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Groundwater Compliance Action Plan for the Green River, Utah, Disposal Site

December 2011

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1.0 Introduction

This Groundwater Compliance Action Plan (GCAP) presents the compliance strategy for groundwater cleanup at the Green River, Utah, former uranium-ore processing site (Figure 1) as mandated by the Uranium Mill Tailings Radiation Control Act (UMTRCA). The compliance strategy is based on the U.S. Department of Energy's (DOE's) evaluation of information included in the Site Observational Work Plan (SOWP) (DOE 2002), groundwater quality and elevation data to date, and field observations. This GCAP serves as a stand-alone modification to the Remedial Action Plan (RAP) (DOE 1991) and Modification No. 2 to the RAP (DOE 1998a) to address groundwater restoration and compliance with the U.S. Environmental Protection Agency (EPA) groundwater protection standards for the UMTRCA Title I processing sites (60 FR 2854).

This GCAP will be the U.S. Nuclear Regulatory Commission (NRC) concurrence document for compliance with groundwater cleanup standards in Subpart B of the *Code of Federal Regulations*, Title 40, Part 192 (40 CFR 192) for the Green River processing site. Because residual radioactive material is stabilized in an on-site disposal cell, the compliance strategy will also be applicable to Subpart A of 40 CFR 192, which prescribes initial disposal cell performance monitoring.

This preliminary final version of the GCAP updates a previous version prepared in February 2008 by addressing comments from the State of Utah Division of Radiation Control received in letters dated October 7, 2003; August 14, 2006; and September 14, 2009; and comments received during a May 5, 2011, telephone conference call. Upon resolution of all issues, the GCAP will be finalized and submitted for regulatory concurrence with the compliance strategy. At that time, the Long-Term Surveillance Plan for the Green River site (DOE 1998b) will be revised accordingly and will be the document of record for implementation of long-term surveillance activities for the entire site.

National Environmental Policy Act issues and environmental concerns will be addressed later in an Environmental Assessment, which will be made available to public officials and stakeholders for their review and comment.

Section 2.0 of this document provides a summary assessment of environmental data relevant to the development of the groundwater compliance strategy. Section 3.0 discusses the development of the groundwater compliance strategy, and Section 4.0 addresses the implementation of the compliance strategy. The application for alternate concentration limits (ACLs) for the Green River site, as required by EPA regulations in 40 CFR 192 and NRC guidance, is included as Appendix A to this report and is summarized in Section 3.0.

2.0 Assessment of Environmental Data

2.1 Hydrogeology

Groundwater in the vicinity of the Green River site occurs in the Green River alluvium, Browns Wash alluvium, and in sandstone units of the Cedar Mountain Formation. Hydrogeologic data relevant to selection of a groundwater compliance strategy are summarized in this section; additional data are available in Modification No. 2 to the RAP (DOE 1998a) and the SOWP (DOE 2002).

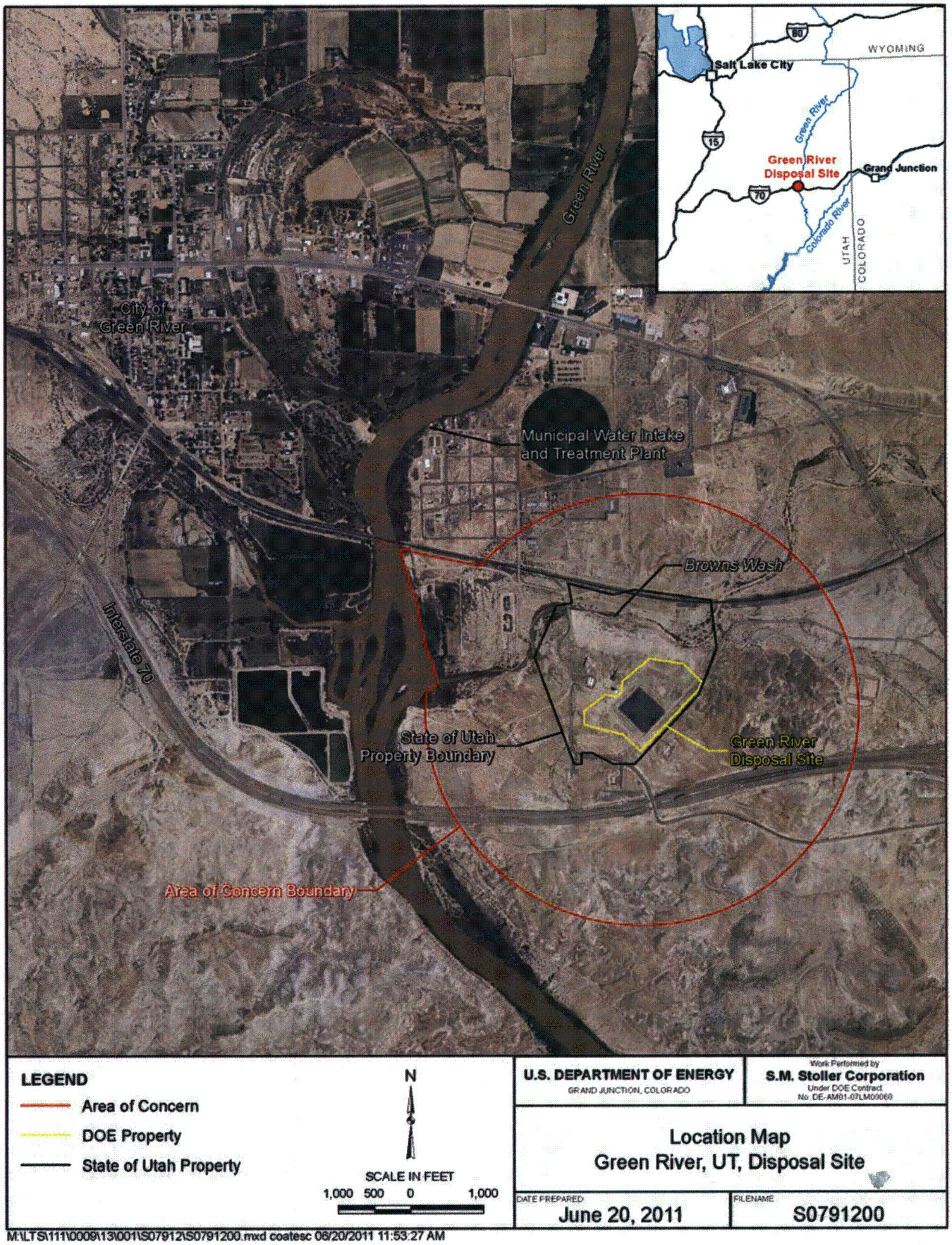

Figure 1. Location of the Green River, Utah, Disposal Site

2.1.1 Browns Wash Alluvium

The Browns Wash channel is located north and west of the site and is approximately 800 feet (ft) from the disposal cell at its nearest point. Groundwater in the Browns Wash alluvium is unconfined and is limited by the lateral extent of the alluvium, which extends up to 400 ft on either side of the wash. The alluvium is directly underlain by bedrock. Depth to groundwater varies from 8 to 17 ft below ground surface in alluvial wells, and saturated thickness ranges from 0 to 3 ft at the base of the alluvium. Groundwater in Browns Wash alluvium is classified as limited use on the basis of low yield and is not considered an aquifer (DOE 2002).

Groundwater in the Browns Wash alluvium flows from east to west and discharges to the Green River alluvial aquifer and eventually the Green River down gradient of the former mill site. Alluvial groundwater also discharges by means of evapotranspiration through deep-rooted plants such as tamarisk and saltbush. Discharge to bedrock appears minimal because of the low permeability of the underlying bedrock (primarily shale) and the upward hydraulic gradient in the water-bearing bedrock units.

Alluvial groundwater receives recharge from infiltration of precipitation and infiltration during storm water events in Browns Wash (Appendix B, Photo 6). Apparently, process water used in milling operations historically contributed recharge to the alluvial system adjacent to the former tailings pile, and moisture contained in tailings deposited over the alluvium on the south side of Browns Wash also likely added recharge.

Upward water flow via fractures in the underlying Cedar Mountain Formation and deeper bedrock units may also contribute recharge to the Browns Wash alluvium. The site is located near the axis of a plunging anticline, and the axis is characterized by vertical fracturing of the associated formations. Several intermittent seeps have been identified in Browns Wash that may be associated with the fractured bedrock system. The primary seep area occurs where the upper unit of the Cedar Mountain Formation (not an aquifer) crops out in Browns Wash northwest of the disposal cell (Appendix B, Photo 5). The middle sandstone unit of the Cedar Mountain Formation is absent beneath this location; well logs indicate that it pinches out somewhere between the disposal cell and Browns Wash.

Small ephemeral pools of water are often present following storm events at several locations in Browns Wash. The pools, usually less than 10 square feet in area, occur in scour holes that form as runoff crosses the bedrock outcrops of the upper unit of the Cedar Mountain Formation and behind boulders in the channel bed (Appendix B, Photo 7). Though temporary and depleted by evaporation, the pools may linger as water continues to feed into them after a runoff event from nearby saturated alluvium. Some pools may also be recharged from seeps at outcrop locations. Frequent observations during 2006, several of which occurred soon after a runoff event, indicated that wildlife do not use the pools as a source of drinking water. Though animal tracks were observed traversing Browns Wash in the general vicinities of two pool locations, few tracks were identified at the pools themselves. Most of the pools had no tracks.

2.1.2 Cedar Mountain Formation

The middle sandstone unit of the Cedar Mountain Formation, which constitutes the uppermost bedrock aquifer beneath the site, occurs approximately 80 ft below the land surface directly under the disposal cell and ranges in thickness from 15 to 40 ft. It is overlain by an upper complexly interbedded unit that acts predominantly as an aquitard. Lithologic logs from boreholes drilled at the site indicated that the middle sandstone unit is unsaturated in some locations, particularly south of the disposal cell. Vertical leakage into and from the middle sandstone has the potential to occur through joints and fractures that intercept it.

Well logs indicate that the middle sandstone unit is not laterally continuous in the vicinity of the site. It pinches out south and west of the disposal site and apparently is not present under Browns Wash northwest of the site. Saturated portions of the unit are observed north and east of the disposal cell. The middle sandstone aquifer is described as being semiconfined along the crest of the plunging anticline, whose axis trends north-northwest about one-third mile west of the disposal cell. The aquifer is considered more confined along the northeast flank of the anticline, where the Cedar Mountain Formation is overlain by the Dakota Formation and the lower unit of the Mancos Shale Formation.

The basal sandstone unit of the Cedar Mountain Formation, also considered an aquifer, occurs approximately 160 ft below land surface at the disposal cell. Groundwater in this unit is largely confined by underlying and overlying sequences of claystone and shale. However, some leakage into and from the basal sandstone appears possible via vertical water migration in joints and fractures associated with the anticline.

Complex structural and stratigraphic features in the bedrock units at the Green River site makes it difficult to clearly identify local groundwater flow direction in the middle and basal sandstone units of the Cedar Mountain Formation. Uncertainties in groundwater flow direction due to the complex hydrogeology associated with the formation in the vicinity of the site are discussed in Section 5.1 of the SOWP (DOE 2002). Continuous water level monitoring in wells completed in the two sandstone aquifer units began in February 2007 to provide a better understanding of flow characteristics (Appendix B, Photos 3 and 4).

Water levels in the middle sandstone unit aquifer have been measured in several monitoring wells since completion of surface remediation in 1989. Hydraulic heads in middle sandstone wells completed near the disposal cell (Figure C–2, Appendix C) generally decreased from 1989 through 1991, remained relatively steady or declined slightly until late 2003. Since 2004, water levels in the middle sandstone unit have increased approximately 8 ft. Water levels at wells screened in the basal sandstone unit (Figure C–1) have appeared to vary independently of water levels observed in the middle sandstone aquifer. Hydraulic heads in the basal unit appear to have increased anywhere from 5 to 11 ft since 2002. It is difficult to attribute changing water levels in the two Cedar Mountain Formation aquifers to specific phenomena, such as transient drainage of moisture from tailings placed in the disposal cell or regional drought conditions that persist for years.

Table 1 and Table 2 provide annual water level measurements for both Cedar Mountain Formation aquifers, obtained from continuous monitoring data collected from 2007 through 2010. Hydraulic gradient calculations using monitored hydraulic heads during this time period suggest that groundwater flow in the middle sandstone unit is toward the northwest, and flow in the basal unit is toward the southwest. Monitoring well 0817, completed in the middle sandstone unit, and well 0582, completed in the basal sandstone unit, are both flowing artesian wells located along the south side of Browns Wash. Because the wells are capped, local water elevations are derived from recorded shut-in pressures. The flowing artesian conditions at these two wells suggest that the intermittently observed seeps from Browns Wash alluvium (Section 2.1.1) may be caused by limited upward migration of Cedar Mountain Formation groundwater in fractures.

Table 1. Groundwater Elevations in the Middle Sandstone Unit Aquifer at the Green River Site

Monitoring Well	Annual Average Groundwater Elevations[a]			
	2007	2008	2009	2010
0171	4087.27	4086.64	4085.70	4085.29
0173	4087.37	4086.64	4085.66	4085.31
0176	4089.23	4088.52	4086.85	4087.00
0179	4088.22	4087.51	4085.97	4086.02
0183	4089.31	4088.43	4086.67	4087.00
0813	4087.38	4086.74	4084.80	4084.97
0817[b]	4087.35	4088.90	4086.10	4088.74

[a] Elevations recorded at 12:00 noon by continuous-monitoring data loggers.
[b] Flowing well; elevation recorded by data logger according to well shut-in pressure.

Table 2. Groundwater Elevations in the Basal Sandstone Unit Aquifer at the Green River Site

Monitoring Well	Groundwater Elevation[a]			
	2007	2008	2009	2010
0182	4084.98	4085.27	4085.42	4085.46
0184	4085.58	4085.92	4086.04	4086.06
0185	4084.71	4085.00	4085.00	4085.12
0582[b]	4083.26	4083.50	4081.52	4080.18
0588	4084.48	4084.72	4084.69	4084.98

[a] Elevations recorded at 12:00 noon by continuous-monitoring data loggers.
[b] Flowing well; elevation recorded by data logger according to well shut-in pressure.

Observations made during the installation of bedrock wells and water level data collected over multiple years indicate that groundwater in the middle sandstone unit directly beneath the disposal cell occurs under artesian conditions. The same types of information collected at basal sandstone wells at the site also indicate the presence of artesian conditions in this deeper unit.

Infiltration of precipitation on outcrops of the middle sandstone unit (the nearest outcrop area is about 2.5 miles southeast of the disposal site) is assumed to be one of the recharge sources for this bedrock aquifer. Additional recharge may occur through vertical leakage from overlying and underlying portions of the Cedar Mountain Formation. Though some middle sandstone groundwater appears to discharge via bedrock joints and fractures into the Green River alluvium and the Browns Wash alluvium, it is assumed that this aquifer loses most of its water through discharge into the Green River, the regional groundwater sink.

Groundwater from the middle sandstone unit is not being used and is generally not a source of domestic water in the area surrounding the Green River site. The underlying basal sandstone unit is considered a more likely source of groundwater in the region. However, a search of State of Utah water well records indicates that no wells are completed in the basal unit within a 5 mile radius of the site. Major sources of usable water in the region are surface water from the Green River and groundwater from the Green River alluvium north (upstream) of Browns Wash.

