SUPPLEMENT TO THE BIOLOGICAL ASSESSMENT OF POTENTIAL IMPACTS TO ENDANGERED AND THREATENED SPECIES FROM THE PROPOSED RECLAMATION OF THE ATLAS MILL TAILINGS SITE, MOAB, UTAH

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1. INTRODUCTION

Atlas Corporation has requested that the Nuclear Regulatory Commission (NRC) approve an amendment to its existing license for a proposed reclamation plan involving onsite disposal of uranium mill tailings at the former mill site in Moab, Utah. In January 1996, NRC published a Draft Environmental Impact Statement [DEIS (NRC 1996a)] evaluating the proposed reclamation plan. During the preparation of the DEIS, NRC staff initiated consultation with the U.S. Fish and Wildlife Service (FWS) and on November 1, 1995, submitted a Biological Assessment (BA) of potential impacts to threatened and endangered species from the proposed onsite reclamation. This Supplement to the BA (henceforth referred to as the Supplement) has been prepared in response to FWS comments on the BA and requests for additional information as discussed below.

In a letter dated February 15, 1996 (Attachment A), the FWS stated that their initial review of the data presented in the BA indicated that the project could affect individual endangered fish. The FWS letter also indicated that (1) they had received additional information, including the DEIS; (2) samples collected by FWS staff in April 1995 had been sent for chemical analyses; and (3) a Biological Opinion would be prepared upon receipt of the results of the analyses of samples. Subsequent to this letter, NRC agreed to assist the FWS with the analysis of radionuclides in the samples.

The FWS submitted comments on the BA to NRC in a letter dated July 22, 1996 (Attachment A), expressing concerns about the additional data collected by Atlas consultants in May 1995. The FWS stated that they could not conclude that the tailings pile, if capped in place, would not harm the endangered fish of the Colorado River system, or would not result in the destruction or adverse modification of designated critical habitat. The FWS recommended that additional data be collected to satisfy the data gaps.

A meeting between Atlas and the FWS was held in Denver on October 17, 1996, to discuss additional data needs. In addition to FWS and Atlas, representatives from NRC, Oak Ridge National Laboratory (ORNL), and Harding Lawson Associates (HLA), a consultant to Atlas, were present. The FWS staff indicated that a focus of their review would be on the groundwater pathway for contaminants moving into the Colorado River. The FWS specifically expressed concern about the levels of selenium that might be released from the pile and analytical detection limits that were used to obtain the data provided by Atlas and by the State of Utah. As a result of this meeting, Atlas agreed to have HLA provide a compilation of available data for use in evaluating impacts to endangered fish species.

A draft compilation of data (HLA 1996a) was provided on October 17, 1996. Atlas and HLA staff presented the data compilation to the FWS at a meeting in Salt Lake City on October 21, 1996. NRC and ORNL staff participated in the meeting via a video conference hookup. During this meeting, NRC and ORNL indicated they would consider the data in this compilation in preparing this Supplement.

In a letter dated January 14, 1997, the FWS expressed concerns about (1) issuing the Final Environmental Impact Statement (FEIS) before completion of Section 7 consultation; (2) not including the groundwater corrective action plan as part of the ongoing Section 7 consultation; (3) not addressing requirements of the Corps of Engineers Section 404 permit relative to the relocation of Moab Wash; (4) detection limits used in analyses provided by Atlas; (5) determination of the constituents of the tailings pile, not the leachate; (6) higher concentrations of ammonia and uranium in recent State samples than were reported in the DEIS; (7) potential bioaccumulation of toxic materials by the southwestern willow flycatcher; and (8) impacts on habitat used by the southwestern willow flycatcher in the vicinity of the Atlas site.

The purpose of this Supplement is to review available data on water quality and biota, including data that has become available since the BA and DEIS were prepared and to provide an updated assessment of potential impacts to threatened and endangered fish species under the Atlas proposed reclamation plan. New data included in this Supplement have been provided by Atlas, the State of Utah (Morton 1996), and the FWS. The Supplement also describes and assesses potential impacts on threatened and endangered species from the development and use of a newly proposed borrow area that Atlas has identified to replace the originally proposed Castle Valley borrow sites evaluated in the DEIS and the original BA. In addition, the Supplement provides analysis of potential impacts from the proposed relocation of Moab Wash on the Atlas site and provides additional analysis of impacts on the endangered southwestern willow flycatcher.

2. BACKGROUND

A detailed discussion of the Atlas proposal is presented in Section 2 of the DEIS, which is currently being revised in response to agency and public comments, and is summarized in the BA. A detailed technical evaluation of the proposed reclamation plan (Smith Technology Corporation 1996) is presented in NRC's Draft Technical Evaluation Report (NRC 1996b), which is currently being revised to address the resolution of the 20 open issues that were identified in the draft report and to respond to public comments. The Final Environmental Impact Statement will be published after Section 7 consultation under the Endangered Species Act has been completed.

The Final Technical Evaluation Report will also be published and made available to interested parties later this year.

2.1 The Atlas Proposal

2.1.1 Overview

Atlas proposes to reclaim the 9.5 million metric-ton (10.5 million-ton) tailings pile on the existing site, located approximately 3.7 km (2.3 miles) northwest of Moab (Figure 1). The pile occupies about 53 ha (130 acres) of land adjacent to the Colorado River. It consists of an outer compacted embankment of coarse tailings and an inner impoundment of both coarse and fine tailings. An interim cover of uncontaminated earth covers the tailings. The water content of the tailings is being reduced to the extent feasible by pumping water from wells in the tailings. Moab Wash, an ephemeral stream channel, is located along the north and northeast sides of the tailings pile, while State Highway 279 and a bluff border the southwest side of the pile. Debris from the dismantlement of the mill buildings and associated structures has been placed in an area at the toe of the pile and covered with contaminated soils from the mill site and clean fill.

Under the Atlas proposal, the tailings pile would be reclaimed at its current location. Rock riprap and clay required for covering the pile would be transported by truck to the site from proposed borrow areas located in Spanish Valley southeast of Moab for cobble-sized rock, near Potash southwest of Moab for larger rock (Section 2.2), and at Klondike Flat northwest of Moab for clay (Figure 1).

2.1.2 Pile Design

The reclaimed pile would be designed to minimize erosion, infiltration of rainwater into the tailings, and the release of radon gas. The pile would be designed to withstand the probable maximum precipitation event and the probable maximum flood (PMF) event. Rock for riprap would have acceptable durability to withstand the forces of weathering. The design would comply with Criterion 6 of 10 CFR Part 40, Appendix A, which states that the design must provide reasonable assurance of control of radiological hazards to be effective for 1000 years to the extent reasonably achievable and, in any case, for 200 years. The layers of the reclaimed pile, from the bottom upward, would include the tailings layer and a cover system (DEIS, Table 2.1-1 and Figure 2.1-3).

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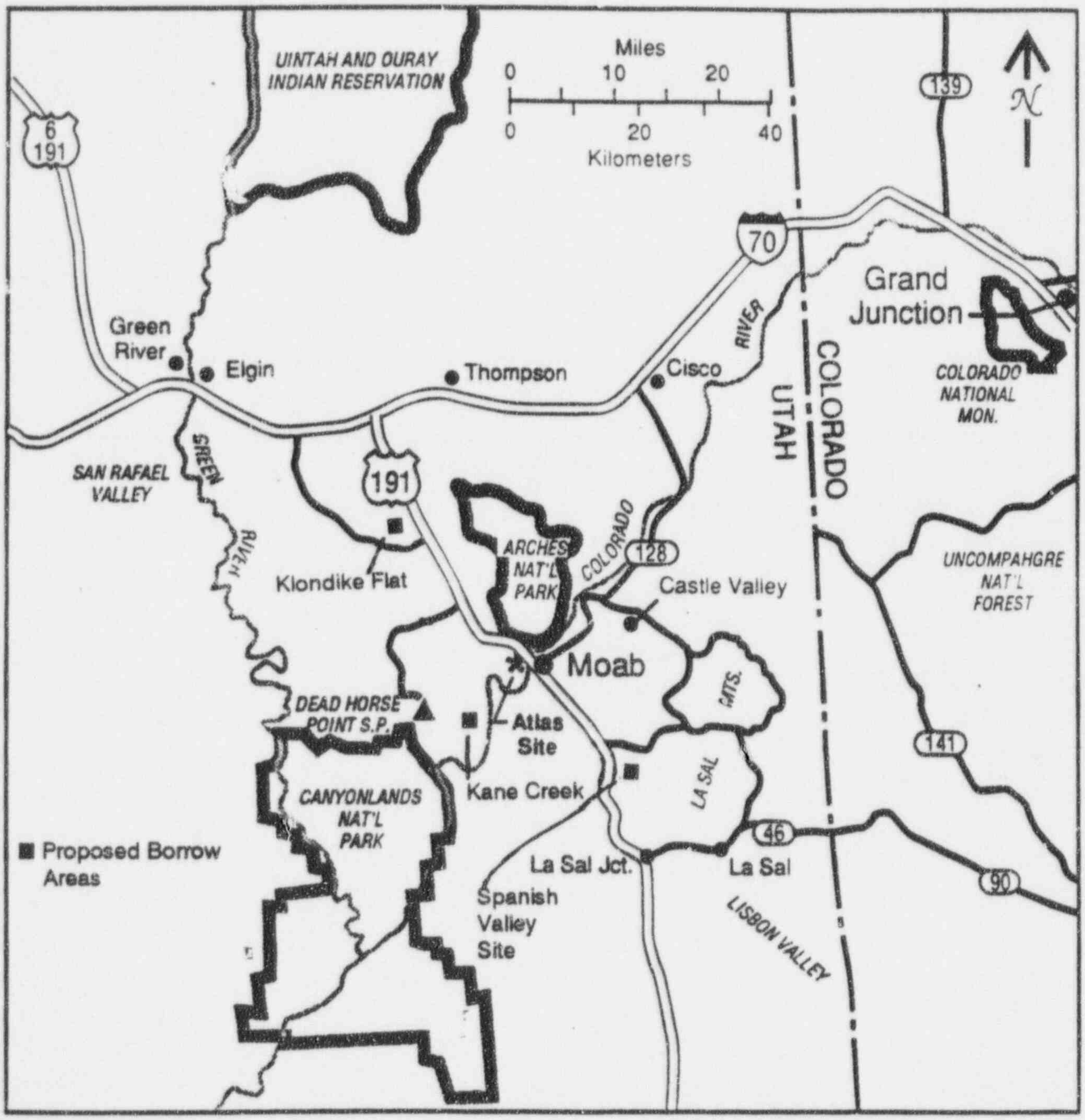

Figure 1 **Regional Location of the Atlas Corporation Site Near Moab, Utah.**

The cover system would provide a minimum of 94 cm (37 inches) of cover above the tailings on the tops and sides of the cell. Generally, the cover would include a layer of affected soil from the mill area and outlying areas directly over the tailings, then a clay layer (radon barrier), a layer of sandy soil, and a surface layer of riprap. As currently proposed, the side slopes of the pile would not have a clay layer. However, if the ongoing review of the revised groundwater corrective action plan reveals the need to further reduce infiltration into the pile, a clay layer on the side slopes may be needed. If necessary to meet surface contour requirements, fill material may be placed in certain low areas over the coarse tailings prior to placing the cover system.

The radon barrier would consist of suitable material to minimize both the escape of radon and infiltration of rain water. The rock, which would be at least 10 cm (4 inches) thick, would protect against erosion and restrict the intrusion of vegetation and burrowing animals into the radon barrier. Tailings include both coarse and fine tailings, with the latter having higher radiation levels. A thicker cover system over fine tailings would be required to meet radon emission limits. The placement of coarse tailings over any fine tailings currently near the surface is proposed.

The relatively flat top of the pile would be sloped slightly downward toward the middle and toward the northwest to promote collection of surface runoff and drainage to Moab Wash, which would be relocated in the vicinity of the pile (Section 2.3). Surface runoff on the top of the pile would flow to several collection ditches that would direct rainwater to a channel leading from the top of the pile to Moab Wash (DEIS, Figure 2.1-3). Another ditch would be constructed between the bluff and the southwest slope of the tailings pile to convey runoff toward the Colorado River. All ditches would be protected with riprap and one or more layers of gravel under the riprap. The gravel layers would be needed in the ditches to provide additional protection against erosion of the underlying soil material during runoff events.

At the toes (bases) of the side slopes, the riprap would be extended a minimum of 0.9 m (3 ft) beneath the earth surface to provide extra protection against flood erosion. Riprap would be extended 2.4 m (8 ft) below the surface at the outlets of the drainage ditches to prevent erosion (headcutting) of the outlets. In addition, the NRC could require any additional protection determined to be necessary as a condition of plan approval.

