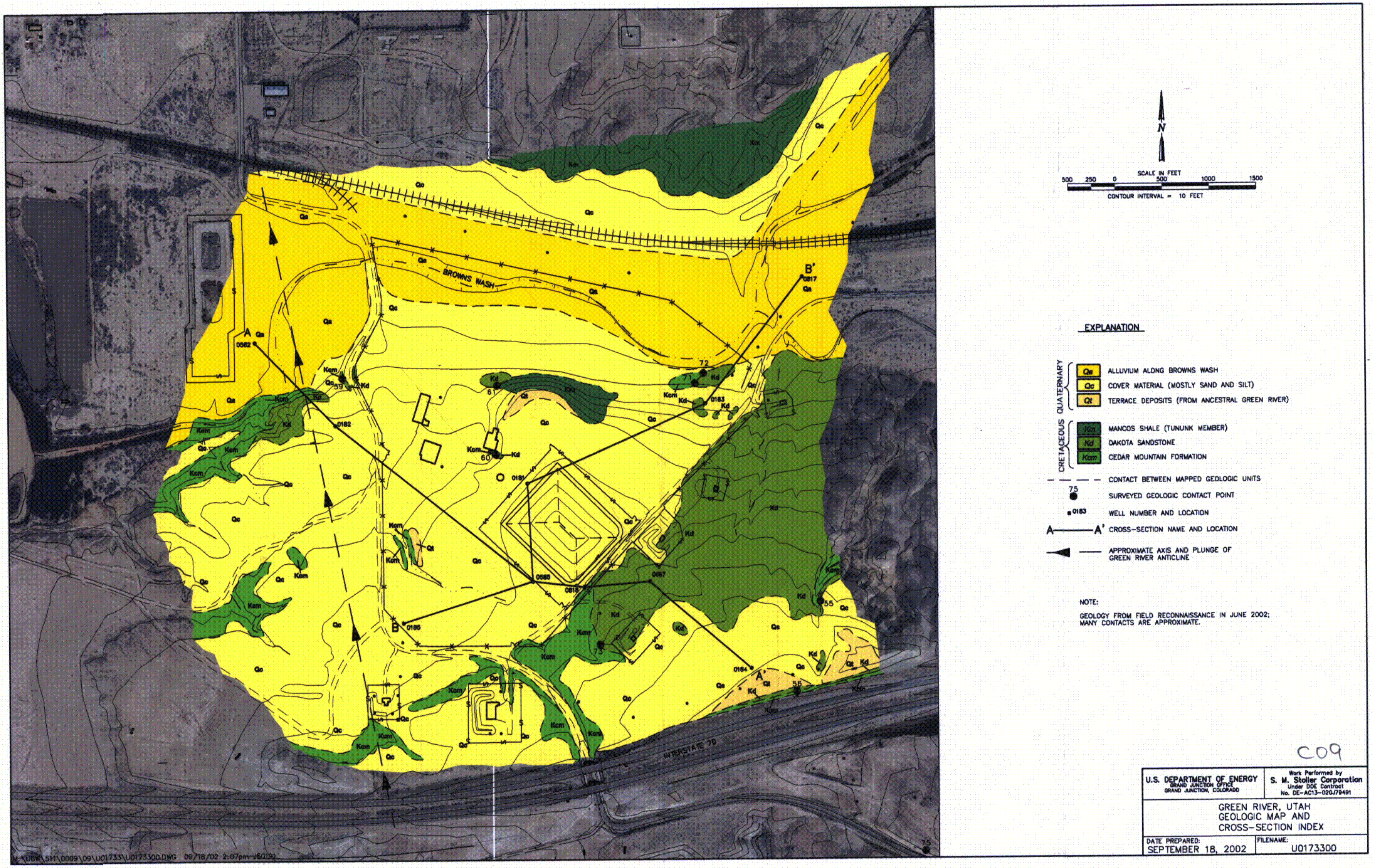

Figure 5–2. Green River, Utah, Geologic Map and Cross-Section Index