2.2 Groundwater Quality

2.2.1 General

When compared to background groundwater-quality conditions, groundwater in the Browns Wash alluvium and the middle sandstone unit of the Cedar Mountain Formation beneath the Green River site appears to have been contaminated by former uranium-ore processing activities; the basal unit appears unaffected by site-related activities. The baseline risk assessment (DOE 1994) indicated that several constituents had concentrations elevated above standards or relevant benchmarks in the Browns Wash alluvium groundwater. These included ammonia, arsenic, manganese, nitrate, selenium, sodium, sulfate, and uranium. With the exception of ammonia and manganese, concentrations of these constituents are elevated above a standard or human health risk-based concentration in the middle sandstone unit aquifer of the Cedar Mountain Formation. Table 3 shows the maximum concentrations for these constituents, obtained through sampling since the disposal cell was completed in 1989.

Table 3. Maximum Concentrations of Contaminants in Groundwater at the Green River Site

Constituent	Human Health Benchmark (mg/L)	Browns Wash Alluvium		Middle Sandstone Unit	
		Maximum Concentration in Background Well 0707 (mg/L)	Maximum Concentration in Monitored Wells[a] (mg/L)	Maximum Concentration in Background Well 0817 (mg/L)	Maximum Concentration in the POC Wells[b] (mg/L)
Ammonia (as NH_4)	32[c]	0.3	45.3	0.3	1.0
Arsenic	0.05[d]	0.1	0.0032	0.01	0.191
Manganese	1.7[e]	0.26	3.15	0.01	0.936
Nitrate + Nitrite (as N)	10.0[d]	30.2	1,200	5.3	427
Selenium	0.05[f]	0.267	0.098	0.01	0.860
Sodium	30-60[g]	2050	13,000	594	5,000
Sulfate	250[h]	6620	38,000	137	9,100
Uranium	0.044[d]	0.029	13.000	0.003	0.229

Key: mg/L = milligrams per liter; POC = point of compliance
[a] Wells 0188, 0189, 0192, and 0194 since monitoring was initiated on July 11, 2002.
[b] Wells 0171, 0173, 0176, 0179, 0181, and 0813 since the disposal cell was completed in September 1989.
[c] EPA lifetime health advisory (67 FR 38222).
[d] 40 CFR 192, Table 1.
[e] Risk-based concentration calculated from data in EPA IRIS database.
[f] The Utah groundwater standard for selenium (0.05 mg/L) is greater than the EPA maximum concentration limit (0.01 mg/L) and is used as the benchmark because of elevated levels of naturally occurring selenium in the region.
[g] EPA benchmark value (non-enforceable, based on aesthetics; EPA 2011).
[h] Non-enforceable secondary drinking water standard (EPA 2011).

Monitoring well 0707, completed in the alluvium adjacent to Browns Wash and upgradient from the former processing site and tailings storage area, is a background well. Monitoring well 0817 (located near 0707) is the background well for the middle sandstone unit; well 0184 is a background well for the basal sandstone unit (Figure 2).

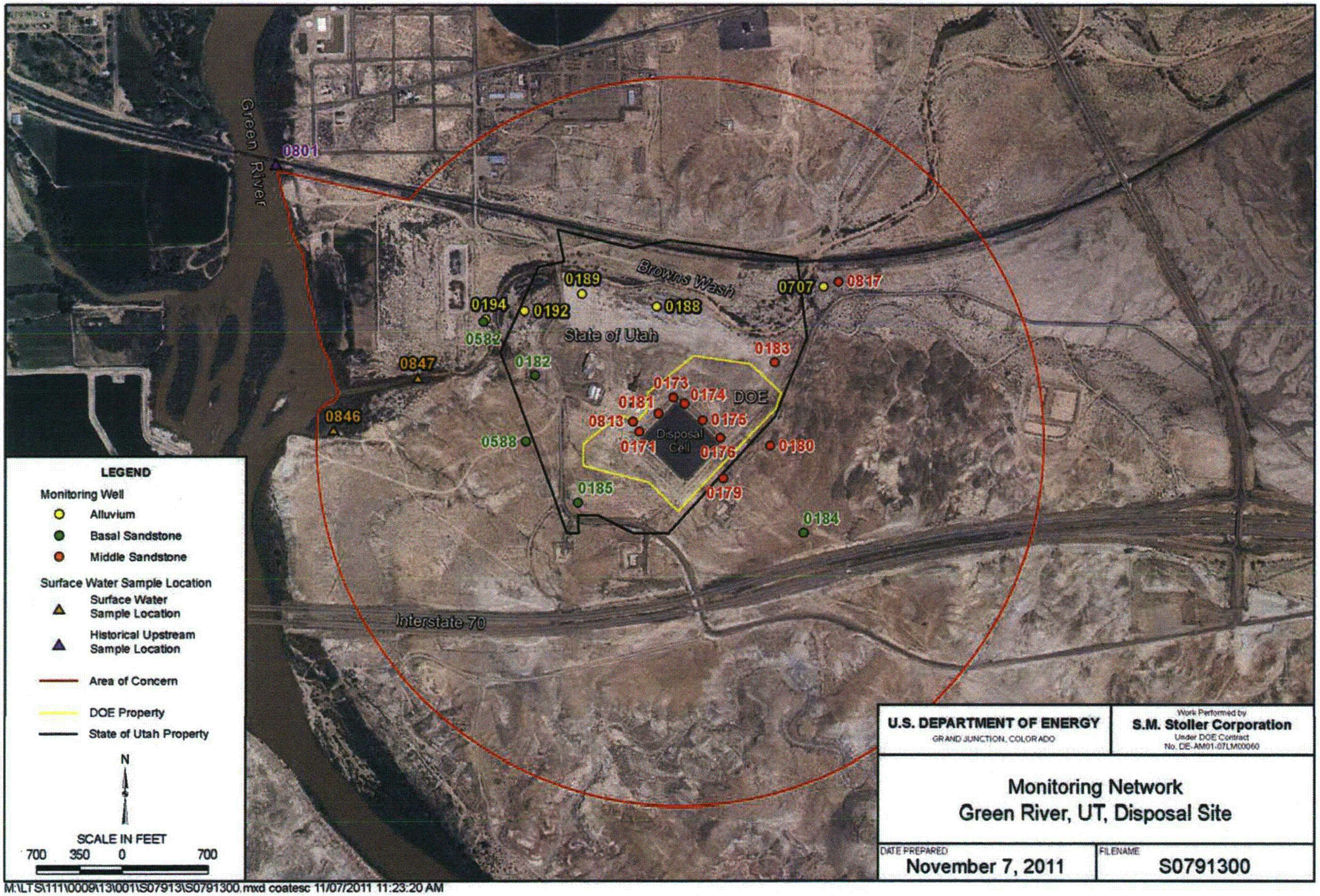

Figure 2. Monitoring Network at the Green River Disposal Site

Of the constituents listed in Table 3, sodium and manganese are not regulated and were therefore eliminated from monitoring requirements. Sulfate also is not regulated, but is a common indicator parameter for uranium mill tailings sites and is part of the analyte suite for monitoring of the site. Table 4 provides a summary of the last five years of monitoring data for the Browns Wash Alluvium wells.

Table 4. Summary of Browns Wash Alluvium Monitoring 2007-2011

Analyte	(all results in mg/L)	0188	0189	0192	0194
Ammonia (total as N)	range	8.2 – 12	0.56 – 43	2.2 – 3.6	<0.1 – 38
	average	9.88	31.11	3.14	10.39
Arsenic	range	0.00022 – 0.00036	0.00055 – 0.0021	0.00022 – 0.00039	0.00045 – 0.0038
	average	0.00028	0.00089	0.00030	0.00257
Nitrate + Nitrite (as N)	range	7.5 – 62	39 – 810	79 – 180	81 – 1,000
	average	20.8	209.2	131.8	590.2
Selenium	range	0.016 – 0.034	0.026 – 0.067	0.069 – 0.111	0.016 – 0.033
	average	0.0248	0.0464	0.091	0.0256
Sulfate	range	7,900[a]	6,200[a]	5,300[a]	23,000[a]
	average	7,900	6,200	5,300	23,000
Uranium	range	0.068 – 0.110	0.100 – 7.1	0.440 – 0.600	0.390 – 13.0
	average	0.087	1.686	0.526	5.158

[a] Only one result during this period

Results indicate considerable intrawell and interwell variability. This is likely due to the fact that the alluvium contains very limited groundwater. Water quality is likely influenced both by precipitation events and prolonged periods of little rainfall and by interaction of groundwater with any residual contamination that may reside on solid phase components comprising the vadose zone. A comparison of data in Tables 3 and 4 shows that, in general, concentrations of all constituents have declined from their maximum values.

2.2.2 Middle Sandstone Unit Aquifer

Historical data suggest that site-related contamination in the middle sandstone unit of the Cedar Mountain Formation is not widespread and is restricted to the area adjacent to the disposal cell (DOE 2002). Table 5 provides summary data for Middle Sandstone Unit wells for the last 5 years. As with the Browns Wash Alluvium, considerable interwell variability exists for certain constituents. However, intrawell variability is quite low. While it appears that some constituents have declined from their maximum observed concentrations (e.g., nitrate, sulfate), other constituents have not (e.g., uranium, selenium). In fact, the maximum observed value for selenium in well 0176 occurred in June 2011. It has been suggested that groundwater movement in the vicinity of the cell is limited based on the structural geology of the Cedar Mountain Formation at the site—along the axis of a plunging anticline (DOE 2002). This results in stagnation of flow and little geochemical variability. Appendix C provides time-concentration plots for arsenic, nitrate, selenium, and uranium in the point-of-compliance (POC) wells.

Table 5. Summary of Middle Sandstone Unit Monitoring 2007-2011

Analyte		0171	0173	0176	0179	0181	0813
Ammonia (total as N)	range	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1 – 0.14
	average	<0.1	<0.1	<0.1	<0.1	<0.1	0.098
Arsenic	range	0.0011 – 0.0015	0.0015 – 0.0024	0.00029 – 0.00065	0.00057 – 0.00074	0.0019 – 0.0048	0.063 – 0.100
	average	0.0013	0.0017	0.00039	0.00065	0.00308	0.0804
Nitrate + Nitrite (as N)	range	44 – 56	170 – 270	54 – 91	19 – 32	64 – 140	<0.01 – 0.1
	average	50.2	238	72.4	21.4	101.6	0.024
Selenium	range	0.14 – 0.210	0.088 – 0.160	0.610 – 0.860	0.200 – 0.420	0.0059 – 0.015	0.00064 – 0.0009
	average	0.176	0.1276	0.762	0.292	0.0104	0.00075
Sulfate	range	3,800[a]	7,900[a]	3,800[a]	3,350[a]	5,400[a]	3,600[a]
	average	3,800	7,900	3,800	3,350	5,400	3,600
Uranium	range	0.093 – 0.130	0.011 – 0.020	0.0024 – 0.0027	0.130 – 0.210	0.011 – 0.016	0.016 – 0.018
	average	0.1058	0.0168	0.00254	0.178	0.0134	0.017

[a] Only one result for this monitoring period

Arsenic concentrations exceed the standard of 0.05 milligram per liter (mg/L) only in well 0813; an overall downward trend has occurred in this well since 1994 (Figure C–3).

As shown on Figure C–4, the nitrate (as N) standard of 10.0 mg/L is exceeded in five of the wells (0171, 0173, 0176, 0179, and 0181). Nitrate concentrations, highest in well 0173, have fluctuated greatly but indicate an overall downward trend since 2002. No trends are apparent in the other wells.

Selenium concentrations exceed the standard of 0.05 mg/L in wells 0171, 0173, 0176, and 0179. The highest selenium concentrations are in wells 0176 and 0179, but they have remained relatively steady in those wells since 1998 (Figure C–5).

Wells 0171 and 0179 have uranium concentrations that exceed the 0.044 mg/L standard, as indicated on Figure C–6. The highest uranium concentrations are in well 0179; although the uranium concentrations have fluctuated in 0179, there has been no visual trend since sampling began in 1990. Uranium concentrations in well 0171 have trended upward since 1997.

All of the wells have sodium and sulfate concentrations substantially above the human health benchmarks listed in Table 3 (neither EPA nor State of Utah groundwater standards have been established for these constituents). Sodium concentrations are greater than 1,000 mg/L in all the POC wells (average background sodium concentration is 550 mg/L). An overall upward trend has been occurring in well 0173, while concentrations have remained steady or decreased in the other wells. Sulfate concentrations are greater than 3,000 mg/L in all the wells and have increased substantially in well 0173 and to a lesser degree in well 0171; concentrations in the other wells have remained steady or decreased (average background sulfate concentration is 130 mg/L). Ammonia and manganese concentrations have never exceeded the human health benchmarks listed in Table 3.

Minor seepage from the disposal cell could have contributed to elevated concentrations of mill-related constituents in the middle sandstone unit of the Cedar Mountain Formation beneath the cell. However, the tailings did not contain appreciable moisture when they were encapsulated, and there has been no consistency or apparent correlation of contaminant concentrations among the different monitoring wells. Processing-related contamination is believed to be primarily responsible for elevated concentrations in the aquifer, although it is possible that some constituents (e.g., selenium) are naturally occurring.

2.3 Surface Water Quality

The main surface water body at the site is the Green River, which is 0.5 mile west of the disposal site. The drainage area for the river is about 24,900 square miles. The river also receives regional discharge from groundwater.

Browns Wash flows only after locally heavy rains. Runoff from the disposal site drains toward Browns Wash, which discharges to the Green River. Very small (<10 square feet) ephemeral pools are often present in the wash after runoff events. In addition, several intermittent seeps occur in the wash. Most of the pooled or seep water evaporates or infiltrates into the Browns Wash alluvium; minor amounts of these two surface water sources migrate via the alluvium to the river backwater area near the mouth of Browns Wash.

Wildlife benchmarks corresponding to No Observed Adverse Effects Level (NOAEL) were obtained from the literature and are presented in Table 6. NOAELs are risk-based concentrations that should present no adverse effects on wildlife if ingested at those concentrations. The NOAELs in Table 6 are for ingestion of contamination through water only; NOAEL values vary depending on the specific study, receptor species, and chemical form. Receptors used in the NOAEL studies include deer, mice, birds, and rabbits, among others. The development of the NOAELs assumes that all water ingested by the receptors is contaminated and that water is the only source of contamination in a receptor's diet. The water-ingestion NOAELs are appropriate for comparison to water quality in the pools in Browns Wash (as opposed to surface water standards for aquatic life) because of the ephemeral nature of the pools and because of the very limited use of the pools by potential receptors. Maximum concentrations of contaminants observed in Browns Wash alluvium are much lower than NOAELs, perhaps with the exception of nitrate. Therefore, even if Browns Wash pools were fed exclusively by the most contaminated water from Browns Wash alluvium, it is highly unlikely that the water would pose an unacceptable risk to potential ecological receptors. The observation of only a few tracks leading to only one pool over a 3-month period of field observations (during a period of several runoff events and active pool formation) indicates that these pools do not serve as an important water source for terrestrial wildlife.

The State of Utah has surface water standards for the protection of aquatic wildlife. These standards apply to the Green River and the backwater area at the mouth of Browns Wash where water is pooled most of the year and where aquatic life is more likely to reside for longer periods. Table 7 presents surface water standards and monitoring results since sampling began in 2001. There is no wildlife surface water standard for uranium.

Table 6. Ecological NOAELs and Browns Wash Alluvium Water Quality

Constituent of Concern	NOAEL Range[a] (mg/L)	Maximum Concentration in Browns Wash Alluvium[b] (mg/L)
Arsenic	0.292–156.9	0.0014
Manganese	377–30,435	3.15
Nitrate[c]	2,719–10,369	1,200 (as N); 940 (as NO_3)
Selenium	0.857–40.662	0.098
Uranium	6.995–488.4	9.5

[a] Sample et al., 1996.
[b] Wells 0188, 0189, 0192, and 0194, monitored since 2002.
[c] Source for NOAELs did not specify how nitrate values were reported.