2.1.3 Reconfiguration of Moab Wash

Under the Atlas proposal, Moab Wash (DEIS, Figure 2.1-1) would be rerouted in the vicinity of the pile to run through the former mill site area. The reconfigured channel would discharge into the river upstream of the current discharge point. Figure 2 shows the proposed route of the

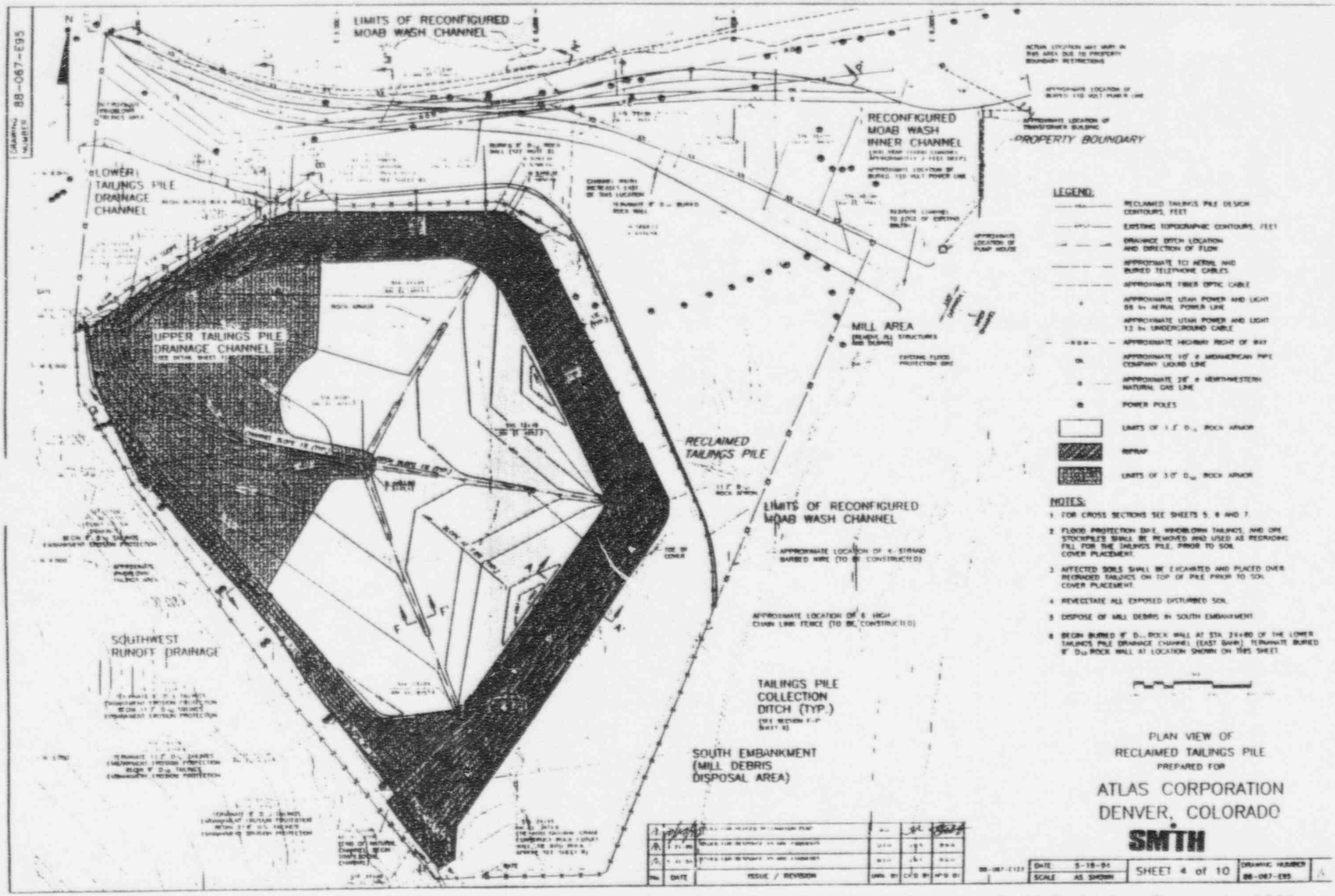

Figure 2. Plan View of Reclaimed Tailings Pile Showing Location of Reconfigured Moab Wash. *Source*: Smith Technology Corporation 1996.

reconfigured channel. An inner channel about 0.6 m (2 feet) deep would be designed to carry runoff for a 200-year flood. Flood protection along the base of the pile would protect the pile from higher floods and the possibility of channel migration. Drainage ditches lined with riprap would be constructed on and adjacent to the pile to direct surface runoff to Moab Wash and the Colorado River. Design for flood protection of the pile is discussed in the DTER (NRC 1996b). Material excavated during construction of the reconfigured channel would be used as cover material for the pile; any materials that were found to be contaminated would be placed on the tailings pile before the cover was installed.

2.1.4 Kane Creek Borrow Area

The licensee's original proposal to obtain large riprap bedrock from two quarries in the vicinity of Castle Valley was withdrawn because local residents expressed significant concerns during the DEIS comment period about potentially significant impacts on residents of the Town of Castle Valley and users of local roads that would have been used to transport the borrow materials to the Atlas site. Atlas recently proposed a new site for obtaining large riprap that would be used for erosion protection along the base of the pile (Blubaugh 1996). The new borrow area, designated by Atlas as the Kane Creek site (Figure 1), is located south of Potash adjacent to the J. L. Eddy riverboat ramp on the Colorado River (T26S, R20E, Section 25). The site is approximately 28 km (17.5 miles) south of the Atlas site and approximately 2.3 km (1.4 miles) from the entrance to the Moab Salt and Potash Production and Packaging Facility. Borrow materials would be transported to the Atlas site via State Highway 279, primarily during the winter months of November through March when tourist traffic is reduced. The proposed quarry sites for smaller riprap in Spanish Valley and for clay at Klondike Flat (Figure 1) would remain the same as described in the DEIS and BA.

2.2 Estimates of Contaminant Transport

Several methods of estimating past, present, and future tailings seepage and groundwater flow conditions were used to evaluate current and potential future contaminant impacts to the Colorado River. Using various methods of estimation allows the development of a realistic and conservative impact evaluation. The differing approaches are derived from measurements and observations collected at the site during milling operations and since milling ceased.

As discussed at the October 17, 1996, meeting, the only viable pathway for contaminants from the pile to reach the river is through the groundwater. Groundwater flow in the alluvial aquifer is controlled by upgradient recharge, Colorado River stage, and characteristics of the alluvial

material, independent of the tailings. Leachate from the tailings seeps into the aquifer and mixes with the aquifer water. This mixed groundwater eventually seeps into the Colorado River. Since the water quality and flow characteristics of the aquifer upgradient of the tailings pile are unaffected by the tailings pile and can be assumed to be in steady state, the seepage of contaminants from the pile degrades the quality of the groundwater that discharges into the Colorado River. Figure 3 provides a simplified depiction of this situation.

As discussed below, installation of the proposed clay cap would significantly reduce seepage from the tailings to the groundwater compared to what it was in the past or under current conditions. During the operation of the mill, the tailings pile was saturated because a pool of water existed on top of the pile. Seepage from the pile was controlled by the permeability of the material at the bottom of the pile and the pressure (hydraulic) head difference between the water in the pile and the underlying groundwater. The head difference between the pile and groundwater can be influenced over short periods of time by changes in river stage. After the proposed reclamation is completed and the mound of water in the pile has dissipated, the seepage rate would be controlled by the infiltration of precipitation into the pile and percolation of this water through the cap and the underlying pile.

Current groundwater contaminant levels reflect past, more severe pile conditions that produced higher than present seepage rates through the pile before dewatering reduced the hydraulic head and the quantity of water in contact with the tailings. The contaminant flux appears to have decreased since the removal of the tailings pond, but the decrease has not been sufficient to reduce contaminants concentrations below levels of concern in monitoring wells located at the toe of the pile. Over time, it is reasonable to assume that the contaminant flux will decrease, but there is uncertainty about the rate and amount of such a decrease.

Figure 4 illustrates staff's conception of the probable development of the contaminant plume beneath the tailings pile that is seeping into the Colorado River. The plume slowly developed during the period from 1956 to approximately 1966 [see Figure 4(a)] and contaminated the Quaternary alluvial aquifer between the pile and the Colorado River. Staff estimate that the time required for dissolved species to migrate from the pile to the Colorado River is on the order of 20 years; the precise rate for each contaminant will vary according to its physical and chemical properties. Once established, the plume continued to flow from the pile to the river under (1) the influence of the hydraulic head exerted by the liquid mound within the pile that was created while Atlas was processing uranium ore and (2) the flow regime of the alluvial aquifer [see Figure 4(b)].

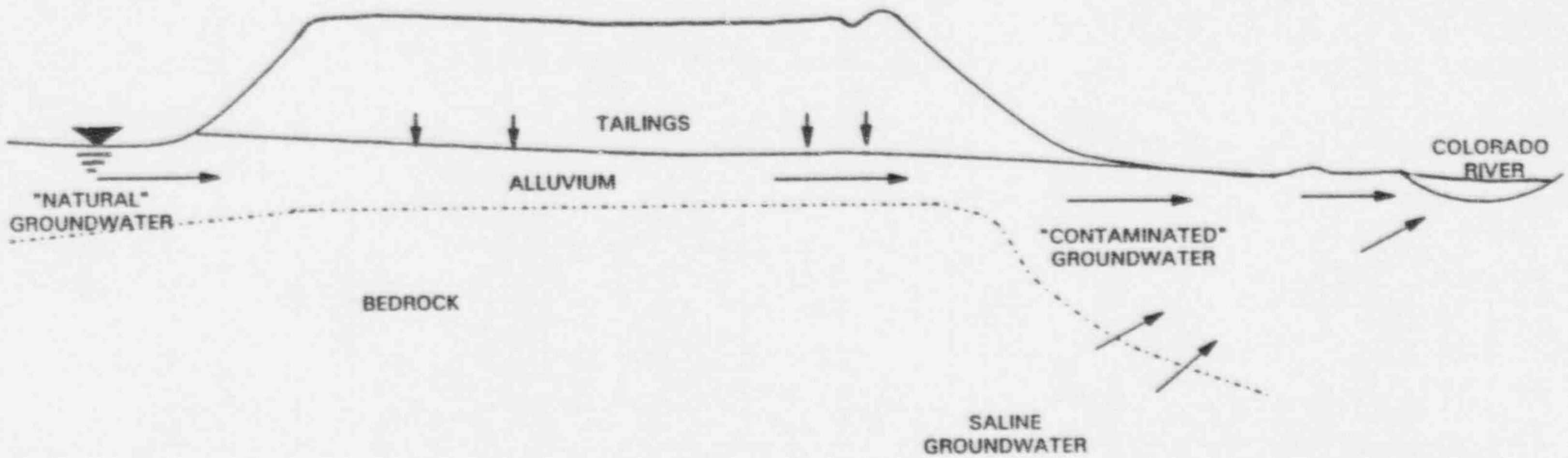

Figure 3. Conceptual Diagram of Seepage and Groundwater Flow. Modified from Figure 3, Canonie 1994 and Plate 2, HLA 1996.