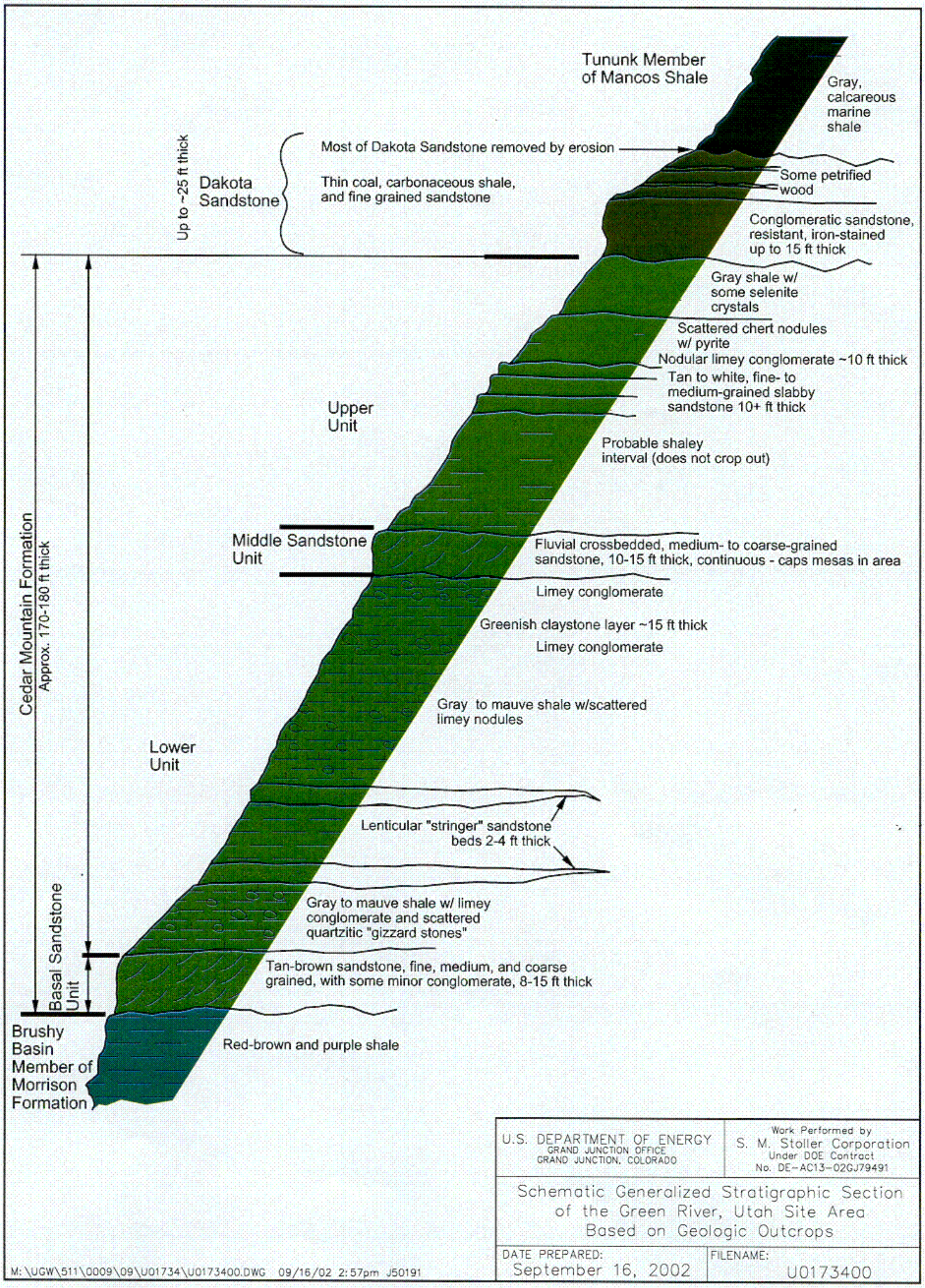

Figure 5–3. Schematic Generalized Stratigraphic Section of the Green River, Utah, Site Area