Table 7. Surface Water Standards for Aquatic Wildlife and Monitoring Results

Constituent of Concern	Surface Water Standard[a] (mg/L)	Maximum Concentration Observed in the Backwater[b] (mg/L)	Maximum Concentration Observed in the Green River[c] (mg/L)
Ammonia (as N)	About 0.5 to 1.0 (pH and temperature dependent)	0.1	0.1
Arsenic	4-day 0.150	0.0014	0.0014
Nitrate (as N)	4	0.14	0.34
Selenium	4 day 0.0046	0.0038	0.00078

[a] Source: Utah Rule R317-2, Standards of Quality for Waters of the State, Table 2.14.2.
[b] Location 0847 in Browns Wash near its confluence with the Green River.
[c] Location 0846 downstream of the Browns Wash confluence with the Green River.

As Table 7 shows, the backwater area and Green River water quality meet surface water quality standards. Because of the low quantity of water discharging from the Browns Wash alluvium, and because it is diluted by the Green River alluvial aquifer prior to entering the backwater area or the Green River, it is likely that Browns Wash alluvium groundwater has very little, if any, influence on the quality of the backwater. Therefore, the Green River is likely the main influence on water quality in the backwater area.

3.0 Groundwater Compliance Strategy

The groundwater compliance strategy for the Green River processing site (Subpart B of 40 CFR 192) is based on the compliance strategy selection framework (Figure 3) following the steps presented in the Programmatic Environmental Impact Statement (PEIS) (DOE 1996). DOE's goal is to implement a cost-effective groundwater compliance strategy at the Green River site that is protective of human health and the environment and returns contaminated groundwater to its maximum beneficial use. Because the disposal cell is located at the Green River processing site, both Subparts A (disposal site) and B (groundwater cleanup) of 40 CFR 192 will be addressed by the groundwater compliance strategy.

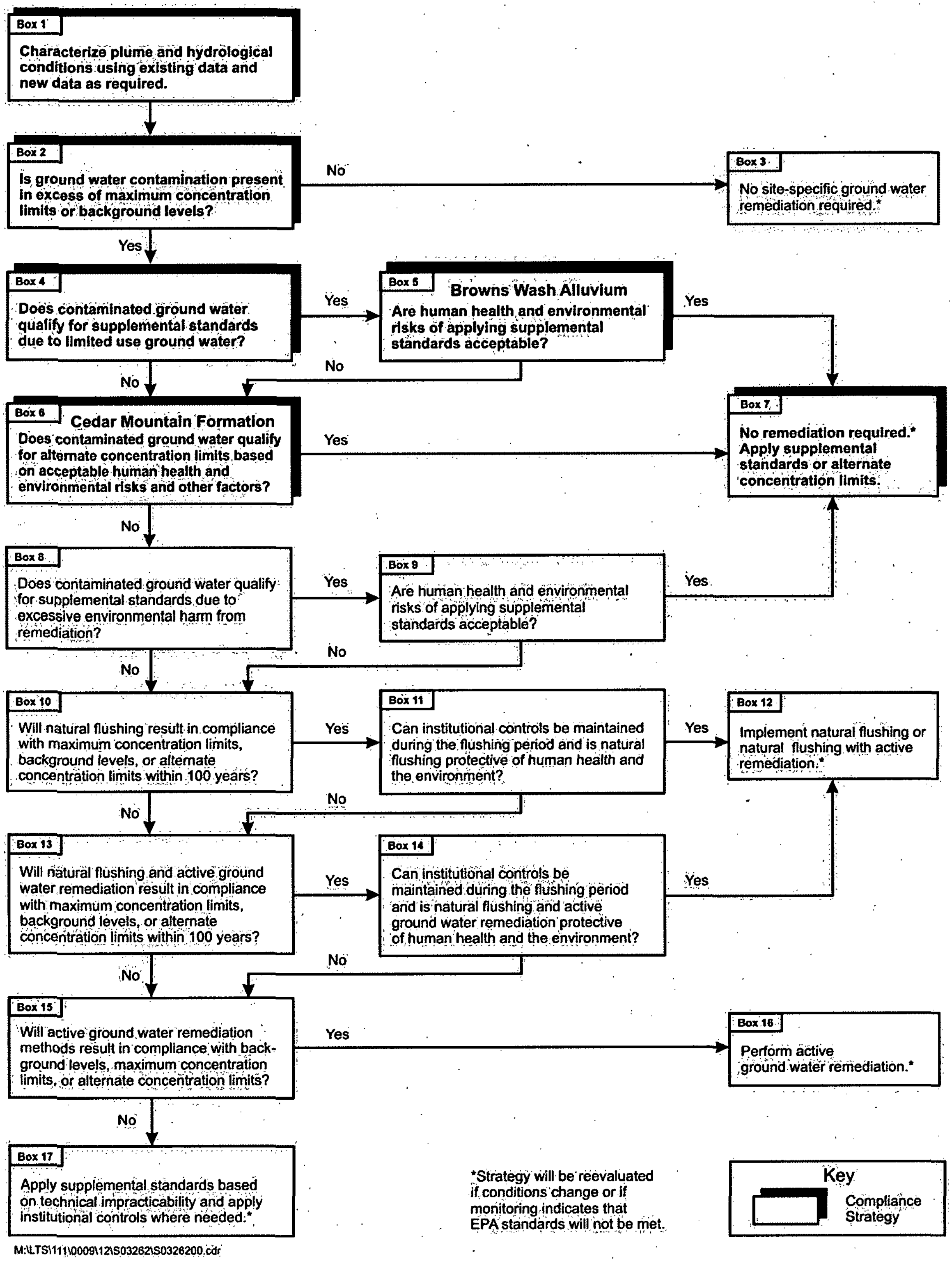

Figure 3. Compliance Strategy Decision Framework

Two distinct hydrostratigraphic units in the vicinity of the site have been impacted by uranium-ore processing activities—the Browns Wash alluvium and the middle sandstone unit of the Cedar Mountain Formation. After an evaluation of existing site information and the decision framework in the PEIS, the compliance strategy is:

- No further remediation with the application of supplemental standards based on limited yield (sustained continuous flow of less than 150 gallons per day) for groundwater in the Browns Wash alluvium; and
- No further remediation and application of ACLs for constituents with concentrations that exceed EPA maximum concentration limits (MCLs) and State of Utah water quality standards for groundwater (Table 3) in the middle sandstone unit of the Cedar Mountain Formation.

The compliance strategy will be implemented in conjunction with groundwater and surface water monitoring to observe the effectiveness of the strategy and through establishment of an area of concern (Figure 1) to provide adequate restriction of nearby groundwater use. Updated risk assessments demonstrate that the compliance strategy will be protective of human health and the environment (DOE 2002 and DOE 2007).

3.1 Browns Wash Alluvium

The compliance strategy for groundwater in the Browns Wash alluvium is no further remediation with application of supplemental standards. This compliance strategy is based on the decision framework in Figure 3 and is explained in Table 8, and it fulfills the requirements for Subpart B of 40 CFR 192.

Table 8. Compliance Strategy Selection Process for Groundwater in the Browns Wash Alluvium

Box from Figure 3	Action or Question	Result or Decision
1	Characterize plume and hydrological conditions.	See conceptual site model presented in Section 5.0 and contaminant screening presented in Section 6.0 of the SOWP. Move to Box 2.
2	Is groundwater contamination present in excess of MCLs or background levels?	Ammonia, manganese, nitrate, selenium, sodium, sulfate, and uranium exceed the EPA MCLs or appropriate benchmarks at one or more monitoring points. Move to Box 4.
4	Does contaminated groundwater qualify for supplemental standards due to limited use groundwater?	Yes. Groundwater in the Browns Wash alluvium qualifies for limited use because it is not capable of a sustained yield of 150 gallons per day. Move to Box 5.
5	Are human health and environmental risks of applying supplemental standards acceptable?	Yes. The quantity of groundwater available would not result in unacceptable exposures. Groundwater currently does not discharge to the surface in quantities sufficient to produce unacceptable environmental risks. Move to Box 7.
7	Compliance strategy	No remediation required. Apply supplemental standards.

Groundwater in Browns Wash alluvium qualifies for supplemental standards based on limited yield (less than 150 gallons per day) as demonstrated by observations of groundwater availability in the alluvial system during field investigations (DOE 2002) and sampling events. Monitoring will be performed as a best management practice in conjunction with the compliance strategy to track and evaluate trends of contaminant concentrations in the alluvium. The monitoring also satisfies a State of Utah concern that supplemental standards consider potential effects on surface water.

3.2 Cedar Mountain Formation

3.2.1 Compliance Strategy

The compliance strategy for groundwater in the middle sandstone unit of the Cedar Mountain Formation is no further remediation with application of ACLs. The compliance strategy is based on the decision framework in Figure 3 and is explained in Table 9, and fulfills requirements for both Subpart A and Subpart B of 40 CFR 192. Implementation of this strategy is presented in this document and will be included in the revised Long-Term Surveillance Plan that is the licensing document for the disposal site (Subpart A of 40 CFR 192).

Table 9. Compliance Strategy Selection Process for Groundwater in the Cedar Mountain Formation

Box from Figure 3	Action or Question	Result or Decision
1	Characterize plume and hydrological conditions.	See conceptual site model presented in Section 5.0 and contaminant screening presented in Section 6.0 of the SOWP. Move to Box 2.
2	Is groundwater contamination present in excess of MCLs or background levels?	Arsenic, nitrate, selenium, and uranium exceed groundwater standards at one or more monitoring points. Move to Box 4.
4	Does contaminated groundwater qualify for supplemental standards due to limited-use groundwater?	Groundwater in the Cedar Mountain Formation is not classified as limited use. Move to Box 6.
6	Does contaminated groundwater qualify for ACLs based on acceptable human health and environmental risks and other factors?	Yes. (1) A disposal cell is above the contaminated area of the aquifer, (2) the State of Utah owns the surrounding land, (3) area of concern can be implemented that would prevent use of contaminated water, and (4) outside the area of concern boundary at the point of exposure, groundwater would be suitable for unrestricted use. Move to Box 7.
7	Compliance strategy	No remediation required. Apply ACLs.

Groundwater in the middle sandstone unit of the Cedar Mountain Formation qualifies for ACLs based on existing conditions at the processing/disposal site (DOE 2002). The application for ACLs for the Green River site, as required by EPA regulations and NRC guidance, is included as Appendix A to this report and is summarized in this section.

At the Green River site, a disposal cell was built at the same location where processing of uranium ores took place. EPA specifically retained the ACL provision in its final groundwater rule (40 CFR 192) "because it is clearly needed, if for no other reason than to deal with the possibilities of unavoidable minor projected seepage over the extremely long-term design life (1,000 years) of the disposal required . . ." (60 FR 2854). The ACL policy was developed for use at sites where concentration levels less stringent than MCLs would still be protective of human health and the environment.

The middle sandstone unit is not laterally continuous, especially to the south and west. State of Utah well records show no wells completed into this unit near the Green River site. Water used for domestic purposes in the Green River area is predominantly surface water obtained from the Green River. The low groundwater flow velocity in the middle sandstone unit impedes the natural flushing of existing contamination from the groundwater system. Because of the limited extent of this unit and associated contamination, and the fact that use of water from this unit is unlikely, active remediation provides little, if any, benefit or risk reduction. Establishment of ACLs with no remediation, therefore, appears to be the most reasonable compliance strategy for the middle sandstone unit of the Cedar Mountain Formation. ACLs may be applied if the constituents will not pose a substantial present or potential hazard to human health and the environment as long as the ACLs are not exceeded. The factors specified in 40 CFR 192.02(c) (3) (ii) (B) have been considered for the Green River site and are included in Appendix A.

3.2.2 Basis for Alternate Concentration Limits

Constituents of potential concern (COPCs) that require ACLs because concentrations exceed their respective EPA groundwater standards (EPA 1995, 40 CFR 192) are arsenic, nitrate, selenium, and uranium. Sodium and sulfate were also identified as COPCs in the SOWP (DOE 2002) because of elevated concentrations; however, these constituents do not have groundwater standards or aquatic benchmarks and will not be monitored. Manganese concentrations—though they exceed aquatic benchmarks—are below human-health risk-based concentrations; therefore, manganese is not considered a COPC for the Cedar Mountain Formation groundwater and will not be monitored.

Based on a comparison of detected concentrations of analytes in groundwater with risk-based concentrations, arsenic is the constituent that makes up greater than 95 percent of the potential risks associated with groundwater use. Nitrate, selenium, and uranium make up most of the remaining risk. Because these four constituents are the only ones of concern at the Green River site for which EPA and the State of Utah have groundwater standards, they are identified as the contaminants for long-term compliance monitoring at the site.

In determining an appropriate method to establish numerical values for ACLs at the Green River site, the methodology used for other uranium mining and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites was reviewed. A case study provided in EPA guidance on groundwater remedial actions (EPA 1988) first considered the potential effect of groundwater discharge on surface water (the point of exposure, or POE). In that study of a former municipal landfill, a dilution factor of 40,000, even under low-flow conditions, led to the conclusion that groundwater discharge would have no impact at the POE. The ACL proposed was simply 10 times the groundwater concentrations observed at that time. This same approach has been used for at least two CERCLA sites (EPA 1989, EPA 1992a). In several other studies with surface water POEs, dilution factors were used to calculate the maximum permissible concentrations in groundwater that would still be protective of discharge to surface water (Umetco 2003; EPA 1990 and 1998). For most sites, it appears that one sitewide ACL was established for each constituent and that the ACL applied to all POC wells (EPA 1998).

At the Green River site, contaminated groundwater in the middle sandstone unit of the Cedar Mountain Formation appears to discharge to surface water in limited quantities. The POE of greatest concern would be Browns Wash. However, because Browns Wash is only likely to contain ephemeral storm water drainage, it is assumed that any groundwater discharging to the wash would be diluted.

The Green River has also been identified as a POE. Average monthly flows in the Green River range from 2,300 to 18,000 cubic feet per second (cfs) in the vicinity of the Green River site (USGS monitoring data for gaging station 09315000, Green River at the city of Green River, Utah). Groundwater discharge from the contaminated portion of the middle sandstone unit is probably less than 10 gallons per minute (0.02 cfs), resulting in a greater than 100,000-fold dilution during low flow periods in the river. This means that, to meet the benchmarks shown in Table 3, concentrations of contaminants in groundwater would have be thousands of times higher than those currently observed.

Because ACL guidance indicates that ACLs should be established at levels that are as low as reasonably achievable, the ACLs are not based on maximum assumed dilution rates. Rather, ACLs are proposed to be two orders of magnitude (100 times) greater than the respective standards and are expected to be achievable based on observed site conditions. As discussed in Section 2.2, some of the monitoring wells adjacent to the disposal cell have experienced great contaminant variability, and further contaminant variability may be expected in the future. The ACLs will accommodate potential future variability and should be more than protective at the POEs, given the assumed dilution rates of the Green River.

The groundwater monitoring network for the ACL compliance strategy for the Cedar Mountain Formation consists of six POC wells adjacent to the disposal cell (0171, 0173, 0176, 0179, 0181, and 0813). These wells are completed in the contaminated middle sandstone unit of the Cedar Mountain Formation and are currently being monitored. The POC wells would monitor potential discharge of contaminants from the disposal cell into the middle sandstone unit of the Cedar Mountain Formation.