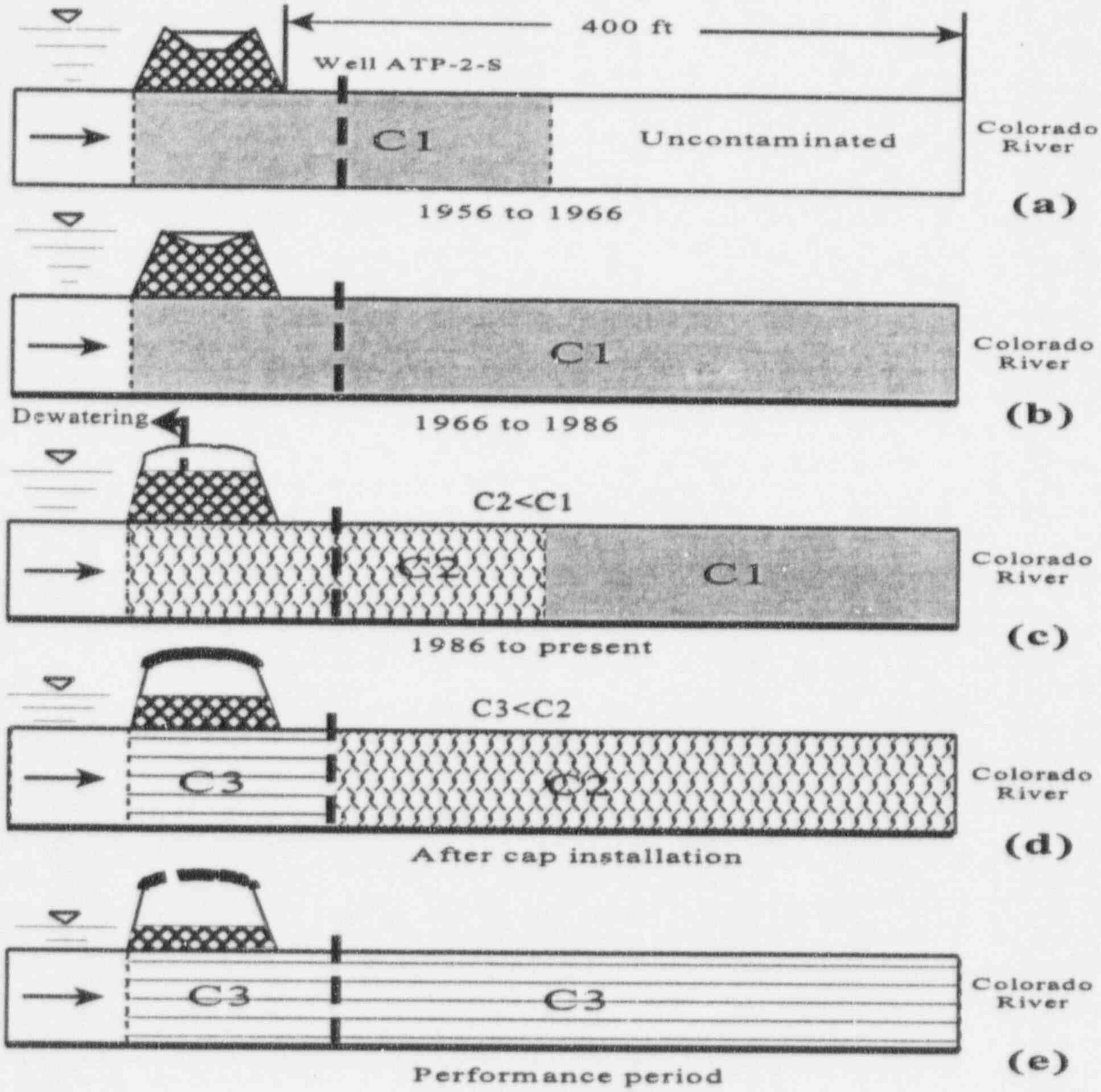

Figure 4. Conceptual Diagram of the Development of the Groundwater Contaminant Plume.

In 1986, Atlas halted operations that added liquids to the pile and began dewatering the groundwater mound within the pile. Dewatering reduced the size of the mound, lowered the hydraulic head pushing dissolved species into the underlying aquifer, and reduced concentrations of dissolved species recorded at monitoring well ATP-2-S located between the toe of the pile and the Colorado River [see Figure 4(c)]. Concentrations of total dissolved solids (TDS) and total uranium radioactivity recorded as a function of time at monitoring well ATP-2-S shown in Figures 5 and 6, respectively, support the evaluation of the behavior and trends of seepage from the pile depicted in Figure 4, and the conclusion that dewatering and installation of an interim cap have reduced the seepage of contaminants into the Quaternary alluvial aquifer that eventually discharges into the Colorado River.

An estimate of the average seepage rate for the period from February 1989 to February 1994 of 33 gpm was made by the licensee (Canonie 1994). During that period, the licensee was dewatering the pile by pumping water to the surface, where it was sprayed into the atmosphere and evaporated. The licensee monitored the volume of water pumped and the drawdown in water level in the tailings. After correcting for the porosity of the tailings (45 percent) and assuming a 15 percent retention of water in unsaturated tailings, the drawdown of water level was greater than could be accounted for by the volume of water pumped out. The difference of 33 gpm was attributed to water that seeped out the bottom of pile. The actual seepage rate from the pile was greater than 33 gpm because additional water was infiltrating the pile as a result of precipitation. In the DEIS and BA, a seepage rate of 25 gpm was calculated, based on the assumption that 30 percent of the mean annual precipitation of 8.2 inches per year infiltrates an 81-hectare (200-acre) pile. Correcting the estimate of the size of the tailings pile to 53 ha (130 acres) that would receive incident precipitation results in a corresponding 35% seepage rate reduction to about 16 gpm. Thus, the average 1989–1994 seepage rate from the pile is estimated to have been about 49 gpm—because of the approximations used in deriving this value, it is rounded to 50 gpm. Because the seepage is controlled by permeability, which remained constant, and head, which was decreasing during the period, the seepage rate was also decreasing during the period.

The seepage rate during the period of mill operation was presumably higher than 50 gpm and the current seepage rate is lower than 50 gpm. As a result of further pumping and seepage, the water level in the pile will continue to drop, reducing the head driving water out the bottom of the pile. At some point in the future, an equilibrium will be established, and the seepage rate will primarily reflect the infiltration rate of precipitation into the pile . In the absence of a cover designed to retard infiltration, approximately 16 gpm will infiltrate the pile and seep out the bottom.

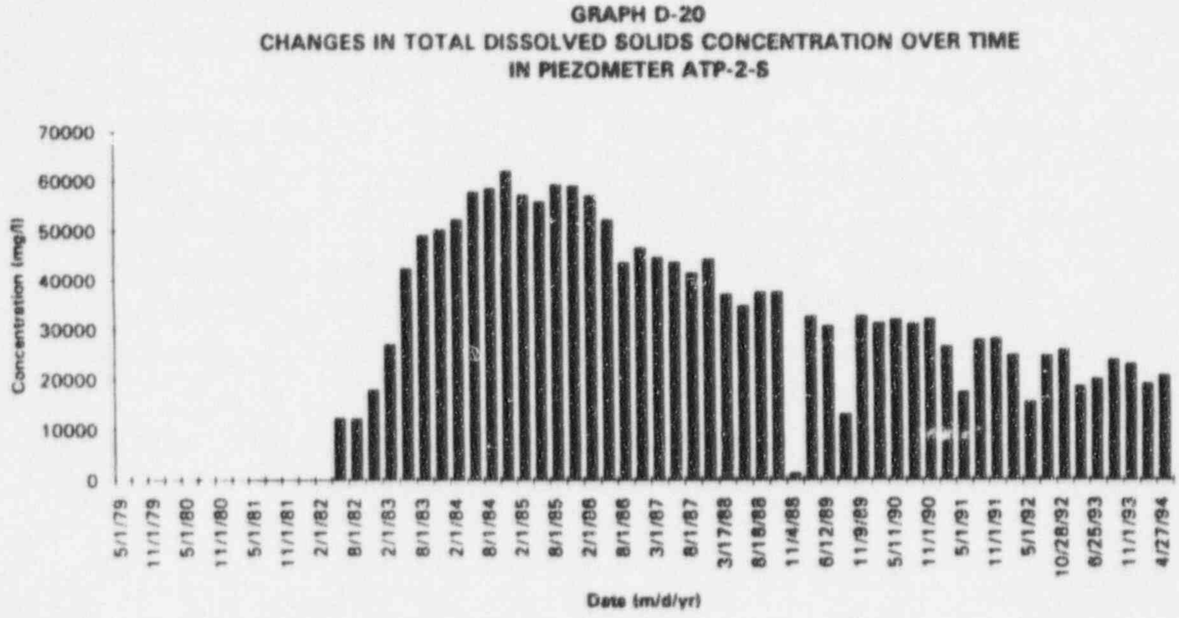

Figure 5. Changes in Total Dissolved Solids Concentrations in Piezometer ATP-2-S Over the Period 1982–1994. *Source*: Canonie 1994.

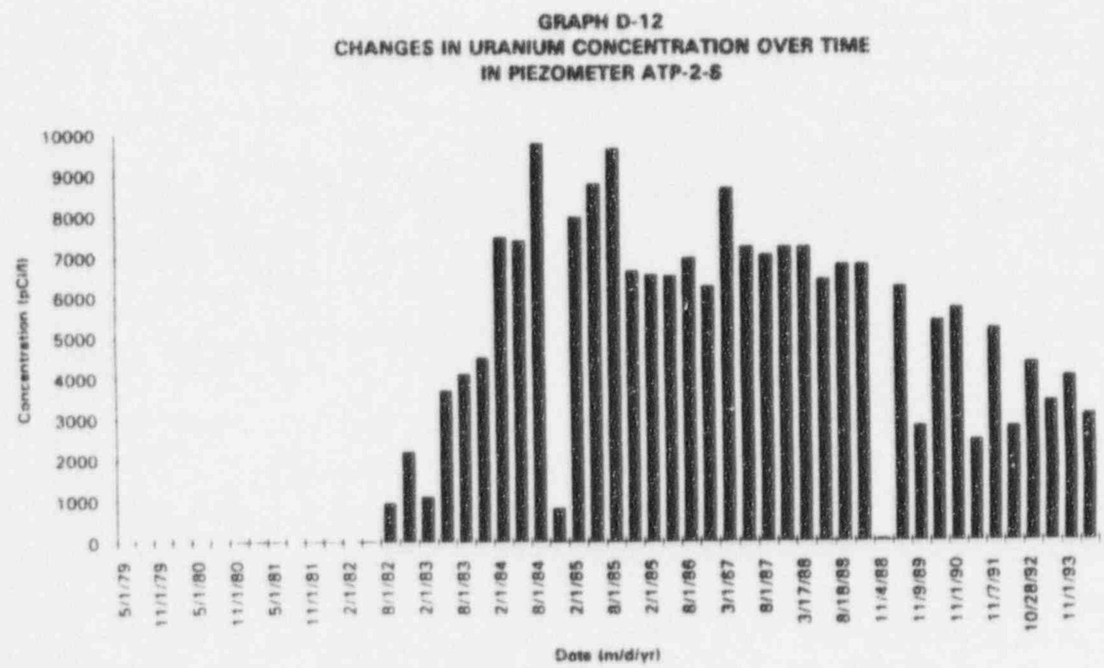

Figure 6. Changes in Uranium Concentrations in Piezometer ATP-2-S Over the Period 1982–1993. *Source*: Canonie 1994.

Installation of the engineered cap would limit the amount of rainfall entering the pile. The proposed cover has a design permeability of 10^{-7} cm/sec. Covers with permeabilities this low and lower have been designed and constructed at other tailings impoundments. A cover with a 10^{-7} cm/sec permeability would limit infiltration to about 8 gpm over the 130-acre pile, assuming that the cover were always saturated. If the cover were not always saturated, the infiltration rate would be less. Thus, the long-term seepage rate from the pile to groundwater would be 8 gpm or less.

Under the proposed design, the performance period of the pile with respect to stability is 1000 years, although it is likely to remain stable for an indefinite period beyond the design life. Because the cover's permeability is the result of the characteristics of the earthen materials used, it is unlikely to change significantly in the future.

The groundwater flow rate passing horizontally beneath the pile into the river may be different than that estimated in the DEIS and BA. A preliminary estimate of the flow rate by HLA, for example, using an approach involving Darcy's Law indicates a groundwater flow rate beneath the pile of only 16 gpm (HLA 1996b)—a value a little more than one order of magnitude less than staff's estimate of 280 gpm based on relative concentrations of TDS in saturated pile leachate and the groundwater (both upgradient and downgradient from the pile), and a pile seepage rate of 25 gpm. Using the estimated 1989–1994 pile seepage rate of 50 gpm discussed above and the relative concentrations of TDS results in a groundwater flow rate of about 560 gpm. The actual flow is likely to be somewhere between these values. A similar flow rate can be obtained using data on ammonia concentrations in pile seepage and in groundwater.

Because there is considerable uncertainty regarding the actual values for seepage rate, volumetric groundwater flow rates, and contaminant concentrations dissolved in seepage and groundwater, and because all three of these quantities vary with time, the assessment of current impacts conservatively uses the higher seepage and groundwater flow rates for calculating contaminant transport to the river and resulting concentrations, doses, and impacts in the river after complete mixing. As discussed above, contaminant fluxes (and thus post-dilution concentrations and effects on water quality in the river) in the future, are expected to be substantially less than staff's conservative estimates of current conditions. The mixing zone in the Colorado River and the numbers of aquatic organisms exposed to contaminant concentrations above water quality criteria, therefore, also would be proportionally smaller in the future.

3. IMPACTS TO THREATENED AND ENDANGERED FISH

The following analysis replaces Section 4.1 of the BA. It uses data and analysis presented in the BA, but it also synthesizes and evaluates data that has become available since publication of the DEIS. Information on the project and the affected environment is presented in the BA and the DEIS.