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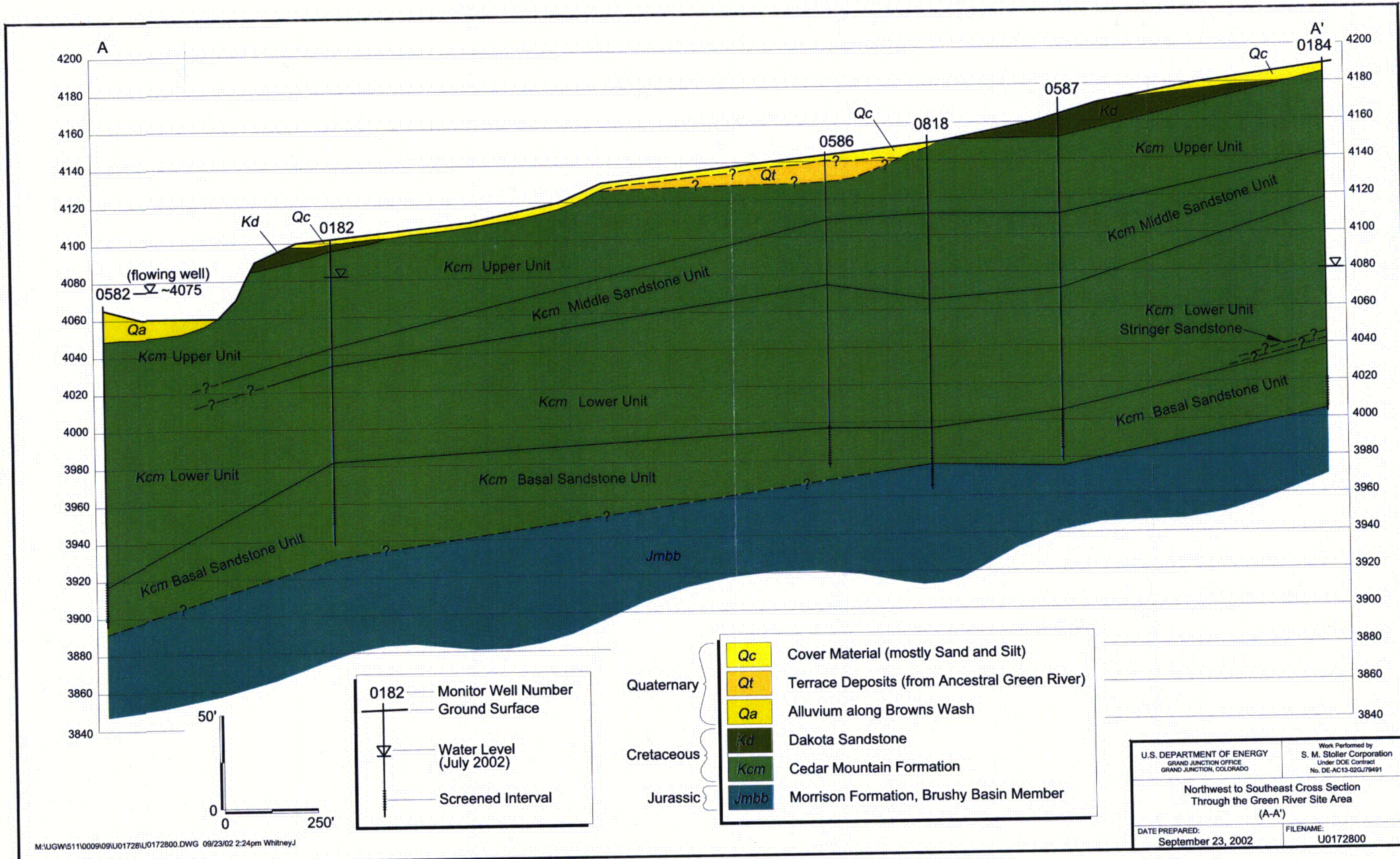

Figure 5–4. Northwest to Southeast Cross Section through the Green River Site Area (A–A')