3.2.3 Alternate Concentration Limits

For simplicity and ease in implementation, and in accordance with EPA guidance (EPA 1992b), sitewide ACLs will be applied to the POC wells. Table 10 presents the ACLs and maximum analytical results through June 2011 for the six POC wells along with UMTRCA groundwater standards for comparison.

Table 10. Alternate Concentration Limits and Maximum Concentrations for the Green River Site

Constituent[a]	Standard (mg/L)	ACL (mg/L)	Maximum Concentration Observed to Date in POC Wells[c] (mg/L)
Arsenic	0.05[b]	5.0	0.19
Nitrate + Nitrite as N	10.0[b]	1,000	427
Selenium	0.05[d]	5.0	0.86
Uranium	0.044[b]	4.4	0.23

[a] Ammonia will be monitored as a best management practice to compare with surface water concentrations.
[b] 40 CFR 192
[c] Wells 0171, 0173, 0176, 0179, 0181, and 0813.
[d] The Utah groundwater standard for selenium (0.05 mg/L) is greater than the EPA maximum concentration limit (0.01 mg/L) and is used as the benchmark because of elevated levels of naturally occurring selenium in the region.

The methodology used for deriving ACLs in this GCAP differs from that originally proposed in the SOWP. The ACLs proposed in the SOWP were somewhat arbitrary (based on maximum observed concentrations) and considered achievable at the time. Since then, it was recognized that higher ACLs would avoid needlessly triggering the corrective action process and would not increase the risk to human health and the environment. The current approach, using established standards and applying a multiplier (100) to account for geochemical attenuation and dilution, was developed to account for the widely variable concentrations observed at some POC wells. This approach will also be protective of groundwater at the POE, and satisfy the requirement of being as low as reasonably achievable.

The ACLs apply only to the POC wells in the middle sandstone unit. Monitoring results of the basal sandstone unit will be evaluated for the presence of trends that might indicate downward migration of milling-related contamination from the middle sandstone unit. Because sulfate is less likely to be affected by natural attenuation (as compared to the COPCs), sulfate will be the indicator analyte for contaminant transport from the middle sandstone unit to the basal sandstone unit.

3.3 Human Health and Environmental Risk

The human health risk assessment update in the SOWP and subsequent assessments concluded that there is no unacceptable risk from site-related contaminants in groundwater with the application of supplemental standards for the Browns Wash alluvial aquifer and ACLs for the middle sandstone unit aquifer of the Cedar Mountain Formation (DOE 2002 and DOE 2007). The ecological risk assessment determined that there is little potential for site-related constituents to affect surface water or sediments and, consequently, ecological receptors. As noted previously, dilution of any contamination potentially discharging to the surface is likely. In addition, any potential exposure of wildlife to contamination is expected to be infrequent and will not result in any unacceptable risks.

4.0 Compliance Strategy Implementation

The compliance strategy for Subparts A and B of 40 CFR 192 for the Green River site will be implemented in conjunction with groundwater and surface water monitoring and the established area of concern boundary.

4.1 Monitoring Program

Groundwater and surface water will be monitored at selected locations annually to observe the effectiveness of the compliance strategy and ensure the long-term protection of human health and the environment. A summary of the monitoring requirements is presented in Table 11.

Table 11. Summary of Monitoring Requirements for the Green River Site

Location	Monitoring Purpose[a]	Analytes	Frequency
Groundwater			
0171, 0173, 0176, 0179, 0181[b], 0813	POC wells adjacent to the disposal cell and completed in the middle sandstone unit of the Cedar Mountain Formation; monitor cell performance.	Ammonia, arsenic, nitrate, selenium, sulfate, uranium	Annually; reevaluate monitoring requirements at a later date. If an ACL is exceeded, quarterly monitoring is triggered.
0188, 0189, 0192, 0194	Best management practice monitoring wells completed in the Browns Wash alluvium; monitor processing-related contaminants.	Ammonia, arsenic, nitrate, selenium, sulfate, uranium	Annually; reevaluate monitoring requirements at a later date.
0182, 0184, 0185, 0588	Contaminant detection monitoring wells completed in the basal unit of the Cedar Mountain Formation; monitor for presence of processing-related contaminants.	Ammonia, arsenic, nitrate, selenium, sulfate, uranium	Annually; reevaluate monitoring requirements at a later date.
0183, 0582, 0707 0817	Evaluate aquifer flow directions.	Water level only.	Continuous monitoring with automated data loggers beginning in 2007 (except for well 0707); reevaluate monitoring requirements at that time.
Surface Water			
0846, 0847, 0801	Potential POE; monitor for degradation of water quality in the backwater area of Browns Wash and in the Green River immediately downstream of Browns Wash. Location 0801 is historical up-stream Green River; sampling suspended in 2004, resumed in 2012.	Ammonia, arsenic, nitrate, selenium, sulfate, uranium	Annually; reevaluate monitoring requirements at a later date. If a surface water standard is exceeded, quarterly monitoring is triggered.

[a] Monitoring program addresses both Subparts A and B of 40 CFR 192.
[b] Monitoring well 0181 was installed as an offset replacement well for monitor well 0172 due to unsatisfactory completion characteristics.

The groundwater monitoring network for the ACL compliance strategy for the middle sandstone unit of the Cedar Mountain Formation consists of six POC wells adjacent to the disposal cell (0171, 0173, 0176, 0179, 0181, and 0813). The POC wells, shown on Figure 2, will be monitored to measure contaminant concentrations in the middle sandstone unit of the Cedar Mountain Formation. If any constituent in any well exceeds the respective ACL, DOE will conduct quarterly monitoring for two years at the well in which the exceedance occurred. The eight quarterly results will be evaluated, and the need for corrective action will be assessed.

Because the conceptual model of the site indicates that artesian pressure in the middle sandstone unit of the Cedar Mountain Formation could potentially cause groundwater to discharge into the Browns Wash alluvial system via vertical fractures in the formation, alluvial wells 0188, 0189, 0192, and 0194 will be monitored as a best management practice to provide an indication of contaminant migration along this pathway. If contaminated groundwater from the Cedar Mountain Formation were to discharge into the Browns Wash alluvium, the presence of those contaminants probably would be masked by the existing processing-related contaminants in the alluvial groundwater. Because application of supplemental standards is the compliance strategy for the Browns Wash alluvium, sample results will not be compared to ACLs and corrective action will not be triggered.

Groundwater in the underlying basal sandstone unit of the Cedar Mountain Formation has not been contaminated by site-related activities; however, basal sandstone unit wells 0182, 0184, 0185, and 0588 will be sampled annually to monitor for potential contaminant migration from the middle sandstone unit. Because sulfate is less likely to be affected by natural attenuation (as compared to the COPCs), sulfate trends will be evaluated and used as an early indicator for contaminant transport. If sulfate concentrations in the basal sandstone unit trend upwards, DOE will evaluate the practicality of some form of corrective action.
Two surface water monitoring locations (0846 and 0847) are currently being sampled; sampling of historical up-stream Green River location (0801) was suspended in 2004 and will be resumed in 2012. Location 0847 is in the backwater area of Browns Wash near its confluence with the Green River (Appendix B, Photo 9); location 0846 is in the Green River immediately downstream of the mouth of Browns Wash. Monitoring occurs in June, at which time this habitat is most important to endangered fish species, specifically the Colorado pikeminnow (*Ptychocheilus lucius*). This is the time that follows spawning and when the river stage is declining. There are times when the backwater area is nearly filled with sediment from runoff events in Browns Wash, thus eliminating the backwater area as a fish habitat. DOE proposes to continue monitoring the surface water at these locations as a best management practice to verify that any contaminated groundwater discharging to the surface in Browns Wash or the Green River would not adversely affect ecological receptors near the confluence of the wash and the river.

DOE will compare the surface water sampling results to the applicable State of Utah surface water standards (Table 7). If a result exceeds a surface water standard, quarterly monitoring will be conducted at that location for a year.

The monitoring program would satisfy requirements in 40 CFR 192. Table 11 presents a summary of the monitoring program, and Figure 2 shows the monitoring locations. DOE will reassess monitoring requirements every five years and recommend modifications to NRC and the State of Utah as necessary. The reassessment would include an evaluation of water quality trends to help determine the extent and duration of continued monitoring.

4.2 Area of Concern

At the request of DOE (with concurrence from the Utah Division of Radiation Control), the State of Utah Division of Water Rights has included into their Area of Concern (AOC) program an area which falls mostly within a circle of approximate 3,000-ft radius and centered on the disposal cell (Figure 2). The AOC polygon location can be found at the State of Utah website address http:maps.waterrights.utah.gov/mapserver/restricted/startup.htm. The AOC is established to restrict the use of groundwater in the Cedar Mountain Formation and the Green River alluvium within this prescribed area. Specifically, the restriction is that no wells shall be completed in the Cedar Mountain Formation within the area and groundwater extracted from the Green River alluvium shall not be used for domestic purposes. Therefore, by definition, a well drilled outside the AOC becomes a potential POE.

The State of Utah updates the AOC program weekly, if a well permit is filed that falls within this area, both the Utah Division of Radiation Control and the DOE are notified. The Utah Division of Radiation Control and the DOE will then file a protest with the State engineers office to deny the well permit application.

Groundwater in the Browns Wash alluvium is not used and is not expected to ever be used because of its low yield and naturally poor quality; therefore, the Browns Wash alluvium is not included in the AOC. Deeper water-bearing formations in the vicinity of the site, such as the Jurassic Entrada Sandstone, a minimum of 450 ft below the Cedar Mountain Formation, are also not included in the AOC restrictions.

The spatial extent of the AOC was derived largely from calculations that examined potential groundwater flow behavior in response to any well drilled in the basal sandstone unit. The objective was to identify a distance from the disposal cell at which pumping of a well would produce limited drawdown beneath the cell, thereby limiting the downward hydraulic gradient between the middle and basal sandstone units. Thus, migration of contaminants from the middle unit to the basal unit would be unlikely, particularly if pumping was intermittent. It was assumed in the base calculations that each pumping period would last about 15 days and would be followed by an equally long period of no pumping. Additional calculations indicated that, even under the unlikely event that uninterrupted pumping occurred just 600 ft from the disposal cell (i.e., within the 3,000-ft radius of the AOC), it would take more than 300 years for contaminants to migrate from the middle unit to the basal unit.

The calculations, summarized in following sections, were performed using reasonable estimates of the hydraulic properties that control groundwater flow in the basal sandstone aquifer. These estimates were derived from descriptions of the Cedar Mountain Formation presented in the geologic literature. The assumed pumping rate for a well was based on the estimated hydraulic properties. One of the calculations produced an estimated radius of influence created by the well, and another made use of the Theis equation (Domenico and Schwartz 1990) for estimating pumping-induced groundwater drawdowns at various distances from the disposal cell. As shown below, an operating well at a distance of 3,000 ft or more from the tailings cell is expected to have a negligible impact on hydraulic conditions (i.e., water levels, flow direction, flow velocities, vertical migration of contaminants) beneath the disposal cell.

Radius of Influence Estimate

The radius of influence (*ROI*) is calculated using a semi-empirical formula (Bear 1979, p. 306):

$$ROI = 2\sqrt{\frac{K_r bt}{S}}$$

where: K_r = horizontal hydraulic conductivity (ft/day),
b = aquifer thickness (ft)
t = pumping time (days),
S = aquifer storativity (dimensionless).

Assuming K = 0.5 ft/day, b= 30 ft, t = 15 days, and S = 0.0001 (confined aquifer), the *ROI* equals 3,000 ft.

Calculation of Drawdowns

Drawdowns of groundwater in a non-bounded confined aquifer are computed using the Theis equation (Domenico and Schwartz 1990, p. 146):

$$s = \frac{Q}{4\pi Kb} W(u)$$

where:

s = drawdown (ft)
Q = pumping rate (cubic feet per day [ft^3/day]),
$W(u)$ = Theis well function (dimensionless),
u = $r^2S/4Kbt$ (dimensionless),
r = radial distance from pumping well (ft),

and all other parameters are as defined in the previous *ROI* calculation.

Table 12 presents calculated drawdowns for several radial distances from the pumping well (r) up to 3000 ft based on the assumptions that Q = 2 gallons per minute (gpm), or 385 ft^3/day, K = 0.5 ft/day, b = 30 ft, S = 0.0001, and t = 15 days.

Potential vertical flow between aquifers in areas of contamination

An estimate can be made of potential vertical contaminant migration between the middle sandstone unit and the basal unit in response to pumping at a pumping well just outside the AOC (i.e., 3,000 ft from the disposal cell). The estimate was made conservative by assuming that contamination is located within the AOC as close as 600 ft from the pumping well. Drawdown (s) at a radius of 600 ft from the pumping well was calculated to be 5.5 ft after 15 days of continuous pumping. Assuming that ambient hydraulic heads in the middle and basal sandstones were equal prior to the start of pumping and that the interlying fine-grained sediments are 60 ft thick (Δz), the vertical hydraulic gradient (i_z) between the aquifers would be

$$i_z = s / \Delta z = 5.5 / 60 = 0.0917$$

Assuming this gradient persists for many years and that the vertical hydraulic conductivity (K_z) and effective porosity (n_e) of the interlying sediments are 0.001 ft/day and 0.20, respectively, the long-term downward interstitial velocity (v_z) would be

$$v_z = K_z \, i_z / n_e = 0.00046 \text{ ft/day}$$

The corresponding travel time across the interlying sediments (t_z) would be:

$$t_z = \Delta z / v_z = 60 \text{ ft}/0.00046 \text{ ft/day} \cong 130{,}000 \text{ days} = 356 \text{ years}$$

Table 12. Calculated Drawdowns in the Basal Sandstone Unit at the Green River Site

Radial Distance from Pumping Well	Hydraulic Conductivity	Aquifer Thickness	Storativity	Pumping Time	Theis Well Function	Pumping Rate	Drawdown
r	K_r	*b*	*S*	*t*	*W(u)*	*Q*	*s*
(ft)	(ft/day)	(ft)	(-)	(days)	(-)	(ft^3/day)	(ft)
300	0.5	30	0.0001	15	4.0379	385	8.3
320	0.5	30	0.0001	15	3.9102	385	8.0
340	0.5	30	0.0001	15	3.7904	385	7.7
360	0.5	30	0.0001	15	3.6777	385	7.5
380	0.5	30	0.0001	15	3.5712	385	7.3
400	0.5	30	0.0001	15	3.4703	385	7.1
420	0.5	30	0.0001	15	3.3745	385	6.9
440	0.5	30	0.0001	15	3.2834	385	6.7
460	0.5	30	0.0001	15	3.1964	385	6.5
480	0.5	30	0.0001	15	3.1134	385	6.4
500	0.5	30	0.0001	15	3.0339	385	6.2
520	0.5	30	0.0001	15	2.9577	385	6.0
540	0.5	30	0.0001	15	2.8845	385	5.9
560	0.5	30	0.0001	15	2.8142	385	5.8
580	0.5	30	0.0001	15	2.7465	385	5.6
600	0.5	30	0.0001	15	2.6813	385	5.5
620	0.5	30	0.0001	15	2.6183	385	5.4
640	0.5	30	0.0001	15	2.5576	385	5.2
660	0.5	30	0.0001	15	2.4989	385	5.1
680	0.5	30	0.0001	15	2.4421	385	5.0
700	0.5	30	0.0001	15	2.3871	385	4.9
720	0.5	30	0.0001	15	2.3338	385	4.8
740	0.5	30	0.0001	15	2.2821	385	4.7
760	0.5	30	0.0001	15	2.2320	385	4.6
780	0.5	30	0.0001	15	2.1834	385	4.5
800	0.5	30	0.0001	15	2.1362	385	4.4
820	0.5	30	0.0001	15	2.0902	385	4.3
840	0.5	30	0.0001	15	2.0456	385	4.2
860	0.5	30	0.0001	15	2.0022	385	4.1
880	0.5	30	0.0001	15	1.9599	385	4.0
900	0.5	30	0.0001	15	1.9187	385	3.9
920	0.5	30	0.0001	15	1.8786	385	3.8
940	0.5	30	0.0001	15	1.8396	385	3.8
960	0.5	30	0.0001	15	1.8015	385	3.7
980	0.5	30	0.0001	15	1.7643	385	3.6
1000	0.5	30	0.0001	15	1.7281	385	3.5
2000	0.5	30	0.0001	15	0.6333	385	1.3
3000	0.5	30	0.0001	15	0.2194	385	0.4

This estimate is considered very conservative because data from the site indicate that contamination in the middle sandstone unit is much farther than 600 ft from the AOC boundary and is more likely to occur in the near vicinity of the disposal cell, or about 1,500 to 2,500 ft from the AOC boundary. Similarly, because groundwater levels in the two aquifers would be expected to quickly recover to pre-pumping levels each time well pumping ceases, the difference in hydraulic head between the two aquifers would not be maintained for the lengthy period (years) assumed here. As a consequence, vertical migration of contaminants from the middle sandstone aquifer to the basal aquifer, if any, would take much longer than the 356 years implied in this calculation. For these reasons, the AOC boundary is expected to adequately protect against downward contaminant migration from the middle sandstone unit.