3.1 Current Effects of the Tailings Pile on Water Quality and Biota

3.1.1 Current Status of the Colorado River

The Utah Administrative Code R-317-2-13 (Water Quality Standards) classifies the Colorado River and its tributaries as

1C Protected as a raw water source for domestic purposes with prior treatment processes as required by the Utah Department of Health;

2B Protected for boating, water skiing, and similar uses, excluding swimming;

3B Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain; and

4 Protected for agricultural uses including irrigation of crops and stock watering.

Both water quality and the native fish fauna of the Colorado River have declined over the years as human activities in the basin have expanded. As suggested by Table 1, exotic fish species introduced by man now tend to dominate the mainstem ecosystem of the Colorado River. Dams and water diversion projects have greatly accelerated water loss through evaporation and consumption, resulting in higher salinities (i.e., TDS), altered temperature and flow regimes, and altered nutrient and suspended solids transport (Carlson and Muth 1989; Upper Colorado Region State-Federal Interagency Group 1971). Industrial development (in particular, mining and milling) and rapid urbanization have introduced wastewaters containing a variety of contaminants into the river, including suspended sediments, acid mine drainage, heavy metals, radionuclides, and organic wastes.

Table 1. Fish that Occur or May Occur in the Colorado River near the Tailings Pile[a]

Common name	Scientific name	Status[b]
Roundtail chub	*Gila robusta*	N
Humpback chub	*Gila cypha*	N, E
Bonytail chub	*Gila elegans*	N, E
Colorado squawfish	*Ptychocheilus lucius*	N, E
Longnose dace	*Rhinichthys cataractae*	I
Speckled dace	*Rhinichthys osculus*	N
Fathead minnow	*Pimephales promelas*	I
Carp	*Cyprinus carpio*	I
Red shiner	*Notropis lutrensis*	I
Sand shiner	*Notropis stramineus*	I
Flannelmouth sucker	*Catostomus latipinnis*	N
Bluehead sucker	*Catostomus discobolus*	N
Razorback sucker	*Xyrauchen texanus*	N, E
Channel catfish	*Ictalurus punctatus*	I
Black bullhead	*Ictalurus melas*	I
Rio Grande killifish	*Fundulus zebrinus*	I
Largemouth bass	*Micropterus salmoides*	I
Green sunfish	*Lepomis cyanellus*	I

[a]Sources: Bates (1994); Carlson and Muth (1989); Lee et al. (1980); NRC (1980).

[b]N = native to upper Colorado River; I = introduced species; E = Federally listed endangered species.

3.1.2 Water Quality Monitoring in the Vicinity of the Atlas Pile

Table 2 summarizes the results of water quality monitoring by the Utah Division of Water Quality and others upstream and downstream of the tailings pile for approximately the last 10 years. The data in this table reveal a very turbid river of considerable hardness, high suspended solids loading, fairly high salinity for a freshwater river (due to a large extent to high sulfate levels), and often wide fluctuations in the concentrations of all of these constituents.

The water quality data collected by the Utah Division of Water Quality (Table 2) indicate that water quality downstream of the tailings pile does not differ measurably from that upstream of the pile. Possible exceptions include suspended solids, pH, manganese, and gross alpha. However, because the upstream and downstream sampling stations are as much as 102 river km (63 miles) apart, many natural and human-related sources other than the tailings pile could account for these differences. Further, the limitations of the database should be recognized—e.g., the relatively small numbers of samples and the high detection levels in some cases.

With regard to suspended solids, over half the difference between upstream and downstream averages can be explained by one exceedingly high measurement at the lower station without a corresponding sample from the upper station until 7 days later. Moreover, a related variable, turbidity, suggests an opposing trend, as average turbidity was slightly lower downstream than upstream. Several constituents at least occasionally exceeded State water quality standards for protection of aquatic life—cadmium, copper, lead, mercury, zinc, ammonia, gross alpha, and gross beta. Of these, only gross alpha *averaged* higher than the standard: 0.59 Bq/L (16 pCi/L) at the downstream station versus the State standard of 0.56 Bq/L (15 pCi/L). Most of the alpha contamination, but not necessarily all, is from other natural or anthropogenic sources. A small amount of the total alpha count at downstream sampling stations almost certainly comes from the Atlas tailings pile. Geologic formations, other old mining and milling operations, and former tailings pile sites far upstream are likely contributors to the relatively high gross alpha counts.

Manganese, a constituent for which no State water quality standard for the protection of aquatic life currently exists, registered substantially higher concentrations downstream from the pile than upstream. Although EnecoTech (1988) reported a manganese concentration of 21 mg/L in the tailings pile liquid (mean of two measurements), the Atlas pile is almost certainly not the principal source of the elevated manganese downstream, as shown in the following discussion. Even at the lowest recorded Colorado River flow of 558 cfs and an assumed pile seepage rate of 50 gpm, the post dilution (completely mixed) increase in manganese concentration attributable to the tailings pile is only 4.1 μg/L. At average flow, the increase would be only 0.30 μg/L. These increases are

Table 2. Comparison of Water Quality of the Colorado River Upstream and Downstream of the Tailings Pile[a]

Parameter	Upstream[b] mean	Range	Downstream[c] mean	Range	Downstream[d] mean	Range	State standard[e]
Flow (cfs)	7,711	558–76,800	7,770	–	6800	–	–
Temperature (°C)	11.7	−0.4–26.1	13.8	0–26.8	17.1	9.7–23.1	27
pH	8.2	7.2–9.0	7.8	6.6–9.0	7.9	7.5–8.2	6.5–9.0
Dissolved oxygen (mg/L)	9.0	5.0–12.9	9.0	5.9–13.5	8.4	7.6–8.9	5.5
Specific conductivity (µS/cm)	1010	270–1600	890	320–1500	749	389–1128	–
Total hardness (mg/L)	330	116–535	302	140–501	300	150–470	–
Total dissolved solids (mg/L)	690	230–1110	600	230–1070	600	300–930	1200
Total suspended solids (mg/L)	470	<3–3480	930	39–10,000	816	66–3980	–
Turbidity (NTU)	173	3.5–>1000	165	13–490	–	–	+10
Total Kjeldahl nitrogen (mg/L)	0.66	0.1–1.7	0.88	<0.1–3.4	0.78	0.17–2.68	–
Ammonia nitrogen (mg/L)	<0.1	<0.1–0.4	<0.08	<0.05–0.24	<0.064	<0.05–0.11	–[h]
Nitrate nitrogen (mg/L)	0.54	0.13–1.1	0.52	0.11–0.97			4
Sulfate	264	51–520	226	59–460	228	78–450	
Orthophosphate (mg/L)	<0.13	<0.01–0.66	0.12	<0.01–0.49			
Arsenic (µg/L)[g]	<2.8	<0.5–6.5	<3.1	<0.5–5.5	<5.0		190 / 0.017[i]
Cadmium (µg/L)	<1	<1–3	<1	<1–3	<1.0	–	1.1
Copper (µg/L)	<21	<10–49	<20	10–25	<22	–	12
Iron (µg/L)	<34	<20–80	<40	<20–77	<25	–	1000
Lead (µg/L)	<7.9	<5.0–30	<8.4	<3–29	<3.5	–	3.2
Manganese (µg/L)	156	15–1000	233	<10–855	<149	<10–360	–
Mercury (µg/L)	<0.2	<0.1–<0.33	<0.3	<0.1–1.0	M<0.2	–	0.012

Table 2. Continued

Parameter	Upstream[b] mean	Range	Downstream[c] mean	Range	Downstream[k] mean	Range	State standard[d]
Molybdenum (µg/L)	<10[e]	<10	–	–	–	–	–
Nickel (µg/L)	<2.5[e]	<1–4	–	–	–	–	–
Selenium (µg/L)	<4.9	<2–10	<4.0	–	<4.0	<2.0–5.0	–
Silver (µg/L)	<2.0	<2.0	<2.0	–	0.07–0.44	<2.0	–
Uranium (natural) [Bq/L (pCi/L)]	0.17 (4.5)[f]	0.06–0.30 (1.6–8.1)[f]	0.19(5.1)[f]	0.07–0.44 (1.8–12)[f]	–	–	–
Vanadium (µg/L)	<6[e]	<6	–	–	–	–	–
Zinc (µg/L)	<30	<10–120	<43	10–100	<31	<20–45	110
Gross alpha [Bq/L (pCi/L)]	0.48 (13)	<0.07–1.85 (<2–50)	16	3–74	–	–	15
Gross beta [Bq/L (pCi/L)]	<1.1 (<30)	<0.4–3.0 (<10–81)	<27	<5–99	–	–	50
Radium-226 [Bq/L (pCi/L)]	<0.04 (<1)	<0.004–0.07 (<0.1–2)	<1	0.1–2	–	–	5[g]
Radium-228 [Bq/L (pCi/L)]	0.04 (1)	0.04 (1)	1	1	–	–	5[g]

[a]Except where noted, all data were provided by Utah Department of Environmental Quality, Division of Water Quality, Salt Lake City. Each average and range of values represents a sample size as low as 5(Se) to as high as 85 (total dissolved solids). Blank spaces mean no data or standards were available.

[b]Colorado River above U.S. 191 bridge.

[c]Above Colorado/Green Rivers confluence.

[d]Water quality standards in Utah Administrative Code R317-2; values shown are the most conservative expression of the standard (e.g., 4-day average criterion for aquatic life).

[e]Based on 4 samples during 1985–86 near Cisco, Utah, upstream of Atlas site (USGS 1987).

[f]From Atlas Corporation Environmental Monitoring Reports for 1989–93.

[g]Total activity for radium-226 and radium-228 combined.

[h]Dependent on temperature and pH.

[i]The first (higher) value is for protection of aquatic life; the second (lower) value is for protection of human health.

[j]For trace elements, the acid soluble fraction is given.

[k]Potash boat ramp, 23 km downstream of pile

[l]Acid-soluble manganese; dissolved manganese concentration were much lower (<10 percent).

very small compared to the mean ambient river concentrations of 156 µg/L upstream of the pile and 233 µg/L downstream. It is unlikely, therefore, that the tailings pile is responsible for the nearly 50 percent increase in mean manganese concentration between the U.S. 191 bridge sampling station and the downstream station just above the confluence of the Colorado and Green rivers. Instead, the increase might be attributable to other sources, both natural and anthropogenic, in the drainage basin between the pile and the downstream sampling station. It should also be noted that the reported manganese values are quite variable; concentrations at the upstream station ranged from 15 µg/L to 1000 µg/L, while downstream concentrations ranged from less than 10 µg/L to 855 µg/L. While the manganese concentrations upstream and downstream of the pile are considerably higher than reported for many other U.S. surface waters, and do exceed the calculated population EC20 of 112 µg/L (the concentration that is estimated from limited data and extrapolation models to cause a 20 percent reduction in recruit abundance of largemouth bass) reported in Suter and Tsao (1996), the mean values are well below the lowest reported *test* EC20 of 1270 µg/L for fish.

Finally, the manganese concentrations reported in Table 2 are for acid-soluble manganese. Dissolved manganese concentrations, for which there were fewer samples taken, were far lower—averaging less than 16 µg/L (n=10) upstream of the tailings pile and less than 10.3 µg/L (n=4) downstream near the confluence of the Colorado and Green Rivers. These concentrations are well within the EPA criterion for domestic water supplies of 50 µg/L. Because dissolved manganese is more likely to be biologically available than manganese soluble only on acidification, the dissolved manganese concentrations are probably more meaningful with respect to water quality and aquatic biota. With tolerance values ranging from 1.5 mg/L to over 1000 mg/L, manganese is unlikely to be a problem for aquatic life (EPA 1986). In conclusion, there may be cause to investigate further the source and biological significance of high manganese concentrations in the Colorado River, but the Atlas tailings pile is very unlikely to be a significant contributor to these relatively high concentrations.