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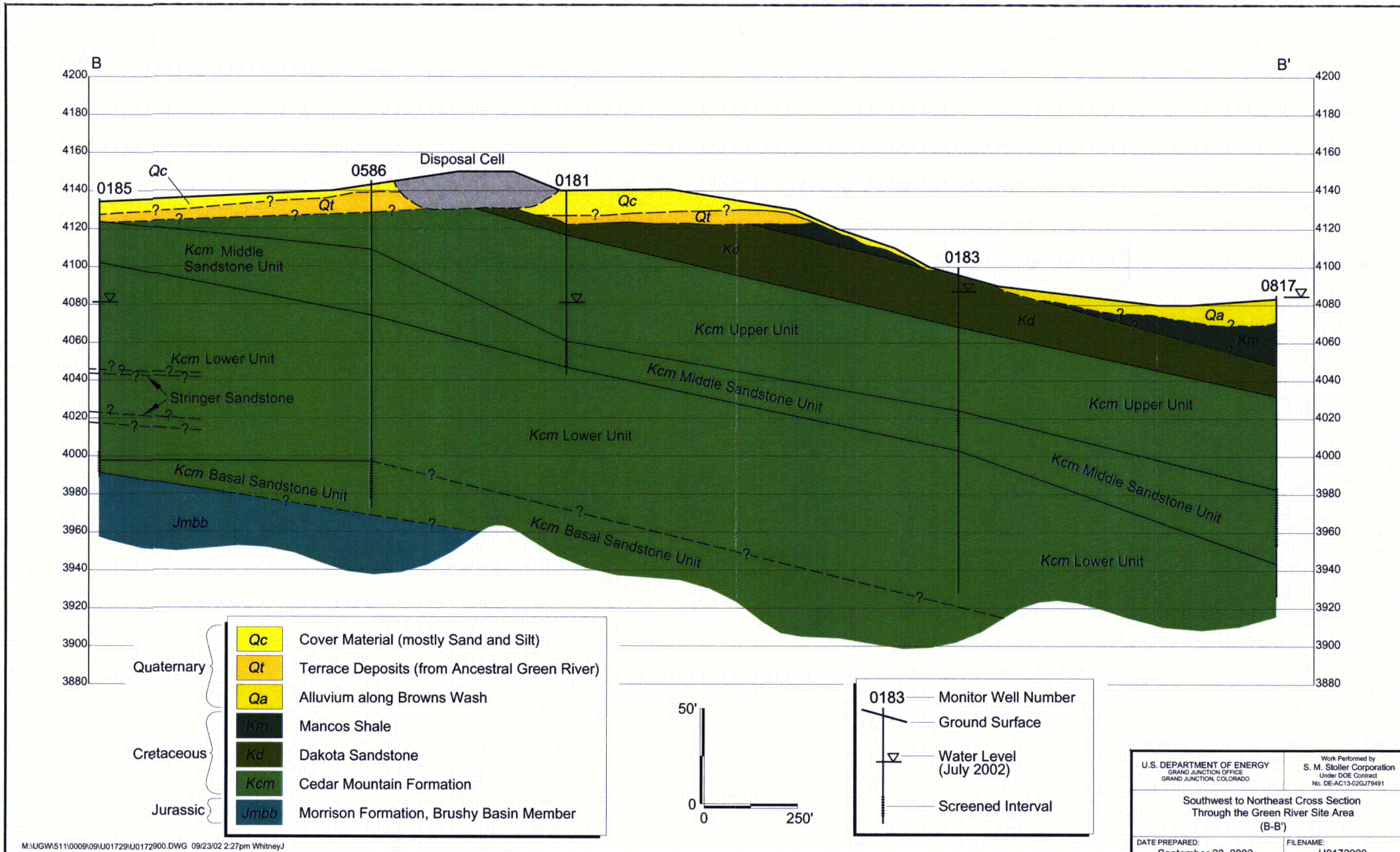

Figure 5–5. Southwest to Northeast Cross Section through the Green River Site Area (B–B')

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