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Appendix A

Application for Alternate Concentration Limits for the Green River, Utah, Disposal Site

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Contents

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1.0 Introduction

1.1 Purpose

The purpose of this document is to fulfill the U.S. Nuclear Regulatory Commission (NRC) requirements for an application for alternate concentration limits (ACL) for uranium and other constituents of potential concern (COPCs) at the Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I disposal site at Green River, Utah. The focus is on groundwater in bedrock of the Cedar Mountain Formation beneath and downgradient from the disposal cell. Much of the information required by NRC for an ACL application (Title 10 *Code of Federal Regulations* Part 40 [10 CFR 40]; Appendix A; and NRC 1996) has been compiled in the Baseline Risk Assessment (DOE 1995), Modification No. 2 to the Remedial Action Plan (DOE 1998a), the Site Observational Work Plan (SOWP) (DOE 2002) for the Green River site, and the Groundwater Compliance Action Plan (GCAP)(DOE 2007).

As an appendix to the GCAP, this document provides a link between NRC evaluation criteria and relevant discussions of those criteria in previous documents. NRC guidance for preparing ACL applications for UMTRCA Title II sites (NRC 1996) was used as a model for this application. This document summarizes pertinent information from the SOWP regarding "Factors Considered in Making Present and Potential Hazard Findings" (Table 1 in NRC 1996; also specified in 40 CFR 192 with slight modifications). It also identifies sections of the SOWP that contain information corresponding to sections listed in the "Standard ACL Application Format" (Table 2 in NRC 1996). This approach ensures that all factors and information related to the proposed ACLs have been considered.

Section 2.0 of this document discusses the constituents for which ACLs are proposed and the rationale for the proposed numerical values. Section 3.0 summarizes the factors considered in making hazard findings. Section 4.0 presents the "roadmap" to the SOWP, following the standard ACL application format.

1.2 Site Background

The Green River disposal site is approximately 1.5 miles southeast of the city of Green River, in Grand County, Utah (Figure A–1). The site is immediately south of the ephemeral Browns Wash and approximately 0.5 mile east of the Green River. Surface elevations at the site range from 4,075 to 4,140 feet. The site is surrounded by State of Utah property that is bounded on the north by U.S. Army and private property, on the south by U.S. Army property, and on the east and west by Umetco Minerals Corporation (Umetco) property. The U.S. Army property is part of the Utah Launch Complex of the White Sands Missile Range.

The city of Green River is a community of approximately 1,000 residents on the border of Emery and Grand counties, Utah. The economy of the area depends mainly on agriculture and tourism. The former uranium-ore processing site is currently owned by the State of Utah, and the disposal cell area is owned by the U.S. Department of Energy (DOE) (Figure A–1). The former processing site is not currently being used. Several of the mill buildings were decontaminated and remain on State property. These buildings are currently abandoned and in a state of disrepair. There is also an abandoned water tower on State property immediately northwest of the disposal cell.

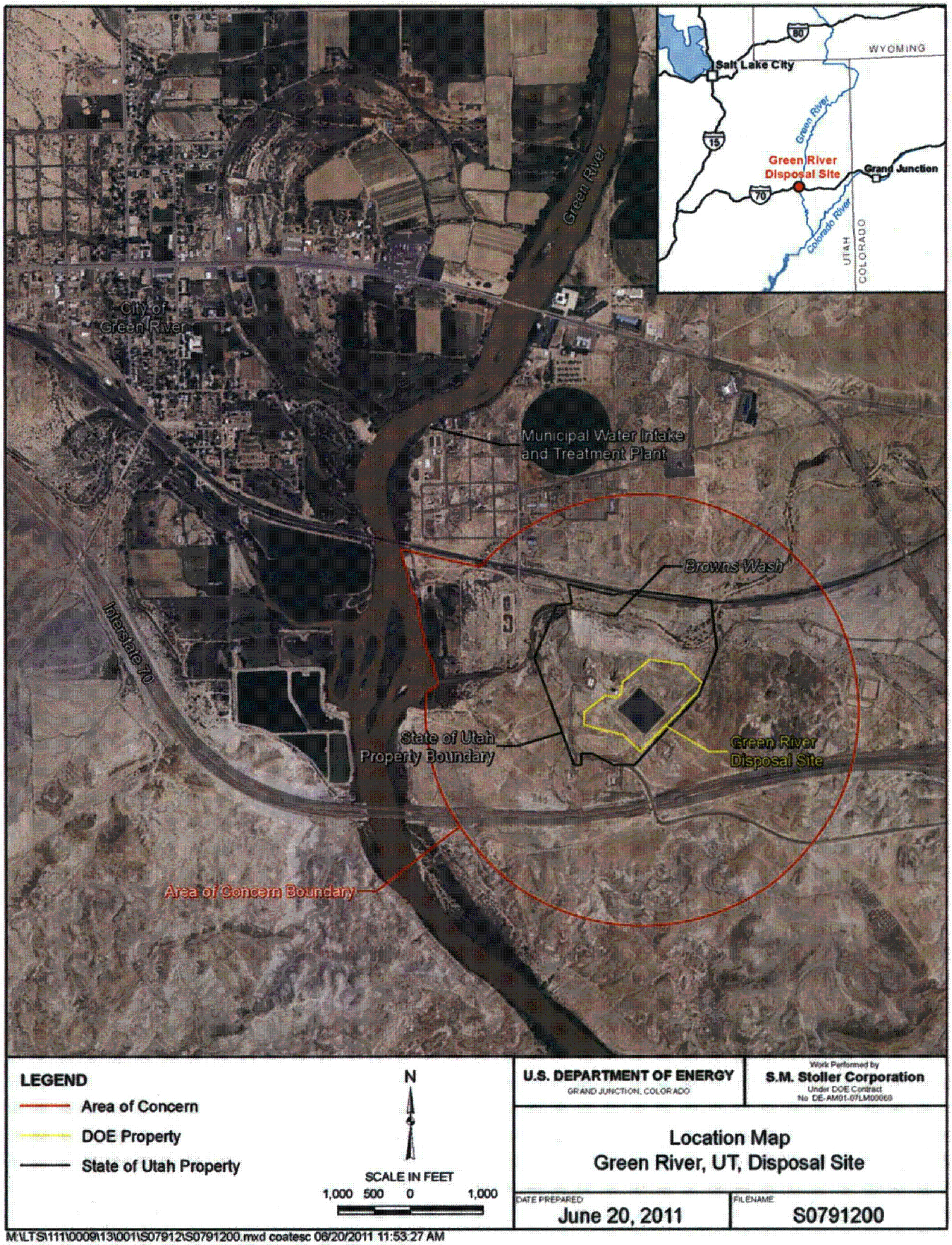

Figure A–1. Location of the Green River, Utah, Disposal Site

Groundwater is not a current source of drinking water in the area of the Green River site because of the availability of good-quality water from the Green River municipal water-supply system (DOE 1995). The water-intake station and treatment plant are on the east side of the Green River, approximately 0.75 mile upstream of the mouth of Browns Wash. Residents of the city of Green River are connected to the municipal water system. One residence west of the site is reportedly not connected to the system, but the owner hauls water for domestic purposes from the city water-supply system and stores it in a water tank. The nearest domestic wells in the area are north of U.S. Highway 6&50 and south of Interstate Highway 70. Groundwater from these wells is used for irrigation (DOE 1995). There are no known current uses of surface water or groundwater along Browns Wash in the vicinity of the site.

The uranium mill at the Green River site was constructed in 1957 and operated from March 1958 through January 1961 by Union Carbide Corporation. The plant was operated for upgrading uranium ore from the Temple Mountain mining district area approximately 60 miles southwest of the site. During its 3 years of operation, the mill processed 183,000 tons of ore with an average grade of 0.29 percent uranium oxide (FBDU 1981). The upgraded ore concentrate was shipped by rail to Rifle, Colorado, for further processing. The former Green River plant generated an estimated 137,000 tons of tailings, which covered approximately 9 acres to an average depth of 7 feet. After milling operations were completed, Union Carbide leased the site to a company under contract with the U.S. Department of Defense, which used the mill buildings for missile testing and assembly. Union Carbide owned the uranium mill site until the State of Utah acquired ownership in 1988.

The processing site was remediated from November 1988 through September 1989, and all mill tailings and residual radioactive materials were stabilized in a partially below-grade disposal cell in the area just southeast of the former mill buildings (Figure A–1). The disposal cell base is about 35 feet below grade, and contaminated materials were emplaced in the cell to about 40 feet above grade. The disposal cell, closed on September 15, 1989, covers approximately 6 acres. The area of the former tailings pile and all areas disturbed at the site during the remedial action were backfilled, graded to promote surface drainage, and revegetated.

2.0 Proposed ACLs

2.1 ACL Applicability

The U.S. Environmental Protection Agency (EPA) provided guidance for applying ACLs at Resource Conservation and Recovery Act (RCRA) hazardous waste facilities (EPA 1987). The NRC used this guidance as a basis for developing ACL guidance for UMTRCA Title II uranium mills (NRC 1996). EPA further indicated that ACLs could similarly apply to UMTRCA Title I processing sites, particularly in instances where a disposal cell is present. As noted in the preamble to the final rule for Title I sites (60 FR 2854), "EPA has decided not to delete the ACL provision because it is clearly needed, if for no other reason than to deal with the possibilities of unavoidable minor seepage over the extremely long-term design life (1,000 years) of the disposal required . . ." Both EPA RCRA ACL guidance and NRC Title II ACL guidance were referenced in these regulations as providing criteria for assessing the appropriateness of using ACLs at a given site.

The ACL policy was developed for use at sites where concentration levels less stringent than EPA maximum concentration limits (MCLs) or background would still be protective of human health and the environment or for application to constituents for which MCLs have not been developed. A further function of an ACL is to serve as a "trigger" to evaluate whether corrective action is required (EPA 1987). For UMTRCA Title I sites, exceedence of an ACL initiates the corrective action process (40 CFR 192.04). Furthermore, ACLs for UMTRCA Title II sites are supposed to be established at levels "as low as reasonably achievable" (ALARA) (NRC 1996).

In the case of the Green River site, a disposal cell was built at the location where uranium ores were once processed. Minor seepage from the disposal cell may have resulted in somewhat elevated concentrations of mill-related constituents in the uppermost aquifer (middle sandstone unit of the Cedar Mountain Formation) beneath the cell, though tailings did not contain appreciable moisture when they were emplaced. Estimates are that the tailings at the Green River site were 15 to 25 percent saturated when placed in the cell (DOE 1991); no slimes were present.

If any transient drainage continues, it should be minimal and probably confined to the immediate vicinity of the disposal cell.

Water levels in wells adjacent to the disposal cell generally increased for about 3 years, declined for the next 11 years, and then began increasing again in late 2004 (Appendix C, Figure C–1). Initial transient drainage from the disposal cell may have caused a temporary increase in water levels in the early 1990s, followed by decreasing levels as drainage slowed. Some of the decrease, to levels below initial measurements, may also be attributable to drought conditions that persisted in the area for several years. Precipitation in the region has returned to normal or above-normal amounts, and current water levels are greater than historical measurements. Since 2004, water levels in the middle sandstone unit have increased approximately 8 feet.

Groundwater flow direction in the middle sandstone unit of the Cedar Mountain Formation is to the northwest, and the flow velocity is apparently very low. Contamination is confined to the immediate vicinity of the cell. The middle sandstone unit is not laterally continuous, especially to the south and west. Although there are no data to verify it, some groundwater from the middle sandstone unit of the Cedar Mountain Formation may discharge through joints and fractures to the alluvium in Browns Wash, which qualifies for supplemental standards due to low groundwater yield, or to the Green River alluvium (DOE 2002).

Water used for domestic purposes in the Green River area is predominantly surface water obtained from the Green River and withdrawn upstream of the Browns Wash confluence. Most of the groundwater used in the area is obtained from the Green River alluvium (DOE 1995). The low groundwater flow velocity in the middle sandstone unit impedes the natural flushing of existing contamination from the groundwater system. However, because of the limited extent of this unit and associated contamination, and the fact that use of water from this unit is unlikely, active remediation provides little, if any, benefit or risk reduction. Establishment of ACLs with no remediation is the most reasonable compliance strategy for the middle sandstone unit of the Cedar Mountain Formation.

2.2 ACLs and Compliance Assessment

2.2.1 Constituents of Potential Concern

Table A–1 shows the maximum concentrations of various contaminants in the Cedar Mountain Formation. Provided for comparison are relevant human health and aquatic benchmarks.

Table A–1. Maximum Groundwater Concentrations in the Cedar Mountain Formation and Relevant Benchmarks for the Green River Site

Constituent	Human Health Benchmark (mg/L)	Aquatic Benchmark (mg/L)	Maximum in Cedar Mountain Formation[a] (mg/L)
Ammonia	30 (total as NH_3) 32 (total as NH_4)[b]	<6 (total as N) <7.7 (total as NH_4)[c]	1.0
Arsenic	0.05[d]	0.150[c]	0.19
Manganese	1.7[e]	0.08[f]	0.94
Nitrate + Nitrite (as N)	10.0[d]	NA	427
Selenium	0.05[g]	0.005[c]	0.86
Sodium	120[h]	NA	5,000
Sulfate	500[i]	NA	9,100
Uranium	0.044[d]	0.0026–0.455[j]	0.23

Key: mg/L = milligrams per liter; NA = not applicable

[a] Wells 0171, 0173, 0176, 0179, 0181, and 0813 were installed after the disposal cell was completed in September 1989.

[b] EPA lifetime health advisory (EPA 2002b).

[c] National Recommended Water Quality Criteria (EPA 2002c).

[d] EPA (EPA 1995; 40 CFR 192, Table 1).

[e] Risk based concentration calculated from data in EPA IRIS database.

[f] EPA Ecotox Threshold (EPA 1996).