Because the two downstream stations were so far downstream of the tailings pile (about 23 and 103 km), the Utah Department of Environmental Quality (DEQ), Division of Radiation Control recently initiated sampling of the Colorado River in the vicinity of the Atlas pile for analytes of special concern. The samples were collected at the previous upstream station, a new downstream station only about 2 km downstream of the pile, and a new "seep" station adjacent to the pile (Morton 1996). This "seep" is actually a hole excavated by DEQ personnel from the bed of Moab Wash. Seepage into this hole is believed to represent groundwater quality before discharging into the Colorado River. The results for chemical and radiological analytes are presented in Tables 3 and 4, respectively—note that resulting contaminant concentrations probably

Table 3. Concentrations of Selected Chemicals in Colorado River and Seep Water. (Utah State Department of Environmental Quality, Division of Radiation Control, 1995-96, Report to M. Fliegel, NRC April 17, 1996)

Analyte	Date										
	3/30/95 (μg/L)	5/11/95 (μg/L)	6/29/95 (μg/L)	8/10/95 (μg/L)	9/21/95 (μg/L)	11/15/95 (μg/L)	12/7/95 (μg/L)	1/18/96 (μg/L)	2/28/96 (μg/L)	4/11/96 (μg/L)	7/25/96 (μg/L)
Arsenic											
Upstream	–	<5.0 D	<5.0 T	<5.0 T	<5.0 T	<5.0 D	<5.0 D	<5.0 D	<5.0 D	<5.0 D	<5.0 D
Downstream	<5.0 H+	<5.0 T	<5.0 T	<5.0 T	<5.0 T	<5.0 D	<5.0 D	<5.0 D	<5.0 D	<5.0 D	<5.0 D
Seep	–	–	–	–	<5.0 D	–	6.0 D	13 D	12 D	<5.0 D	–
Cadmium											
Upstream	–	<1.0 D	<1.0 T	<1.0 T	<1.0 T	<1.0 D	<1.0 D	<1.0 D	<1.0 D	<1.0 D	<1.0 D
Downstream	<1.0 H+	<1.0 T	1 T	<1.0 T	<1.0 T	<1.0 D	<1.0 D	<1.0 D	2.0 D	<1.0 D	<1.0 D
Seep	–	–	–	–	<1.0 D	–	<1.0 D	<1.0 D	2.0 D	<1.0 D	–
Chromium											
Upstream	–	<5.0 D	<5.0 T	<5.0 T	6.0 T	7.0 D	<5.0 D	<5.0 D	<5.0 D	<5.0 D	<5.0 D
Downstream	<5.0 H+	<5.0 T	<5.0 T	<5.0 T	5.0 T	<5.0 D	<5.0 D	<5.0 D	<5.0 D	<5.0 D	<5.0 D
Seep	–	–	–	–	<5.0 D	–	<5.0 D	<5.0 D	<5.0 D	<5.0 D	–
Copper											
Upstream	–	<12	<12 T	<12 T	<12 D	12 D	<12 D	<12 D	<12 D	<12 D	<12D
Downstream	<12 H+	<12 T	<12 T	<12 T	<12 T	<12 T	<12 T	<12 T	< 12 T	–	<12 D
Seep	–	–	–	–	27 D	–	30 D	21 D	40 D	28 D	–
Mercury											
Upstream	–	<0.2 D	<0.2 T	<0.2 T	<0.2 T	<0.2 D	<0.2 D	<0.2 D	<0.2 D	<0.2 D	<0.2 D
Downstream	<0.2 H+	<0.2 T	<0.2 T	<0.2 T	<0.2 T	<0.2 D	<0.2 D	<0.2 D	<0.2 D	<0.2 D	<0.2 D
Seep	–	–	–	–	<0.2 D	–	<0.2 D	<0.2 D	<0.2 D	<0.2 D	–
Lead											
Upstream	–	<3.0 D	13.0 T	<3.0 T	6.0 T	<3.0 D	<3.0 D	<3.0 D	<3.0 D	9.0 D	<3.0 D
Downstream	3.0 H+	<3.0 T	13.0 T	3.0 T	6.0 T	<3.0 D	<3.0 D	<3.0 D	<3.0 D	<3.0 D	<3.0 D
Seep	–	–	–	–	<3.0 D	–	<3.0 D	<3.0 D	<3.0 D	<3.0 D	–

Table 3. Continued

Analyte	Date										
	3/30/95 (μg/L)	5/11/95 (μg/L)	6/29/95 (μg/L)	8/10/95 (μg/L)	9/21/95 (μg/L)	11/15/95 (μg/L)	12/7/95 (μg/L)	1/18/96 (μg/L)	2/28/96 (μg/L)	4/11/96 (μg/L)	7/25/96 (μg/L)
Manganese											
Upstream	–	<5.0 D	120 T	<5.0 T	74 T	11 D	13 D	17 D	39 D	7.7 D	<5.0 D
Downstream	81 H+	<5.0 T	120 T	39 T	94 T	10 D	95 D	13 D	23 D	50 D	5.2 D
Seep	–	–	–	–	2300 D	–	3600 D	2200 D	2000	3470 D	–
Molybdenum											
Upstream	–	–	–	–	4 T	–	4.0 D	4.0 D	6.0 D	8.0 D	7.9 D
Downstream	–	–	–	–	4 T	–	33 D	6.0 D	7.0 D	3.0 D	8.7 D
Seep	–	–	–	–	1390 T	–	1200 D	1200 D	1550 D	1550 D	–
Selenium											
Upstream	–	2.0 D	<1.0 T	<1.0 T	4.0 T	3.0 D	4.0 D	4.0 D	1.0 D	2.0 D	3.8 D
Downstream	2.0 H+	2.0 T	<1.0 T	2.0 T	4.0 T	3.0 D	2.0 D	3.0 D	2.0 D	1.0 D	3.8 D
Seep	–	–	–	–	<1.0 D	–	1.9 D	3.0 D	1.0 D	<1.0 T	–
Vanadium											
Upstream	–	–	–	–	<40 T	–	<40 D	<40 D	<40 D	<40 D	<40 D
Downstream					<40 T		<40 D	<40 D	<40 D	<40 D	<40 D
Seep	–	–	–	–	84 T	–	140 D	280 D	278 D	96 D	–
Zinc											
Upstream	–	<30 D	33 T	<30 T	<30 T	30 D	<30 D	<30 D	<30 D	<30 D	<30 D
Downstream	<30 H+	<30 T	61 T	<30 T	<30 T	<30 D	<30 D	<30 D	<30 D	46 D	<30 D
Seep	–	–	–	–	60 D	–	48 D	<30 D	110 D	<97 D	–
Ammonia Nitrogen											
Upstream	–	–	–	–	–	<50	<50	–	230	132	52
Downstream	–	–	–	–	–	156	910	–	326	127	158
Seep	–	–	–	–	300,000	–	220,000	–	2120	219,000	–

[a]T = total; D = dissolved; H+ = acid soluble.

Note: Concentrations of Hg, Ag, V, and Ni in all samples, upstream and downstream, were below limits of detection (0.2 for Hg, 2.0 for Ag; 40 for V; and 10 for Ni).

Table 4. Concentrations of Selected Radionuclides in Colorado River and Pile Seep Water.
(Utah State Department of Environmental Quality, Division of Radiation Control, 1995-96, Report to M. Fliegel, NRC, April 17, 1996)

Radionuclide	3/30/95 (pCi/L)	5/11/95 (pCi/L)	6/29/95 (pCi/L)	8/10/95 (pCi/L)	9/21/95 (pCi/L)	11/15/95 (pCi/L)	12/7/95 (pCi/L)	1/18/96 (pCi/L)	2/28/96 (pCi/L)	4/11/96 (pCi/L)	7/25/96 (pCi/L)
Gross Alpha											
Upstream	–	3±4	5±3	7.9	5±4	<2	7±3	<2	6±4	12±1.3	15±1.0
Downstream	7±7	6±4	5±3	5.3	5±4	<2	8±3	3±4	8±4	19±1.0	22±1.3
Seep	–	–	–	–	298±29	–	201±23	101±22	900±150	720±5.0	°
Gross Beta											
Upstream		12.5±5	<10	<10	11±6	<10	10±4	<10	<10	<10	<10
Downstream	10±8	11.2±5	<10	<10	17±6	<10	<10	<10	<10	11.5±6.3	<10
Seep	–	–	–	–	493±21	–	539±21	239±15	237±17	890±74	°
Radium-226											
Upstream		2.6±1.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3±0.3	<0.5
Downstream	<0.5	2±1	1.5±0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1±0.6	<0.5
Seep	–	–	–	–	6±1	–	<0.5	10.3±1	9.7±1.0	6.5±0.8	°
Radium-228	–										
Upstream		<1	1±2	<1	0.7±2	<1	<1	<1	<1	2.8±2.2	<1
Downstream	<1	<1	<1	<1	2±2	1.3±2	1±2	<1	<1	<1	<1
Seep	–	–	–	–	<1	–	2±2	2±3.5	3.6±2.0	5.4±2.3	°
Uranium-total											
Upstream	–	–	–	–	5.7±1	5.4±1	5.0±1	4.1±1	7.1±2.1	3.2±1.0	1.0±1.0
Downstream	8.4±1.9	–	1.3±0.7	–	5.3±1	4.7±0.9	4.0±0.9	5.0±1.1	23±3.0	4.6±1.4	2.8±1.0
Seep	–	–	–	–	948±12	–	955±14	1187±15	787±16	825±15	°

represent conditions of hydraulic head and saturation prevailing in the pile roughly 20 years ago. These data tend to support the general indications shown in Table 2 that the pile is not contributing significantly to the river's burden of most chemical and radiological contaminants, even though the seep data do indicate that groundwater downgradient of the pile is enriched, to a greater or lesser extent, in arsenic, manganese, molybdenum, vanadium, zinc, ammonia, radium-226, radium-228, and natural uranium (mainly uranium-238 and uranium-234 on an activity basis). This groundwater discharges to the Colorado River.

Based on this most recent sampling, the only contaminants that appear to increase downstream of the pile are manganese, molybdenum, ammonia, and uranium. Of these contaminants, only ammonia (at a maximum of 10.8 mg/L as nitrogen) appears to potentially exceed Utah water quality criteria for protection of aquatic life (0.36 mg/L at typical river pH and temperatures). Only one of four downstream samples yielded a higher concentration of manganese (95 μg/L dissolved) than upstream samples (11-39 μg/L dissolved). This higher level is unlikely to pose a threat to aquatic life, although it is higher than the criterion of 50 μg/L for domestic water supplies [primarily to prevent staining of laundry and objectionable taste, not for protection of aquatic life (EPA 1986)].

Available data indicate that the pile also causes a slight increase in TDS in the river, and although the increase is unlikely to be biologically significant (2 mg/L at average river flow and 28 mg/L at extreme low flow), the increase does not comply with requirements of the Colorado River Salinity Control Act. Importantly, neither the seep data nor the downstream data for cadmium, chromium, mercury, lead, and selenium indicate that the pile contributes significant amounts of these toxic trace elements to the river—in one seep and one downstream sample, cadmium was detected at a concentration of 2 μg/L, just above the limit of detection. However, it is clear that 2 μg/L cadmium in groundwater entering the river at a flow rate of about 1.2 cfs would be diluted to trivial levels [0.31 parts per trillion) in a river that averages 7770 cfs].

In April 1996, the Utah DEQ sampled the Colorado River at three additional sampling stations as well as at the upstream station and the downstream station approximately 1.6 km (1 mile) below the pile (Morton 1996). One of these three stations was located in the river but adjacent to the Moab Wash seep station. The other two were sited in the river 0.40 km (0.25 mile) and 0.80 km (0.5 mile) downstream of the Moab Wash seep station. Tables from Morton's report summarizing the results of this sampling effort are reproduced in Attachment B.

These data, in concert with the contaminant levels shown in Tables 3 and 4, lend further support to the conclusion that the tailings pile is not contributing substantial quantities of most

contaminants to the Colorado River. Moreover, the percentages of sample results exceeding water quality criteria, and downstream results exceeding upstream results as shown in the last row of Table 1 of Attachment B support this conclusion. Of the downstream stations, for example, only the station adjacent to the seep produced more exceedances of water quality criteria (14 percent) than the upstream station (9 percent). Also, the highest percentage of downstream sample concentrations exceeding upstream concentrations was only 36 percent (the station adjacent to the seep). If no differences between upstream and downstream sample concentrations were expected, then one would expect approximately 50 percent of the downstream concentrations to exceed upstream concentrations.

These observations are especially important with respect to some of the substances particularly toxic to endangered fish and other aquatic biota such as selenium and mercury. None of the four downstream stations showed selenium concentrations, for example, higher than that reported for the upstream station. Once again, ammonia is an important exception. The river station nearest the seep produced ammonia concentrations as high as 10.8 mg/L ammonia as nitrogen, well above levels known to be toxic to aquatic biota and much higher than the State water quality criterion for protection of aquatic life (0.44 mg/L) and the upstream concentration of 0.132 mg/L. Dissolved manganese measured nearly 50 μg/L at the station 1.6 km (1 mile) below the pile, or more than 6 times the upstream concentration, but was only 5 μg/L at the station adjacent to the Moab Wash seep. Even 50 μg/L manganese in a relatively small area, however, is unlikely to pose a hazard to endangered fish or other aquatic life. Moreover, at all but the lowest river flows, the pile's contribution to post-dilution dissolved manganese is only a small fraction of typical background concentrations.