[g] The Utah groundwater standard for selenium (0.05 mg/L) is greater than the EPA MCL (0.01 mg/L) and is used as the benchmark because of elevated levels of naturally occurring selenium in the region.

[h] EPA benchmark value (nonenforceable; 67 FR 38222).

[i] EPA health-based advisory for acute effects (EPA 2002a).

[j] Suter and Tsao 1996.

COPCs that require ACLs because concentrations exceed their respective EPA (EPA 1995; 40 CFR 192) or State of Utah (Rule R317-6-2) groundwater standards are arsenic, nitrate, selenium, and uranium. Sodium and sulfate were also identified as COPCs in the SOWP (DOE 2002); concentrations are substantially elevated above human health benchmarks, but no MCLs exist for these constituents and no ACLs are proposed for them. Manganese concentrations, though they exceed an aquatic benchmark, are below human-health risk-based concentrations; therefore, manganese is not a COPC for the Cedar Mountain Formation groundwater. Ammonia concentrations have never exceeded human health or aquatic benchmarks in Cedar Mountain Formation groundwater samples.

Based on a comparison of detected concentrations of analytes in groundwater with risk-based concentrations, arsenic comprises greater than 95 percent of the potential risks associated with groundwater use. Nitrate, selenium, and uranium comprise most of the remaining risk. Because these four constituents (arsenic, nitrate, selenium, and uranium) are the only contaminants of concern at the Green River site for which EPA and Utah have groundwater standards, they are proposed as the contaminants for long-term compliance monitoring at the site.

2.2.2 Point of Compliance and Point of Exposure

In establishing an ACL, two locations must be defined—the point of compliance (POC) and point of exposure (POE). The POC is defined as the site-specific locations in the uppermost aquifer where the groundwater protection standards must be met. In contrast, the POE is defined as the locations where humans, wildlife, or other environmental receptors could reasonably be exposed to hazardous constituents from the groundwater (NRC 1996). In the ACL guidance for UMTRCA Title II sites, NRC notes "The POE, in most situations, will be located at the downgradient edge of the land that will be transferred to either the Federal government or the State where the site is located for long-term institutional control . . ."

In the case of the Green River site, the disposal site itself is currently owned by DOE, and the State of Utah owns the land surrounding the disposal cell. Six monitoring wells completed in the middle sandstone unit and located adjacent to the disposal cell are currently being monitored as POC wells for Subpart A compliance. Borehole data indicate that the middle sandstone unit is generally absent south and west of the perimeter of the State-owned property, and groundwater-level monitoring data indicate that the groundwater flow direction in the middle sandstone is to the northwest from the cell. Based on information presented in the SOWP (DOE 2002), Browns Wash and the Green River are the most likely discharge areas for groundwater in the middle sandstone unit. Therefore, these will be considered potential POEs. Also, any well drilled outside of the area of concern is a POE.

DOE currently monitors two surface water locations to be evaluated as POEs: in the backwater area of Browns Wash near its confluence with the Green River (location 0847) and in the Green River immediately downstream of the confluence of Browns Wash (location 0846). Because of the uncertainty of the discharge location for the middle sandstone unit, however, elevated contaminant levels at the POE locations may not be able to be correlated with the POC sample results, and no corrective action will be triggered.

Revision 2 of the Long-Term Surveillance Plan (LTSP), which was the regulatory document required by NRC when the disposal site was licensed (DOE 1998b), addresses only Subpart A of 40 CFR 192 and consists of monitoring four POC wells adjacent to the disposal cell. This proposed monitoring program, consisting of six POC wells and two POE surface locations to address disposal cell performance and contaminated groundwater from the former processing site, would satisfy requirements for both Subpart A and Subpart B of 40 CFR 192 and would be incorporated into Revision 3 of the LTSP.

2.2.3 Rationale and Implementation

In establishing ACLs for the Green River site, DOE evaluated historical trends in groundwater quality. Time-concentration plots for arsenic, nitrate, selenium, and uranium in monitoring wells adjacent to the disposal cell are shown in Appendix C of the GCAP (Figures C–2 through C–5). Many of these plots show erratically fluctuating concentrations over time, and in some wells, concentrations of some constituents that trend upward while others show a downward trend. The fluctuating constituent concentrations in the groundwater have not been correlated to any natural event.

In determining an appropriate method to establish numerical values for ACLs at the Green River site, the methodology used for other uranium mining and Comprehensive Environmental

Response, Compensation, and Liability Act sites was reviewed. One case study on groundwater remedial actions (EPA 1988) first considered the potential effect of groundwater discharge on surface water (POE). In that study of a former municipal landfill, a dilution factor of 40,000, even under low-flow conditions, led to the conclusion that groundwater discharge would have no impact on water quality at the POE. The ACL proposed was simply 10 times the groundwater concentrations observed at that time. This same approach was used for at least two CERCLA sites (EPA 1989, EPA 1992a). In several other studies with surface water POEs, dilution factors were used to calculate ACLs that would still be protective of surface water (Umetco 2003; EPA 1990 and 1998). For most sites, one sitewide ACL was established for each constituent, and the ACL was applied to all POC wells (EPA 1998). As explained below, DOE proposes that ACLs for the Green River site be 100 times the respective EPA and State of Utah standards and that they be applied to each of the POC wells.

If the contaminated portion of the middle sandstone unit of the Cedar Mountain Formation has a surface exposure, it is likely the Green River. Average monthly discharge rates for the Green River, based on U.S. Geological Survey monitoring data, range from 2,300 to 18,000 cubic feet per second (cfs) in the vicinity of the Green River site. Assuming a conservative groundwater discharge rate of 10 gallons per minute (0.02 cfs), the dilution would be greater than 100,000-fold during low flows in the river. This means that to meet the benchmarks contained in Table A–1, concentrations of constituents in groundwater at the POC wells could be thousands of times higher than those currently observed.

Because NRC ACL guidance indicates that ACLs should be established at levels that are ALARA, DOE did not base the proposed ACLs on maximum assumed dilution rates. Rather, ACLs are proposed to be two orders of magnitude (100 times) greater than the respective standards and are expected to be achievable based on observed site conditions. The proposed ACLs are high enough to accommodate potential future increases and should protect the POEs based on the dilution rates of the Green River.

For simplicity and ease in implementation, and in accordance with EPA guidance (EPA 1992b), sitewide ACLs will be applied to each of six POC wells adjacent to the disposal cell. Table A–2 presents the proposed ACLs along with maximum analytical results through June 2011. Analytical results for the POC wells are discussed in Section 2.2 of the GCAP and are shown as time-concentration plots in Appendix C.

The proposed groundwater monitoring network for the ACL compliance strategy for the middle sandstone unit of the Cedar Mountain Formation will consist of six POC wells adjacent to the disposal cell (0171, 0173, 0176, 0179, 0181, and 0813). The POC wells will monitor potential discharge of contaminants from the disposal cell into the middle sandstone unit of the Cedar Mountain Formation. If any constituent in any well exceeds the respective ACL, DOE will initially resample that well and then evaluate if quarterly monitoring for two years is warranted. If so, the eight quarterly results would be evaluated to assess the need for additional monitoring and/or modifying institutional controls.

Table A–2. Proposed Alternate Concentration Limits for the Green River Site

Constituent[a]	Standard (mg/L)	ACL (mg/L)	Maximum Concentration Observed to Date in POC Wells[c] (mg/L)
Arsenic	0.05[b]	5.0	0.19
Nitrate + Nitrite as N	10.0[b]	1,000	427
Selenium	0.05[d]	5.0	0.86
Uranium	0.044[b]	4.4	0.23

Key: ACL = alternate concentration limit; mg/L = milligrams per liter; POC = point of compliance.
[a] Ammonia will be monitored in groundwater as a best management practice to compare with surface water concentrations.
[b] 40 CFR 192
[c] Wells 0171, 0173, 0176, 0179, 0181, and 0813.
[d] The Utah groundwater standard for selenium (0.05 mg/L) is greater than the EPA maximum concentration limit (0.01 mg/L) and is used as the benchmark because of elevated levels of naturally occurring selenium in the region.

3.0 Factors Considered in Making Present and Potential Hazard Findings

The list of factors below is from the UMTRCA Title I regulations (40 CFR 192.02[c][3][ii][B][1] and [2]), which differ slightly from those in the NRC Title II guidance, and adds another factor to the groundwater quality list.

3.1 Potential Adverse Effects on Groundwater Quality

3.1.1 Physical and chemical characteristics of constituents in the residual radioactive material at the site, including their potential for migration: The processing site was remediated from November 1988 through September 1989, and all uranium mill tailings and residual radioactive material were stabilized in a partially below-grade disposal cell on site. Uranium is the principal COPC in groundwater in the uppermost aquifer; migration in groundwater is limited (see Sections 3.4, 5.2, and 5.3 of the SOWP).

3.1.2 Hydrogeological characteristics of the site and surrounding land: Groundwater occurs in the Browns Wash alluvium and bedrock units of the Cretaceous Cedar Mountain Formation. Characterization of the site hydrogeology is explained in Section 3.5 of Mod No. 2 of the RAP, Section 5.1 of the SOWP, and Section 2.1 of the GCAP.

3.1.3 Quantity of groundwater and the direction of groundwater flow: Groundwater discharge from the Browns Wash alluvium to the Green River is estimated to be 1,250 gallons per day. Groundwater discharge from the contaminated portion of the middle sandstone unit of the Cedar Mountain Formation (uppermost bedrock aquifer) is estimated to be 540 gallons per day; the flow direction is toward the northwest (see Section 2.1 of the GCAP). Calculations are based upon data contained in the SOWP; the assumed width of the contaminated section of middle sandstone unit is 800 feet.

3.1.4 Proximity and withdrawal rates of groundwater users: There is no known groundwater withdrawal in the vicinity of the site. The nearest wells, located more than a mile away from the site, are completed in the Green River alluvium (unassociated with Browns Wash) and are used for irrigation.

3.1.5 Current and future uses of groundwater in the region surrounding the site: There are no known current uses of groundwater along Browns Wash in the vicinity of the site. The wash flows only in response to storm runoff, and its groundwater is of poor quality and is classified as limited use.

Groundwater from the Cedar Mountain Formation is not a current or potential source of drinking water in the area of the Green River site because of the low yield of the aquifer in the region and the generally poor water quality (several constituents exceed Safe Drinking Water Act standards) compared to the Green River municipal water-supply system. The municipal system derives its water from the Green River; the intake and treatment plant are located approximately 0.75 mile upstream of the Browns Wash confluence and, therefore, are unaffected by groundwater from the Browns Wash alluvium.

3.1.6 Existing quality of groundwater, including other sources of contamination and their cumulative impact on groundwater quality: Background groundwater quality in the Browns Wash alluvium is variable but generally poor due to the presence of elevated concentrations of nitrate, selenium, sodium, sulfate and uranium. Elevated contaminant concentrations may be affected by septic and agricultural waste, but they are most likely due to natural sources. However, the background concentrations are approximately an order of magnitude lower than concentrations of contaminants in the Browns Wash alluvium.

Background quality of groundwater in the Cedar Mountain Formation meets EPA groundwater standards. If lateral groundwater flow occurs at the site, it is possible that dilution of the contaminated middle sandstone unit aquifer could occur over a long but undetermined period of time. The basal unit is currently uncontaminated but will be monitored to verify that no contamination has migrated downward from the middle sandstone unit.

3.1.7 Potential for health risks caused by human exposure to constituents: There are no unacceptable risks to human health associated with the site because there is no human exposure to the groundwater, and the groundwater is not being used, and is not projected to be used, for any purpose (see Section 6.1 of the SOWP).

3.1.8 Potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents: The Green River site is disturbed from past use and subsequent remediation activities. The overall potential risk to all receptors was determined to be very low (Section 6.2 of the SOWP [DOE 2002] and Section 4.0 of the draft Environmental Assessment [DOE 2007]).

3.1.9 Persistence and permanence of potential adverse effects: Contaminant levels in groundwater in the Cedar Mountain Formation could remain elevated for a number of years, particularly uranium levels. However, no adverse effects from existing contamination have been observed, and no adverse effects are expected while groundwater contaminant concentrations will attenuate over time.

3.1.10 Presence of underground sources of drinking water and exempted aquifers identified under 40 CFR 144.7: There are no current sources of drinking water or exempted aquifers that can be affected by contamination at the site. The main source of domestic water is surface water from the Green River, which is unaffected by site-related contamination.

3.2 Potential Adverse Effects on Hydraulically Connected Surface Water Quality

3.2.1 Volume and physical and chemical characteristics of the residual radioactive material at the site: The stabilized disposal cell at the site contains 382,000 cubic yards of compacted uranium mill tailings and contaminated surface material. The calculated total activity of radium-226 in the cell is 30 curies.

3.2.2 Hydrogeological characteristics of the site and surrounding land: Groundwater occurs in the Browns Wash alluvium and bedrock units of the Cretaceous Cedar Mountain Formation. Characterization of the site hydrogeology is explained in Section 3.5 of Mod No. 2 of the RAP, Section 5.1 of the SOWP, and Section 2.1 of the GCAP.

3.2.3 Quantity and quality of groundwater and the direction of groundwater flow: The quality of groundwater in Browns Wash is affected by residual contamination from the former mill tailings pile. This effect is expected to continue for an indeterminate period of time due to the low groundwater flow velocity in the alluvial groundwater flow system. Browns Wash is an ephemeral stream that flows only as a result of heavy rainstorms. The effect that contaminated alluvial groundwater has on surface water is proportional to the quantity of surface water flow in Browns Wash.

Groundwater from the middle sandstone unit of the Cedar Mountain Formation may discharge to the Green River alluvium. Average monthly surface water discharge in the Green River ranges from 2,300 to greater than 18,000 cfs near the city of Green River. Because of the high dilution rate, neither the former mill site nor the disposal cell has had any measurable impact on the quality of water in the Green River. (Section 3.6, Mod. No. 2 RAP).

3.2.4 Patterns of rainfall in the region: Annual precipitation averages approximately 6 inches. Rainfall occurs during the summer and fall in high-intensity, short-duration thunderstorms that can produce runoff. Winter precipitation occurs primarily as snowfall.

3.2.5 Proximity of the site to surface waters: The ephemeral Browns Wash is north of the site and discharges into the Green River. The Green River is approximately 0.5 mile west of the site.

3.2.6 Current and future uses of surface waters in the region surrounding the site and any water-quality standards established for those surface waters: The Green River is the primary source of drinking water for the city of Green River area. The water intake station and treatment plant are approximately 0.75 mile upstream of the confluence of Browns Wash; consequently, the municipal water supply is not affected by contaminants at the Green River site. State water-rights records indicate that there are several irrigation surface diversion points a short distance upstream and downstream of the Browns Wash confluence. Surface water standards for the river are established by the State of Utah, and the river meets these standards in the vicinity of the site.

3.2.7 Existing quality of surface water, including other sources of contamination and the cumulative impact on surface water quality: Water in the Green River in the vicinity of the site is designated high quality by the State of Utah. The site has no measurable effect on the surface water quality of the Green River.

3.2.8 Potential for health risks caused by human exposure to constituents: There are no unacceptable risks to human health associated with the site because of the intermittent presence of water in Browns Wash and the lack of use. Neither is there any excess human health risk associated with site-derived contamination impacting surface water in the Green River.

3.2.9 Potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents: There is no potential damage as site contamination has no impact on water quality of the Green River. The ecological risk assessment showed that the potentially elevated concentrations in pooled water in Browns Wash from storm runoff or groundwater seeps would have no adverse effect on potential receptors, including wildlife and vegetation (Section 6.2 of the SOWP [DOE 2002] and Section 4.0 of the draft Environmental Assessment [DOE 2007]).

3.2.10 Persistence and permanence of the potential adverse effects: No adverse effects are currently present in the Green River or in Browns Wash, and none are expected in the future.

4.0 Roadmap to the SOWP and Additional Information

4.1 General Information

Introduction—Section 1.0 of SOWP

Facility Description—Section 3.0 of SOWP

Extent of Groundwater Contamination—Sections 5.2 and 5.3 of SOWP

Proposed Alternate Concentration Limits—Section 3.2 of GCAP

Hazard Assessment—Generally corresponds to Section 6 of the SOWP, which contains human health and ecological risk assessments

Source and Contamination Characterization—Sections 5.2 and 5.3 of SOWP

Transport Assessment—Section 5.3.5 of SOWP

Exposure Assessment—Section 6.1 of SOWP for human health; Section 6.2 of SOWP for ecological risk

Corrective Action Assessment—Included in this Appendix to GCAP

4.2 Results of Corrective Action Program

Surface remediation at the Green River site commenced in November 1988 and was completed in September 1989. Tailings and other contaminated surface materials totaling approximately 382,000 cubic yards were placed in a disposal cell located on site.

DOE, the State of Utah, and Umetco Minerals Corporation currently own property underlain by site-related groundwater contamination. An environmental covenant will be implemented for the land affected by site contamination that prohibits use of groundwater for any purpose, without the permission of both DOE and the State of Utah, on the land affected by groundwater contamination. This restriction is essentially perpetual, though it can be lifted once concentrations have decreased to levels that permit unrestricted use.

4.3 Feasibility of Alternative Corrective Actions

DOE has performed remedial action at the Green River site to mitigate exposures to contaminated soil. The corrective-action assessment in this Appendix to the GCAP indicates that active remediation of contaminated groundwater would be complicated and expensive and would provide no economic benefit or reduction in risk to human health and the environment. The disposal cell at the site will remain indefinitely and ensures that institutional controls will be observed. Therefore, ACLs are proposed for constituents monitored at the POC wells that have concentrations that could remain elevated for the life of the disposal cell.

4.4 Corrective Action Costs and Benefits

Corrective action cleanup costs were not estimated for the Green River site because there was no reasonable scenario for active groundwater remediation. Generally, active remediation of the uppermost aquifer would be complicated and expensive because of the thinness of the aquifer and the overall lack of water. The limited extent of the aquifer makes it a limited resource as well. No one is currently using the aquifer, and there are no plans to use it in the future. Therefore, remediation of the uppermost aquifer to reduce concentrations of contaminants provides no real benefit.

4.5 ALARA Demonstration

The general aim of achieving a cleanup goal that is ALARA is satisfied by applying ACLs that are more conservative than permissible based on likely dilution at the POE. It would not be reasonable to pursue active remediation of groundwater for the negligible risk reduction that could be realized, particularly considering the availability of an alternative water source (the Green River), that groundwater in the vicinity of the site is not used as a water source, and that environmental covenants will prohibit groundwater use.

4.6 Proposed Alternate Concentration Limits

Proposed Alternate Concentration Limits—Section 3.2 of GCAP; Section 2.2 of GCAP Appendix A

Proposed Implementation Measures—Section 4.0 of GCAP

References—Section 8.0 of SOWP; Section 5.0 of GCAP Appendix A

Appendixes and Supporting Information—Appendixes A through G of SOWP; Appendix C of GCAP

5.0 References

10 CFR 40. U.S. Nuclear Regulatory Commission, "Domestic Licensing of Source Material," *Code of Federal Regulations*, January 1, 2011.

40 CFR 144.7. U.S. Environmental Protection Agency, "Identification of Underground Sources of Drinking Water and Exempted Aquifers," *Code of Federal Regulations*, July 1, 2010.

40 CFR 192. U.S. Environmental Protection Agency, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," *Code of Federal Regulations*, July 1, 2010.

60 FR 2854. U.S. Environmental Protection Agency, "Ground Water Standards for Remedial Actions at Inactive Uranium Processing Site; Final Rule," *Federal Register*, January 11, 1995.

67 FR 38222. U.S. Environmental Protection Agency, "Announcement of Preliminary Regulatory Determinations for Priority Contaminants on the Drinking Water Contaminant Candidate list," *Federal Register*, June 3, 2002.

DOE (U.S. Department of Energy), 1991. *Remedial Action Plan and Final Design for Stabilization of the Inactive Uranium Mill Tailings at Green River, Utah*, Final, UMTRA-DOE/AL-050510.GRN0, Albuquerque, New Mexico, March.

DOE (U.S. Department of Energy), 1995. *Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Green River, Utah*, DOE/AL/62350-116, Rev. 1, Albuquerque, New Mexico, September.

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Appendix B

Photos

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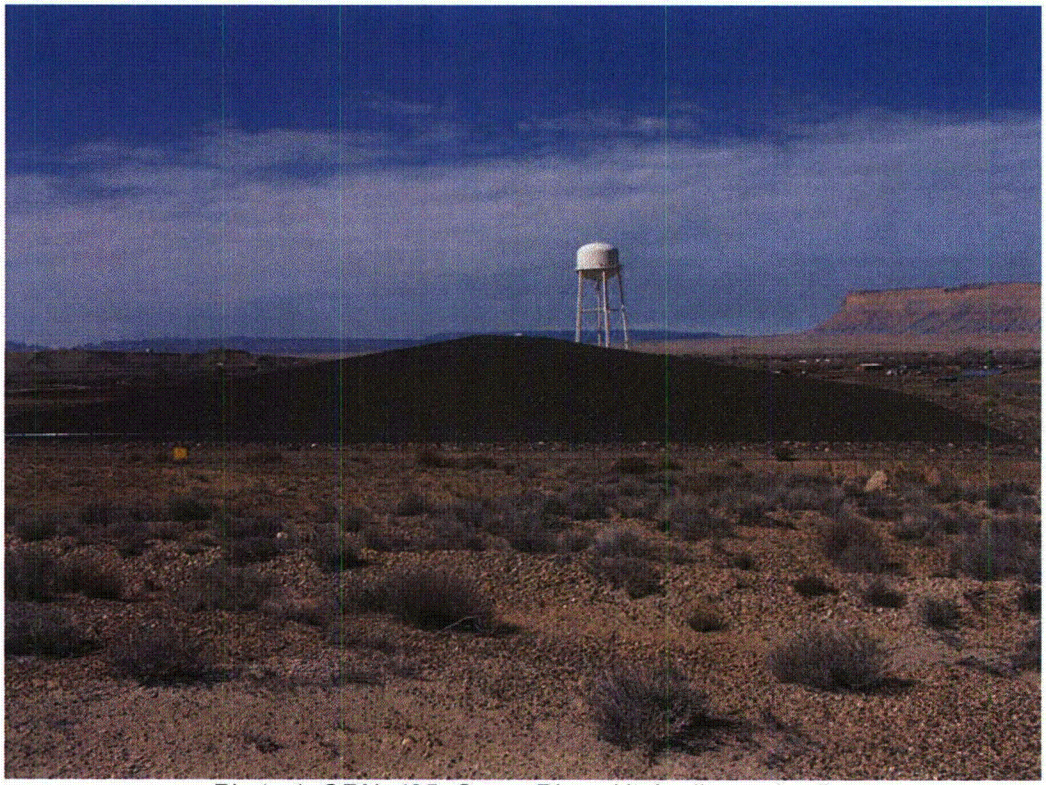

Photo 1. GRN_425. Green River, Utah, disposal cell.

Photo 2. GRN_420. Granite site marker near the base of the disposal cell.

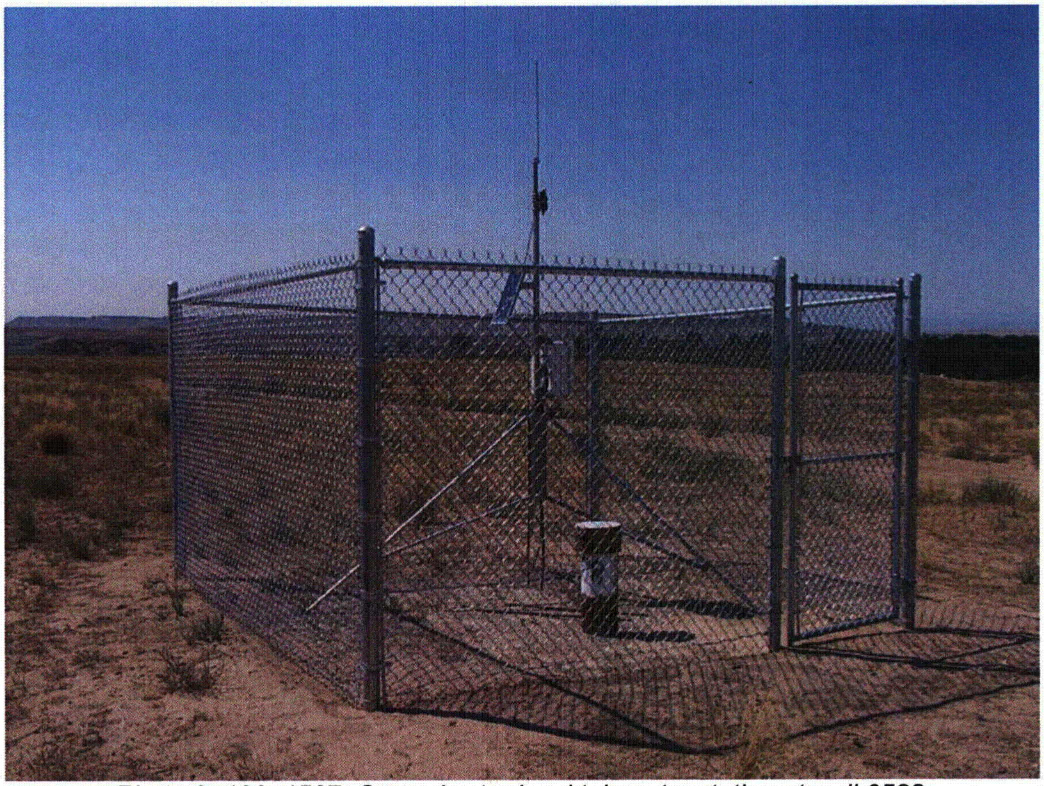

Photo 3. 100_1507. Groundwater level telemetry station at well 0588.

Photo 4. GRN07_003. Groundwater level data receiving/transmission station on top of the disposal cell.

Photo 5. 100_1510. Browns Wash at the Cedar Mountain Fm outcrop area (upper unit) and location of seep 0718. No pools were present in the wash on this day (9/7/07).

Photo 6. 100_1067. Browns Wash at the Cedar Mountain Fm outcrop area (upper unit) immediately after a storm event (9/15/06).


Photo 7. 100_1096. Small pool in a runoff-caused scour hole at seep 0718 on 9/30/06.


Photo 8. 100_1219. Algae at seep 0718 during extended period of sub-freezing temperatures (1/31/07).

Photo 9. 100_1095. Browns Wash backwater area—upper portion of the photo (9/30/06).

Photo 10. 100_1515. Backwater area completely filled with sediment at surface sampling location 0847 (9/7/07).

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Appendix C

Hydrograph and Time-Concentration Plots

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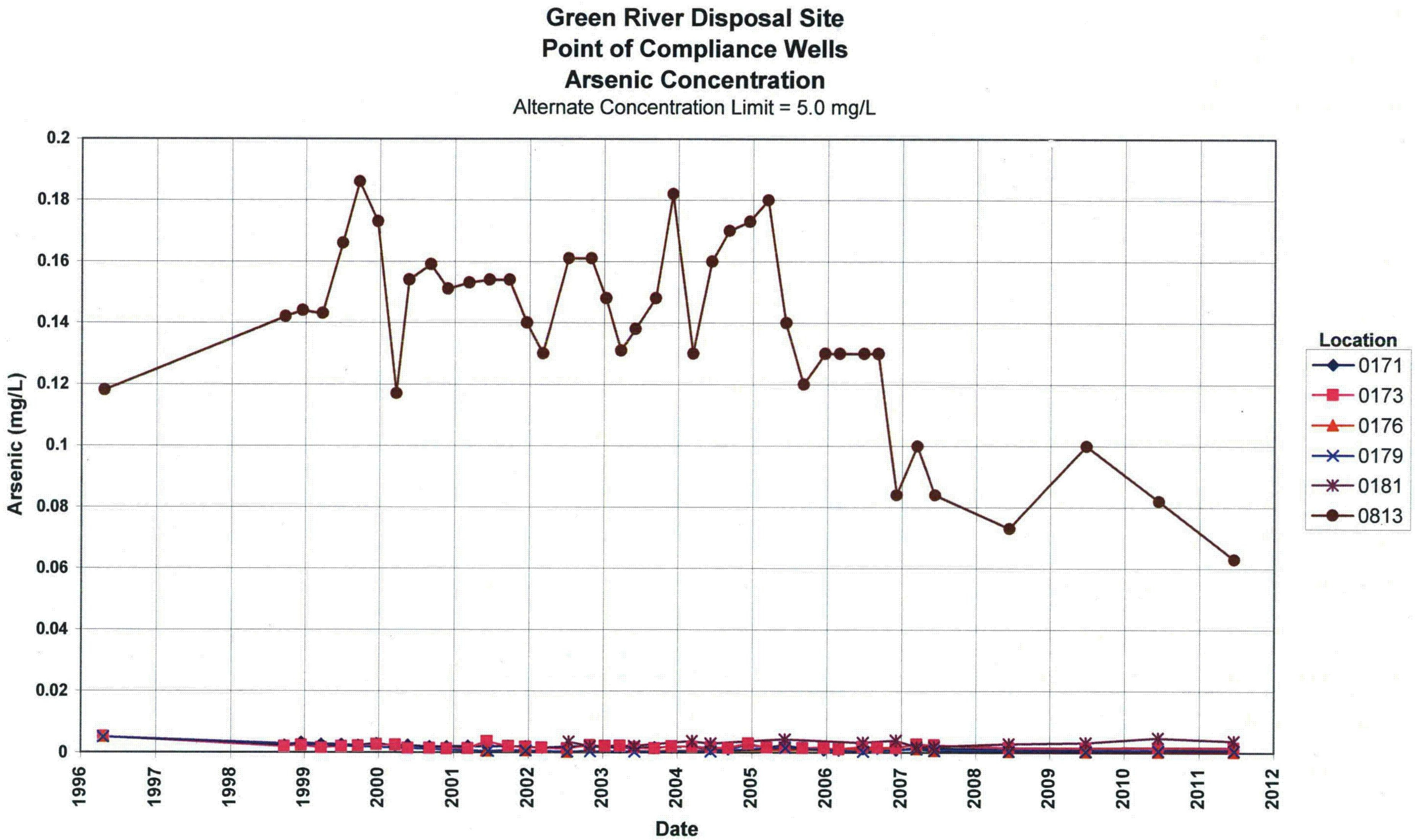
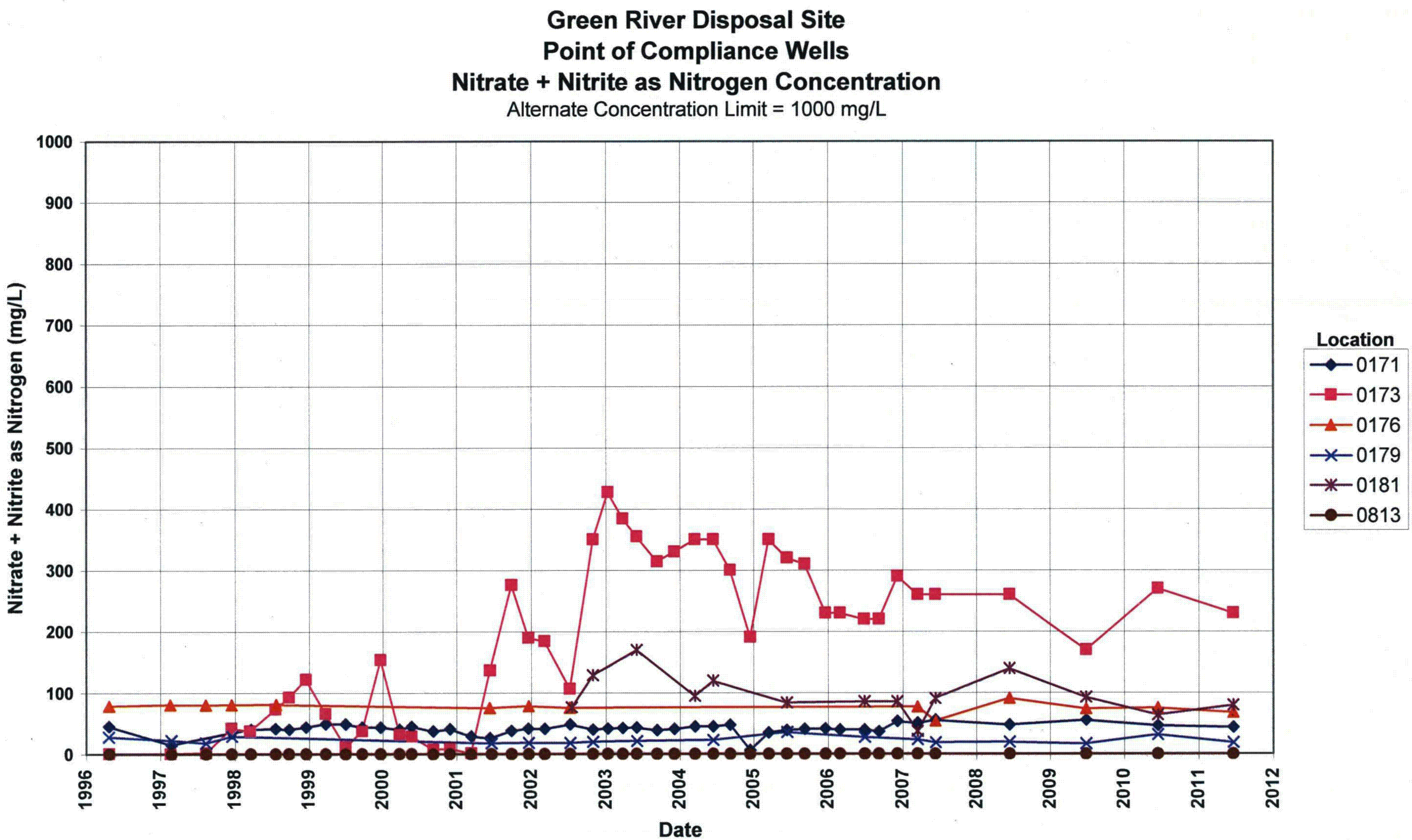