One other nonradioactive element that showed a large jump in concentration in the river was barium (350 μg/L) at the station 0.80 km (0.5 mi) downstream of the seep, compared to 63 μg/L upstream. Nevertheless, the spike in barium concentration is probably unrelated to the tailings pile because seep concentrations of barium are only slightly higher than upstream concentrations. Moreover, barium is unlikely to be toxic to endangered fish or other aquatic life at these concentrations.

From the second table in Attachment B, it can be seen that radionuclide concentrations increased somewhat adjacent to and downstream of the seep compared to upstream. The most substantial increase was exhibited by gross alpha—12 pCi/L upstream of the seep, 50 pCi/L adjacent to the seep. At 1.6 km (1 mile) downstream of the seep, the gross alpha concentration of 19 pCi/L still exceeded the State water quality criterion of 15 pCi/L.

With respect to river sediments, contaminant concentration data is less plentiful. The gross alpha and beta counts for unreplicated grab samples taken by Atlas adjacent to and downstream of the tailings pile in November of 1994 (Edwards 1994) indicate that sediments in the immediate vicinity of the pile may be slightly contaminated with alpha- and beta-emitting radionuclides.

3.1.3 Recent Fish and Sediment Studies by WestWater and FWS

A one-day sampling program proposed by the National Park Service and the FWS to clarify some of the uncertainties in data discussed above was partially implemented on May 3, 1995, by WestWater Engineering, an Atlas consultant. The effort was hampered by time constraints (one day for all sampling), few or no replicates for individual sampling stations coupled with considerable variability among upstream and downstream stations, a rapidly rising river level which flooded backwater areas selected earlier for representative deposition area sampling sites, and the absence of adequate quantities of invertebrates and periphyton so early in the season. The results of this study (WestWater Engineering 1995) are discussed in the BA. The FWS conducted a sampling effort at the same or nearby sampling stations a few weeks before the WestWater sampling.

Figure 7 of the BA shows the location of the sampling stations. The single day sampling campaign conducted by WestWater shows no clear evidence of sediment contamination adjacent to or downstream of the pile by either radionuclides or other nonradioactive contaminants. Data for uranium-234, iron, lead, manganese, arsenic, and chromium suggested very slight enrichment in sediments adjacent to and/or downstream of the pile. These results, however, may have been influenced by rising water levels immediately preceding and during the sample collections.

The FWS sediment and fish burden data (Mizzi 1996) resulting from samples collected from the Colorado River a few weeks earlier and from the same or adjacent stations used by WestWater agree fairly well for the most part with the WestWater data. The FWS data have some of the same limitations discussed above for the WestWater data, including lack of replication, and, more importantly, no data were obtained for upstream fish. The sediment data showed no arsenic enrichment adjacent to or downstream of the pile relative to upstream (up to 4 mg/L dry weight). Except for a single station (Station 9) yielding a mercury concentration of 0.24 mg/kg dry weight, all sediment samples for mercury upstream and downstream of the pile were below the detection limit of about 0.08 mg/kg.

The FWS sediment manganese concentrations averaged slightly higher upstream of the pile, although the highest downstream concentration (360 mg/kg dry weight at Station 4B) slightly

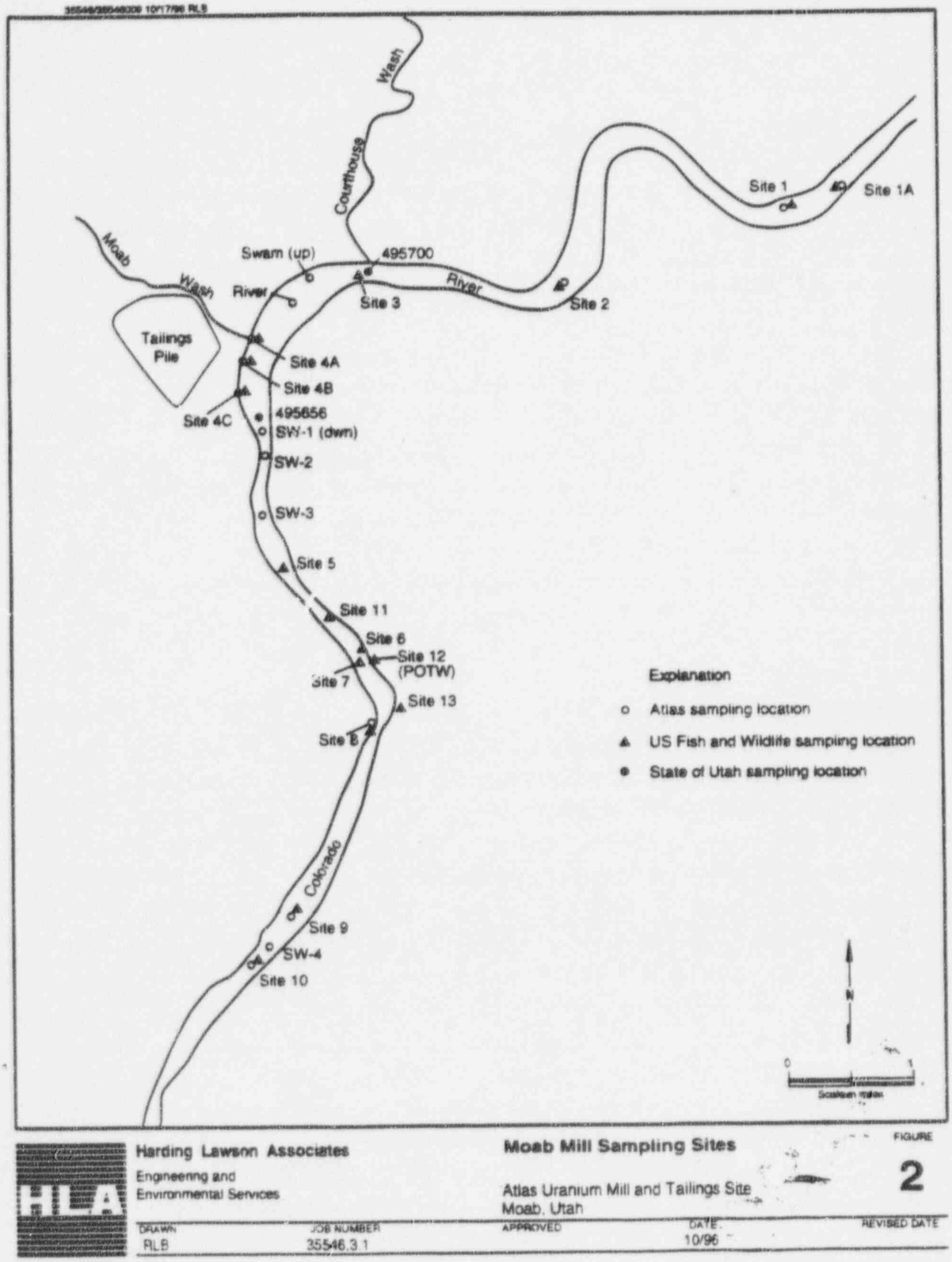

Figure 7. Sampling Locations Used by Atlas, U.S. Fish and Wildlife Service, and the State of Utah.
Source: Figure 2, HLA 1996.

exceeded the highest upstream concentration (330 mg/kg). No molybdenum sediment samples upstream and downstream of the site exceeded the detection limits ranging from 6 to 9 mg/kg dry weight. Similarly, WestWater reported that all molybdenum concentrations for both fish and sediments were less than the minimum detection limit of 0.5 mg/kg.

FWS sediment lead concentrations also averaged somewhat higher upstream (9.4 mg/kg dry weight) than downstream of the pile (6.2 mg/kg dry weight). Except for measurements of 0.16 mg/kg selenium (dry weight) at upstream Station 3 and 0.20 and 0.19 mg/kg dry weight at downstream Stations 8 and 9 respectively, all sediment selenium concentrations upstream and downstream of the pile were below the detection limits of 0.09 to 0.16 mg/kg dry weight, whereas the WestWater data averaged about 0.6 mg/kg downstream of the pile (nearly the same as upstream). Vanadium concentrations in sediment also tended to be slightly higher upstream (14 mg/kg dry weight) than downstream (9.7 mg/kg dry weight).

FWS and Atlas data from the 1995 river sediment sampling effort are summarized in Table 5. None of these data indicate that substantial enrichment of sediments with these contaminants is occurring downstream of the pile. Moreover, nearly all of the downstream contaminant concentrations are below published background soil concentrations for the continental United States. Only selenium and zinc concentrations exceed the mean background concentrations for the United States, and then by only a small amount (e.g., well within one standard deviation from the mean). The FWS and Atlas fish contamination data and their implications for adverse effects are discussed in Section 3.1.7.

3.1.4 Estimated Contribution of the Pile to Contaminant Levels in the River

To better understand the potential effects of the pile on river water quality, tailings leachate data obtained from dewatering wells sunk into the tailings pile (Table 6) and groundwater quality data from Atlas environmental monitoring reports (1989-93) for groundwater downgradient of the pile were used to estimate the *contribution* of the pile to contaminant levels in the Colorado River at average and low flows. The results are summarized in Table 7. Where dewatering well data were available, the post-dilution concentration in the river was calculated by dividing the estimated pile seepage or leachate flow rate of 0.11 cfs (50 gpm) by the river rate of flow and multiplying the resulting dilution factor by the leachate concentration. Where groundwater concentrations for contaminants downgradient of the pile were available, the contaminant concentrations were multiplied by the estimated flow of leachate to the river [the estimated rate of flow of the contaminated groundwater is based on a comparison of estimated ammonia as nitrogen concentration in the pile (about 2,800 mg/L) and the groundwater (as represented by the Moab

Table 5. Mean Sediment Dry Weight (DW) Concentrations Upstream and Downstream of the Atlas tailings Pile Compared to Published[a] Mean Background Concentrations for U.S. Soils. Sediment data collected in May 1995 by FWS (Mizzi 1996) and WWE (WestWater Engineering 1995).

	Sediment concentrations				
Analyte	FWS Upstream	WWE Upstream	FWS Downstream	WWE Downstream	Background Soil Concentration[a]
	(mg/kg dry weight)[b]				
Arsenic	3.6	4	2.4	5	7.2
Cadmium	0.66	0.3	0.39	0.4	0.5
Manganese	283	343	219	379	550
Mercury	<0.084	--	< 0.056 (max=0.24)	-	0.10
Molybdenum	< 8.4	< 0.5	< 9.2	<0.5	0.97
Nickel	< 7.56	9.67	< 5.40	12	19
Lead	9.38	14	6.22	17.8	19
Selenium	< 0.12 (max=0.16)	0.53	< 0.16 (max=0.20)	0.58	0.39
Uranium		2.6		2.7	2.7
Vanadium	14	15.8	9.7	17.3	80
Zinc	44.8	70	31.9	80	60

[a] Shacklette and Boerngen 1984 (except for the cadmium value published by Parr et al. 1983).
[b] Where individual concentration values were below the limit of detection, one half of the detection limit was used in calculating mean values.

Table 6. Mean Concentrations of Dissolved Contaminants in Tailings Solutions Removed from the Tailings Pile Dewatering Well from 1990 to 1996[a]

Analyte	Tailings solution (mg/L)	Standard deviation
Arsenic	<1[b]	-
Cadmium	0.06[b] (total)	-
Chromium	<0.01	-
Copper	1.3[b]	-
Lead	0.12	0.12
Manganese	14.4[b]	-
Molybdenum	2.2	0.48
Nickel	0.38	0.24
Silver	0.031	0.017
Vanadium	1.7	0.97
Selenium	0.37	0.27
Zinc	<0.2[b]	-
Ammonia	2800[b]	-
Sulfate	23,000	4800
Total dissolved solids	31,000	5900
pH	6.9–7.4	-
Gross alpha	19,000 pCi/L	5100
Uranium-natural	21	6.3
Radium-226	61 pCi/L	48
Radium-228	1.2 pCi/L	1.0
Thorium-230	20 pCi/L[b]	-
Lead-210	62 pCi/L[b]	-
Polonium-210	42 pCi/L[b]	-

[a]Data from Atlas Corporation Corrective Action Program Review Reports to U.S. Nuclear Regulatory Commission, 1990–1996.

[b]From a single composite sampie taken June 1996 (Barringer Laboratories, Inc. 1996).

Table 7. Mean Concentrations of Selected Tailings Contaminants in Groundwater and Contaminant Contribution to the Colorado River Following Complete Dilution at Average (7770 cfs) and Minimum (558 cfs) River Flows

Contaminant	Tailings plume concentration[a]	Contributed to river at mean flow[b]	Contributed to river at low flow[b,c]	Ambient river concentration[d]
Uranium (natural) [pCi/L (µg/L)][e]	3100 (4500)	0.50 (0.72)	7.0 (10)	4.8 (7.0)
Thorium-230 (pCi/L)[j]	2.0	0.00032	0.0045	0.90
Lead-210 (pCi/L)[e]	5.5[h]	0.00090	0.012	2.7
Gross alpha (pCi/L)[e]	2700	0.44	6.2	14
Polonium-210	3.7[h]	0.00060	0.0084	3.7
Radium-226 (pCi/L)[e]	6.6[i]	0.0011	0.015	<1
Radium-228 (pCi/L)[e]	2.1	0.00034	0.0048	1
Arsenic (µg/L)	7.2[i]	<0.0012	<0.016	<5.0
Cadmium (µg/L)	5.3[h]	0.00085	0.012	<1
Chromium (µg/L)	0.44[i]	0.00007	0.00098	<5.0
Copper (µg/L)	34[i]	0.0055	0.076	<20
Lead (µg/L)	<3.0[i]	<0.00048	<0.0067	<7.9
Manganese (µg/L)	2700[i]	0.44	6.1	20
Mercury (µg/L)	<0.2[i]	<0.000032	<0.00045	<0.2
Molybdenum (µg/L)	1400[i]	0.22	3.1	<10[f]
Nickel (µg/L)	33[h]	0.0053	0.074	<2.5[f]
Selenium (µg/L)	<24	<0.0038	<0.054	<4.9
Silver (µg/L)	2.7[h]	0.00043	0.0060	<2.0
Vanadium (µg/L)	180[i]	0.028	0.39	<6[f]
Zinc (µg/L)	56[i]	0.0090	0.13	<30
Ammonia N (µg/L)	250,000[h]	40	560	<100
Nitrate/Nitrite N (mg/L)[j]	120	0.019	0.27	0.54
Total dissolved solids (mg/L)	12600[g]	2.0	28	630

Table 7. Footnotes

[a]As measured in groundwater monitoring wells between the pile and river; groundwater flow assumed to be 1.25 cfs (560 gpm).
[b]The leachate contribution is the amount by which the leachate increases the ambient concentrations.
[c]Minimum recorded flow from 1895–1986 (USGS 1987).
[d]Without contribution from tailings leachate. Sources: Utah Department of Environmental Quality, Division of Water Quality, Salt Lake City; Atlas Corporation Environmental Monitoring Reports for 1989-93.
[e]Conversion: 1 pCi/L = 0.037 Bq/L.
[f]Based on four samples from the Colorado River near Cisco, upstream from the Atlas site (USGS 1987).
[g]Corrected for background (6770 mg/L).
[h]Derived from tailings pile dewatering date in Table 4.6 by applying a groundwater dilution factor of 11.3.
[i]Calculated from Moab Wash seep date (Table 3)
[j]From draft compilation of analytical data by HLA (1996).

Wash seep—about 250 mg/L ammonia as nitrogen), yielding a flow rate of about 1.2 cfs (560 gpm)]. Dividing the resulting estimated mass flux of each contaminant in µg/s or pCi/s by the river flow in L/s produces an estimate of the *contribution* of the tailings pile to the ambient contaminant concentration in the river. These contributions are presented in Table 7 for the mean river flow of 220 m^3/s (220,000 L/s or 7,770 cfs) and the record low flow of 15.8 m^3/s (15,800 L/s or 558 cfs). It is conservatively assumed that there is no significant contaminant attenuation at work through such mechanisms as sorption and precipitation.

From the above discussion and Table 7, it is evident that, at average river flows, the tailings leachates currently contribute only minimal amounts of known contaminants compared to the relatively high reported ambient concentrations of contaminants in the river. Given minimal dilution at record low flow conditions, however, uranium, gross alpha (nearly all from uranium and its daughters), ammonia, and molybdenum from the tailings could under current conditions contribute a significant fraction of the river's contaminant concentrations in the vicinity of the pile. Nevertheless, under record low flow conditions, only gross alpha and ammonia concentrations would be likely to approach the State water quality standards. Of these two contaminants, only ammonia, at measured river concentrations as high as 10.8 mg/L under normal flow conditions, could pose a toxicity hazard to aquatic animals (see Table 8), especially at low river flows. The contaminant concentrations (e.g., ammonia) in and near the interface where groundwater discharges into the river may be sufficiently high to be toxic to organisms residing on or near the substrate (see Tables 3, 4, and 7).

3.1.5 Assessment of Existing Impacts

Under conservative contaminant flux estimates discussed in Section 2.2, contaminant concentrations in the downstream river water containing diluted tailings leachate were calculated for those contaminants having river or leachate concentrations high enough to be a concern. These values were then compared with ambient (i.e., upstream) river concentrations, State water quality standards, and published toxicity benchmarks for aquatic life for some contaminants for which standards have not been established (see Table 8 and the discussion in Section 3.5.2 of the DEIS) (Suter, Futrell, and Kerchner 1992). This analysis assumes conservatively that sorption and other processes that may attenuate contaminant levels are not significant and that no effective cover is in place. As noted above, this assessment is based on current conditions which reflect seepage from a saturated tailings pile. An effective cover which would be installed under the proposed action would substantially reduce movement of contaminants into the Colorado River and, therefore, exposure of aquatic biota to contaminants.

Table 8. Contributions of Tailings Leachates to the Colorado River during Mean and Low River Flows, as Compared with Ambient Concentrations, Water Quality Standards for Protection of Aquatic Life, and Toxicity Benchmarks[a] (See Table 4.5._for data sources)

Contaminant	River at mean flow[b]	River at low flow[b,c]	Utah water quality standards	Benchmarks[l] (aquatic life)	Ambient river[g]
Uranium (natural) (pCi/L)[k]	0.5	7.0	–	98[l]	4.8[i]
Thorium-230 (pCi/L)	0.00032	0.0045	–	–	0.90
Lead-210 (pCi/L)	0.00090	0.012	–	–	2.7
Gross alpha (pCi/L)[k]	0.44	6.2	15	–	14[g]
Polonium-210 (pCi/L)	0.00059	0.0082	–	–	3.7
Radium-226 (pCi/L)[k]	0.0011	0.015	5[d]	–	<1[g]
Radium-228 (pCi/L)[k]	0.00034	0.0048	5[d]	–	1[g]
Arsenic (μg/L)	0.0012	0.016	190	–	<5.0
Cadmium (μg/L)	0.00085	0.012	1.1–2.7[m]	–	<1
Chromium (μg/L)	0.00007	0.00098	11	–	<5.0
Copper (μg/L)	0.0055	0.076	12	–	<20
Lead (μg/L)	<0.00048	<0.0067	3.2	–	<7.9
Manganese (μg/L)	0.44	6.1	50	–	20
Mercury (μg/L)	<0.000032	<0.00045	0.012	–	0.2
Molybdenum (μg/L)	0.22	3.1	10	880	<10[h]
Nickel (μg/L)	0.0053	0.074	160	–	<2.5[h]
Selenium (μg/L)	<0.0038	<0.054	5	88	<4.9[g]
Silver (μg/L)	0.00043	0.0060	–	0.12	<2.0
Vanadium (μg/L)	0.028	0.39	–	80	<6[h]
Zinc (μg/L)	0.0090	0.13	110	–	<30
Ammonia N (μg/L)	40	560	360	–	100
Nitrate/Nitrite N (mg/L)	0.019	0.27	4	90	0.54
Total dissolved solids (mg/L)	2.0	28	1200[e]	–	630[g]

[a]See Table 7. Complete dilution is assumed. Mean flow is 220 m^3/s (7770 cfs). Minimum flow is 15.8 m^3/s (558 cfs). Blank spaces indicate data are unavailable. Leachate concentrations were measured in groundwater monitoring wells between the tailings pile and the river. Groundwater flow was assumed to be 1.25 cfs (560 gpm).

[b]Each value is the increase (i.e., the increment only) in river concentration caused by the tailings leachate.

[c]Minimum recorded flow from 1895–1986 (USGS 1987).

[d]Radium-226 and -228 combined standard for protection of agricultural uses.

[e]For protection of agricultural uses.

[f]142 μg/L (lowest reported chronic value).

[g]Utah Department of Environmental Quality, Division of Water Quality (1994).

[h]Based on four samples from Colorado River near Cisco, upstream of tailings pile (USGS 1987).

[i]Mean of river concentrations reported in Atlas Corporation river monitoring reports for the period November 1989 through June 1993.

[j]Variable, depending on temperature, pH, and concentration of un-ionized ammonia at a pH of 8.5 and temperature of 15°C, the State standard is 360 μg/L (total ammonia as nitrogen).

[k]Conversion: pCi/L = 0.037 Bq/L.

[l]Lowest chronic value; Suter and Tsao 1996.

[m]Varies with water hardness. Value of 2.7 μg/L applies to hardness of 300 mg/L which is typical for the Colorado River.

Based on the data presented in Table 8 and Section 4.5.2.4 of the DEIS, even at the record low flow (15.8 m^3/s or 558 cfs), contaminant concentrations (leachate contribution plus ambient concentration) beyond the mixing zone are well below both State water quality standards and toxicity benchmarks, with the exception of ammonia and gross alpha. Ammonia concentrations in the tailings liquid (up to 2,800 mg/L) could result in adverse effects on aquatic biota, including endangered species, depending on river flow, pH, temperature, and ammonia removal processes (e.g., biological assimilation, and nitrification), even after complete dilution during very low river flows. Should natural ammonia removal processes prove inadequate, post-dilution concentrations of ammonia in the river could exceed 0.56 mg/L as nitrogen under extreme low flow conditions and 0.040 mg/L under average flow conditions. The higher concentration exceeds the State standard for protection of aquatic life in the Colorado River (a 4-day average of 0.36 mg/L total ammonia, NH_3, as nitrogen at a pH of 8.5 and temperature of 15° C). Until recently, State monitoring of ammonia downstream of the tailings pile (Table 2) showed no evidence of increased ammonia levels; these monitoring stations, however, are many kilometers downstream of the pile. More recent data collected much closer to the pile by the Utah DEQ (Table 3) indicate that ammonia levels, at least within the mixing zone (as high as 0.91 mg/L), do at least occasionally exceed the Utah water quality criterion as well as the post-dilution concentrations predicted on the basis of the analysis summarized in Table 8. These few relatively high ammonia concentrations in excess of the predicted concentrations may indicate the samples were taken before complete dilution had been achieved (i.e., within the mixing plume for the discharging contaminated groundwater).

To examine the levels of ammonia more closely, the Utah Division of Radiation Control collected additional water samples in September 1996 along both banks of the Colorado River in the vicinity of the pile (Morton 1996). Two of nine sampling stations near each bank were about 300 m and 100 m upstream of the mouth of Moab Wash, while the remaining stations were located at roughly equal intervals of about 330 m in length from about 230 m to 2300 m downstream of the mouth of Moab Wash.

None of the upstream stations on either bank nor the downstream stations sited along the southeast bank had ammonia nitrogen concentrations above the detection limit of 0.05 mg/L. Water samples from all of the downstream river stations on the northwest bank (i.e., nearest the tailings pile), on the other hand, had ammonia concentrations well above the detection limit and the concentrations reported for the upstream stations. The highest measured concentration of 10.8 mg/L occurred at a site about 230 m downstream of the mouth of Moab Wash (still adjacent to the pile). This value is about three times as high as the highest ammonia concentration previously reported for the river in this reach, and is high enough to be potentially toxic to any

endangered fish or other aquatic biota that may reside in the affected area. Ammonia concentrations declined fairly rapidly with distance at downstream stations as follows: 7.2, 3.5, 0.63, 0.44, 0.33, and 0.13 mg/L. Measured concentrations did not drop below the Utah water quality criterion of about 0.36 mg/L ammonia as nitrogen, however, until Station 8, nearly 2 km below Moab Wash. Thus, under the conditions prevailing during the sampling period, up to about 2 km (1.2 miles) of the river along the northwest shoreline may have had ammonia concentrations toxic to endangered fish and other aquatic life. It should be noted that as long as toxic levels of ammonia are confined to the mixing zone, many fish may be able to detect and successfully avoid areas of potential toxicity.

Under record low flows, and assuming gross alpha levels are not otherwise affected by the conditions leading to such low flows, the tailings contribution could cause the gross alpha concentration in the river to exceed the State standard of 0.56 Bq/L (15 pCi/L), when ambient alpha concentrations are not already above the standard. As demonstrated later, however, the radiological hazards to aquatic biota represented by discharge of contaminated groundwater into the Colorado River are very low.