Figure C-3. Time-Concentration Plots of Arsenic in Groundwater at the Green River, Utah, Disposal Site



Note: All nitrate results have been converted to nitrate-as-nitrogen to facilitate comparison.

Figure C−4. Time-Concentration Plots of Nitrate (as N) in Groundwater at the Green River, Utah, Disposal Site

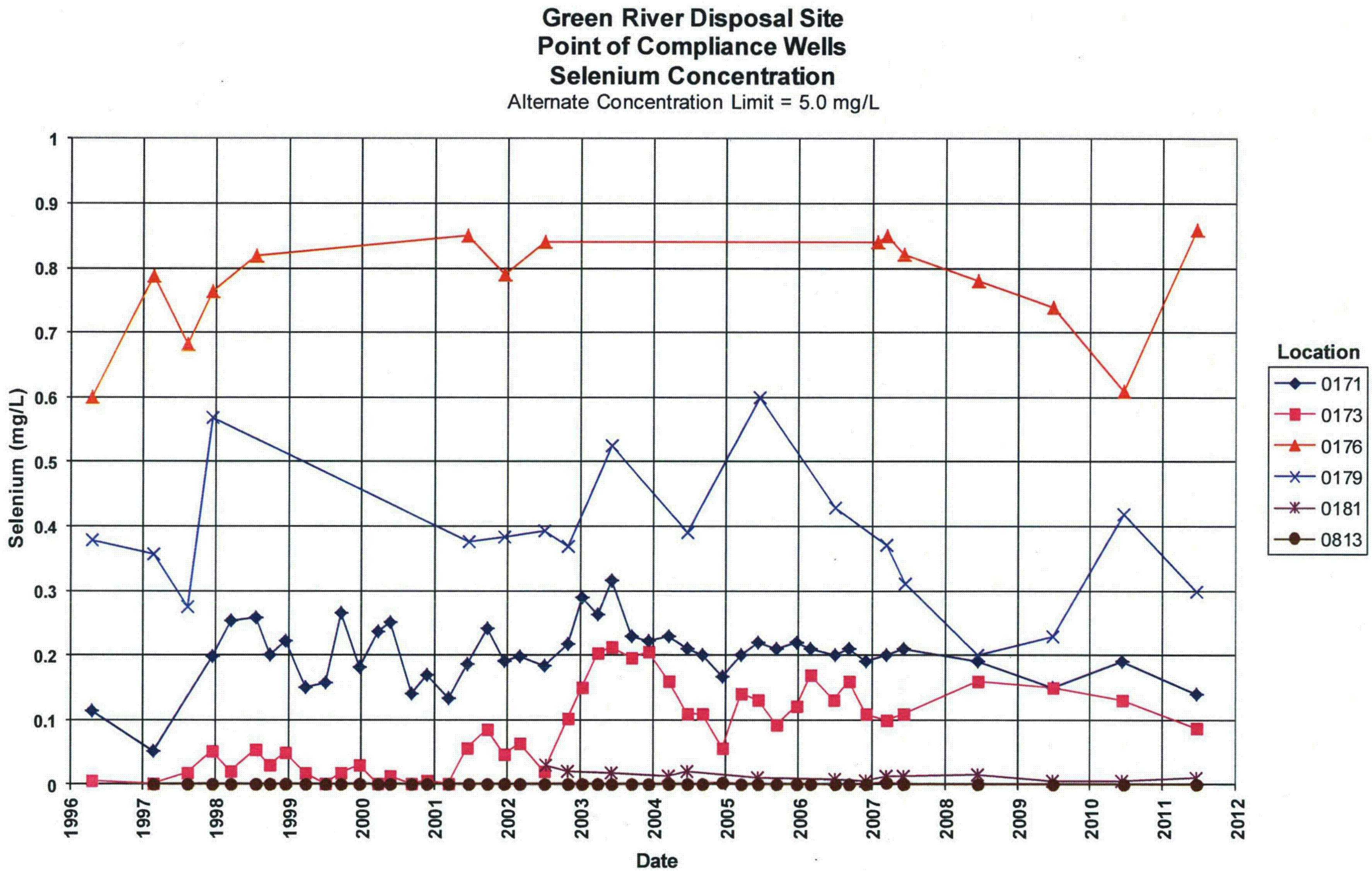


Figure C−5. Time-Concentration Plots of Selenium in Groundwater at the Green River, Utah, Disposal Site

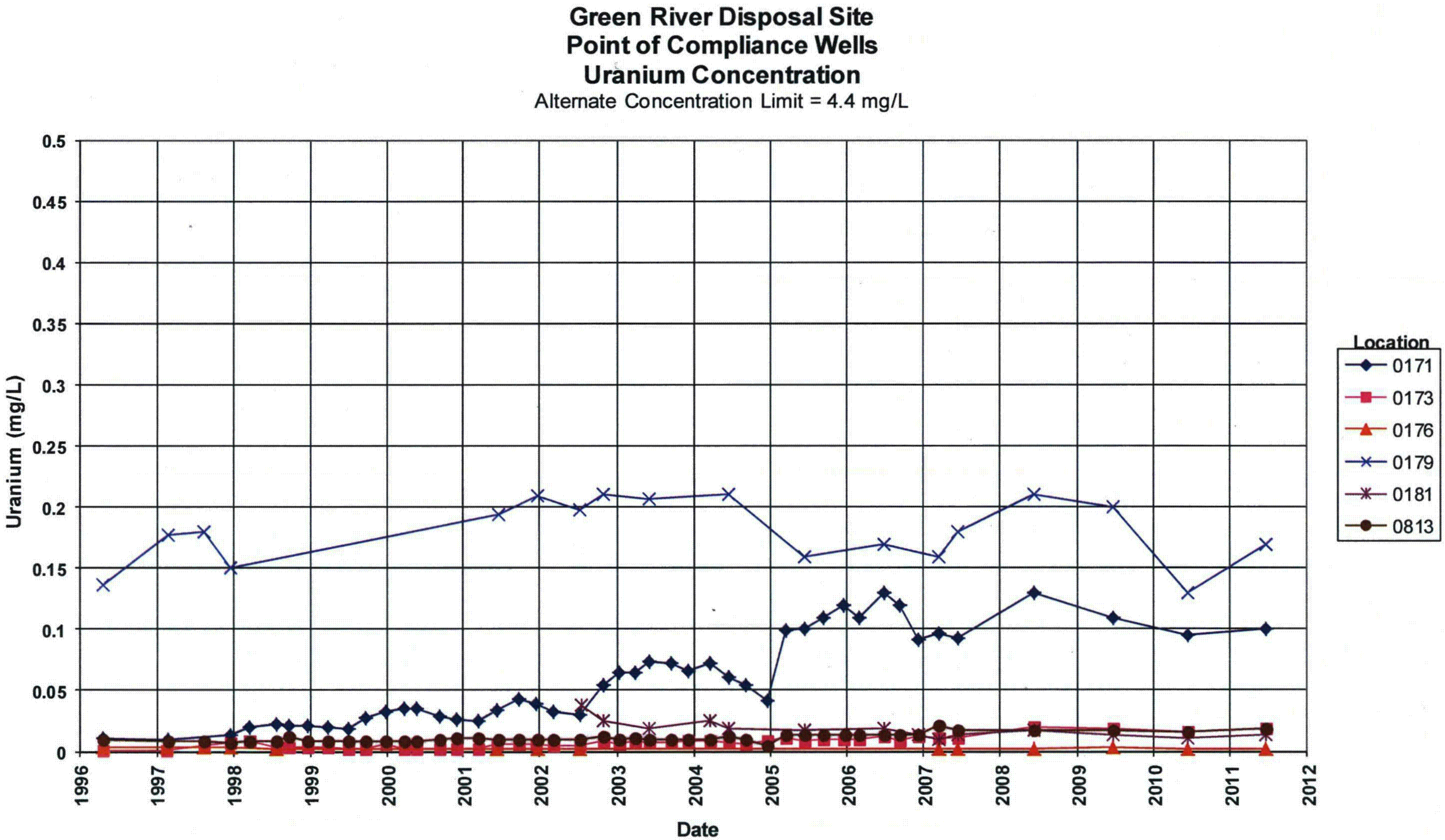


Figure C–6. Time-Concentration Plots of Uranium in Groundwater at the Green River, Utah, Disposal Site

Appendix D

State of Utah Comments

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U.S. Department of Energy Office of Legacy Management

Record of Review

Due Date	Review No.	Project	Type of Review
	1	LM00-501-02-107	Technical

Document Title and\or Number and Revision
Groundwater Compliance Action Plan for the Green River, Utah, Disposal Site (LMS/GRN/SO7892)

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Reviewers' Recommendation

- ☐ Release Without Comment
- ☐ Consider Comments
- ☒ Resolve Comments and Reroute for Review

Rusty Lundberg
Signature of Reviewer and Date

- ☒ Comments Have Been Addressed

Mark Kautsky 2011.12.22 08:59:23 -07'00'
Signature of Author and Date

- ☒ Comment Resolution Satisfactory
- ☐ Comment Resolution Unsatisfactory

Rusty Lundberg
Signature of Reviewer and Date

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
1	On Page 11, Table 7 of the GCAP, shows both a 4-day and a 1-hr surface water standard for arsenic and selenium. It was previously agreed by the DRC and DOE that for purposes of environmental protection, the 4-day chronic standard would be used instead of the 1-hr acute standard for both arsenic and selenium. Please remove the 1-hr acute standard from Table 7 for both arsenic and selenium.			Will remove reference to 1-hr acute standard.
2	On Page 16, Table 10 of the GCAP, shows DOE's proposed site wide ACLs, which will be applied to the POC wells. The methodology used to calculate the ACLs differs from what was proposed in the previous draft version of the GCAP and the August 2007 EA. In the previous draft version of the GCAP and the August 2007 EA, the DOE proposed ACLs that were 100 times the respective EPA Maximum Concentration Limit (MCL). The proposed ACLs were as follows:			Will change ACL calculation methodology to 100 times the MCL, as originally agreed to by State of Utah and DOE.

Record of Review (continuation)

Review No.	Project

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
	Arsenic - 5.0 mg/L Nitrate + Nitrite (as N) - 1,000 mg/L Selenium - 1.0 mg/L Uranium - 4.4 mg/L In the November 2011 GCAP, the DOE now proposes ACLs to be calculated by taking the maximum concentration observed to date in all POC wells for a specific parameter and multiply that result by a factor of 10. The new proposed ACLs are as follows: Arsenic - 1.9 mg/L Nitrate + Nitrite (as N) - 4,270 mg/L Selenium - 8.5 mg/L Uranium - 2.3 mg/L Using this new methodology is a concern to the state. Although the proposed ACLs for arsenic and selenium have been slightly reduced and are more protective of the environment, the proposed ACL's for Nitrate + Nitrite as N (4X) and selenium (8X) has increased significantly. During a May 5, 2011 conference call with the DOE, the DRC agreed that the proposed ACLs of 100 times the MCL could be accepted as long as the DOE agreed to begin sampling of the basal sandstone unit of the Cedar Mountain Formation. The DOE agreed with the DRC proposal. The DRC recommends changing the methodology back to what was previously agreed to by both parties (i.e. 100 times the EPA MCL), it is more protective of the environment than what is now proposed. The DRC disagrees with DOE rationale described on Page 17, on why the methodology was changed.			
3	On Page 19 of the GCAP, the DOE describes how the basal sandstone unit wells will be sampled. They also state: "If contamination is detected in the basal sandstone unit, DOE will evaluate the need for further characterization."			Because sulfate does not attenuate like other contaminates, sulfate concentration/trends will be monitored as an early detection anlayte.

Record of Review (continuation)

Review No.	Project

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
	How will the DOE determine that contamination has been detected? Above the Utah Groundwater Quality Standard, EPA Standard, etc...? The DOE needs to clarify how it will be determined that the basal sandstone unit has been contaminated.			
4	The DOE has agreed to sample the wells on site that are located in the basal sandstone unit of the Cedar Mountain Formation. The plan is to sample basal wells 0182, 0184, 0185, and 0588. Why is the DOE not including basal well 0582 in the sampling program?			Well 0582 is a flowing artesian well that has been sealed 4 feet below grade with a manually operated packer. A transducer has been installed below the packer to measure hydraulic head. The way the packer is installed makes it very difficult to obtain a water sample, therefore, DOE proposes not to sample this well.

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