The doubling of suspended solids concentrations in the Colorado River far downstream of the pile also cannot be attributed to the tailings pile. Nearly all precipitation over the pile is prevented from directly entering the river and that which percolates through the pile picks up only about 7.5 mg/L before mixing with groundwater. Both upriver (470 mg/L) and downriver (930 mg/L) suspended solids concentrations reported in Table 2 are within the ranges typically reported for rivers of the arid western United States. Native fish and invertebrates would be expected to be well adapted to the high and highly fluctuating suspended solids concentrations characteristic of this river. Note also that the discussion of the elevated suspended solids level in Section 4.5.2.4 of the DEIS indicates that more than half the difference between upstream and downstream averages can be accounted for by one exceedingly high measurement at the lower station without a corresponding sample from the upper station until 7 days later.

3.1.6 Effects of Specific Contaminants

The following discussion of the potential effects under current conditions of specific trace elements and radionuclides from the pile is based on the results of the limited studies done by WestWater Engineering (1995) and the FWS (Mizzi 1996) and the information presented in Section 4.5.2.4 of the DEIS and Table 8. These surveys, their limitations, and results are described in Section 3.1.3 above.

As indicated in Figures 4–14 of the BA, the WestWater Engineering data suggest that, at least for certain contaminants, concentrations in fish and/or sediments were elevated at one or more sampling stations adjacent to or downstream of the pile. These contaminants include arsenic, iron, lead, manganese, mercury, selenium, vanadium, gross alpha, gross beta, lead-210, polonium-210, radium-226, thorium-230, and total uranium. Of the non-radioactive contaminants, only selenium and mercury concentrations in fish at adjacent or downstream stations appear to exceed upstream concentrations by more than a factor of 2 or 3.

The FWS sediment and fish burden data (Mizzi 1996) resulting from samples collected from the Colorado River a few weeks before and from some of the same stations used by WestWater for the most part agree fairly well with the WestWater data—the FWS data have the same limitations as the WestWater data, including lack of replication; moreover, no data were obtained for upstream fish in the FWS study.

Arsenic. Except for about twice as much arsenic in a single sediment sample from Station 9 (0.8 mg/kg) as was found at other stations, no trend toward increasing arsenic levels in sediment downstream of the pile is evident. Moreover, 0.8 mg/kg is well below the national mean of 7.4 mg/kg for uncontaminated soils reported by Eisler (1988a). The FWS sediment data showed no arsenic enrichment adjacent to or downstream of the pile relative to upstream (up to 4 mg/kg dry weight). River water concentrations of 9, 6, and 8 μg/kg (sampled only at three substations adjacent to the pile) were somewhat elevated compared to the range of values reported for the Colorado River (≤3 μg/kg) in Table 2 and for rivers around the nation by Eisler (≤3 μg/kg; 1988a). Dvorak et al. (1978), on the other hand, reported a basin-wide average river concentration of 53 μg As/L.

As Figure 4 in the BA shows, arsenic body burdens in fathead minnows appear to increase slightly adjacent to the tailings pile (Station 4; 0.6 mg/kg dry weight) and at one station downstream (Station 8; 0.8 mg/kg) of the pile. These values differ little from the concentrations published by Eisler (1988a) for various species of fish, or the geometric mean and 85th percentile concentrations (0.6 and 1.1 mg/kg dry weight, respectively) of arsenic reported by Schmitt and Brumbaugh (1990) for whole fish from 109 stations located around the country. The highest arsenic concentration in fish in the FWS study was 0.79 mg/L dry weight—almost the same reported by WestWater (see BA Figure 5). In summary, there appears to be little likelihood that arsenic levels in the Colorado River are high enough to harm resident aquatic biota, including the endangered Colorado squawfish and razorback sucker.

Iron. At 10 to 15 mg/L, river water concentrations of iron were very high. These high values, however, are most likely attributable to the fact that the analyses were conducted on whole, unfiltered water containing suspended iron-laden minerals. As shown in Table 2, iron concentrations in river water above and below the pile have averaged <40 µg/L over a period of several years. In the FWS study, upstream sediment concentrations of iron were at least as high as downstream concentrations.

On the other hand, Figure 5 of the BA indicates enrichment of iron, an essential nutrient, by a factor of 2 or 3 in fathead minnows at downstream sampling Stations 8 and 9, but not adjacent to the tailings pile (Station 4). No such trends were observed for the sediments in either sampling campaign. Station 8 fish yielded the highest iron level in the WestWater study, 700 mg/kg dry weight. The FWS study produced an even higher body burden for fish from Station 7B (1640 mg/kg dry weight). These values are considerably higher than the concentration (155 mg/kg; wet or dry not specified) cited by Dvorak et al. (1978) for fish residing in an ash basin receiving stream or by Bowen (1979) for marine fish (9–88 mg/kg dry weight). Even so, upstream concentrations also exceed these values; there is no evidence that iron in the environment downstream of the tailings pile represents a hazard to fish or other aquatic organisms.

Lead. Fathead minnows collected at Station 4 (adjacent to the pile) and downstream Stations 8 and 9 exhibited elevated lead levels (by up to a factor of 3) compared to all three upstream stations and Station 10 (BA, Figure 6). However, even the highest concentration, 0.9 mg/L is no higher than the 85th percentile concentration reported by Schmitt and Brumbaugh (1990) for whole fish from 109 sampling stations located around the country. In the FWS study, downstream fish lead burdens ranged from less than 0.39 mg/kg dry weight to 1.5 mg/kg dry weight (Station 7A). Other studies report comparable or higher mean lead concentrations in fish from other rivers and lakes (Eisler 1988b). Water concentrations at Station 4 (20 µg/L) were within the range of lead values in the Colorado River shown in Table 2, and lower than the mean concentration reported by Dvorak et al. (1978) for the Colorado River basin as a whole. Sediment concentrations appeared to be very slightly higher downstream of the pile (11–22 mg/kg), but differed little from U.S. soil concentrations (mean of 20 mg/kg, range of 10–700 mg/kg) as reported by Eisler (1988b). Sediment lead concentrations as determined in the FWS study actually averaged somewhat higher upstream (9.4 mg/kg dry weight) than downstream of the pile (6.2 mg/kg dry weight). In conclusion, lead concentrations do not appear to represent a threat to resident aquatic biota, including endangered species.

Manganese. The manganese concentration (36 mg/kg dry weight) in whole fathead minnows collected from downstream Station 8 were a little more than twice the upstream concentrations

(BA, Figure 7), while concentrations further downstream at Stations 9 and 10 progressively approached upstream levels. The single sample of fish from Station 4 (adjacent to the pile) yielded a body burden lower than in fish from two of the three upstream stations. In the FWS study, downstream fish concentrations of manganese ranged from 24 to 76 mg/kg dry weight. The limited published data on background manganese concentrations in freshwater fish range from about 2.6 (*Coregonus clupeaformis*) to 12 mg/kg dry weight corrected from wet wt (*Esox lucius*)(Jorgensen, Nielsen, and Jorgensen 1991). The fact that these values were for eviscerated fish while the fathead minnows were analyzed as whole fish may explain part, but not all, of the difference.

Sediment concentrations of manganese (480 mg/kg) were slightly elevated at Station 9 compared to upstream stations, but below the 1150 mg/kg reported by Salomons and Förstner (1984) for suspended river sediments and 850 mg/kg for shallow water sediments elsewhere. The sediment manganese concentrations actually averaged slightly higher upstream of the pile, although the highest downstream concentration (360 mg/kg dry weight at Station 4B) determined in the FWS study slightly exceeded the highest upstream concentration (330 mg/kg). The water concentrations at Station 4 were about 1.5 to 3 times higher than the long term average for this reach of the river (which is itself relatively high in manganese compared to most unpolluted U.S. surface waters (see Table 2; Dvorak et al. 1978; Jorgensen, Nielsen, and Jorgensen 1991), but this difference may well reflect the presence of suspended manganese-bearing minerals in the whole water samples. In any event, there is little evidence that manganese concentrations in the river approach levels potentially toxic to aquatic biota [e.g. a maximum of 450 µg/L at Station 4 (much of which is probably bound to suspended minerals and not directly available to fish) compared to the lowest reported chronic toxicity value for fish of 1770 µg/L (Suter and Tsao 1996)]. With tolerance values reportedly ranging from 1.5 mg/L to over 1000 mg/L, manganese is unlikely to be a problem for aquatic life (EPA 1986).

Finally, the manganese concentrations reported in Table 2 are for acid-soluble manganese. Dissolved manganese concentrations, for which there were considerably fewer samples taken, were far lower [averaging less than 16 µg/L (n=10) upstream of the tailings pile and less than 10.3 µg/L (n=4) downstream near the confluence of the Colorado and Green Rivers]. These concentrations are well within the EPA criterion for domestic water supplies of 50 µg/L. Because dissolved manganese is more likely to be biologically available than total manganese or manganese soluble on acidification, the dissolved manganese concentrations are probably more meaningful with respect to water quality and aquatic biota.

Mercury. Mercury in fathead minnows was not detected at the lowest detection limit of 0.1 mg/kg dry weight at the upstream stations, but ranged from 0.2 to 1.2 mg/kg dry weight at the adjacent and downstream stations (Atlas data in Fig. 6 of Appendix F, DEIS). All fish mercury concentrations determined by the FWS were below the limit of detection ranging from 0.19 to 0.77 mg/kg dry weight. Concentrations of mercury as high as 1.2 mg/kg dry weight in fish suggest possible mercury pollution of anthropogenic origins. Schmitt and Brumbaugh (1990) reported geometric mean, 85th percentile, and maximum concentrations of mercury in whole fish nationwide to be 0.1, 0.17, and 0.37 mg/kg wet wt respectively, or, adjusting for the difference between wet weight and dry weight, approximately 0.4, 0.68, and 1.5 mg/kg dry weight respectively.

Dissolved mercury in seep, surface water and sediments was undetectable at all stations (detection limit = 0.2 µg/L for water and 0.1 mg/kg for sediment) (Tables 3 and 5) , but analysis of a single seep sample for total mercury yielded a concentration of 1.2 µg/L. Except for a single station (Station 9) yielding a mercury concentration of 0.24 mg/L dry weight, all sediment samples upstream and downstream of the pile as determined by the FWS also were below the limit of detection of about 0.08 mg/kg. Even the single measurement of 0.24 mg/kg is only 2.4 times the mean background concentration for soils in the United States (Table 5).

In his synoptic review of mercury hazards to fish, invertebrates, and wildlife, Eisler (1987) summarized results of an earlier survey that indicated a mean mercury concentration for fish in the southwest United States of only 0.3 mg/kg dry weight (range: <0.2–0.48). Thus the 1.2 mg/kg dry weight reported for fish from the station adjacent to the pile (Station 4) and the nearest station downstream (Station 8) are only slightly lower than the highest concentration reported in Schmitt and Brumbaugh's nationwide survey, and about 2.5 times the maximum reported by Eisler for fish in the southwest. Eisler (1987) further notes that the highest mercury concentrations in whole fish reported for the 1969–1981 period were from a relative of the Colorado squawfish, the northern squawfish (*Ptychocheilus oregonensis*) of the Columbia River Basin. Granting that the presence of major cinnabar deposits and use of mercury in mineral mining in the river basin may be the primary source of mercury in these fish, Eisler (1987) nevertheless speculates that "Northern squawfish may have a natural tendency to accumulate high concentrations of mercury in their flesh—as is well known for older specimens of long-lived predatory fish . . ."

In their review of literature on the effects of mercury body burden levels on fish, Efroymson and Suter (1995) reported a minimum lowest observed effects concentration (on reproduction) for fathead minnows of 0.66 mg/kg wet weight (about 2.6 mg/kg dry weight)—more than twice the

highest levels reported for fathead minnows near or downstream of the pile. Interestingly, they reported the lowest observed effects concentrations for brook and lake trout to be much higher—5.6 mg/kg wet weight (about 22 mg/kg dry weight) or more. Thus even the highest levels reported for fish near the pile do not appear to be dangerously high. Moreover, none of the FWS analyses showed body burdens exceeding their detection limits ranging from 0.19 to 0.77 mg/kg dry weight.

Eisler's review, on the other hand, also noted that 0.05 to 0.5 mg/kg (wet or dry was not specified, but mercury body burdens are usually expressed as wet weight) in the diet were harmful to sensitive birds; and 1.1 mg/kg was harmful to sensitive mammals (it should be noted that the lower value of 0.05 mg/kg, whether wet or dry, is less than Eisler's estimate of mean mercury body burden for fish of the southwest United States of 0.3 mg/kg dry weight). If this range of 0.05 to 0.5 mg/kg is indeed valid, then the fish at Stations 4 and 8 could be potentially toxic to some predatory birds and mammals should they feed largely on fish and other potentially contaminated organisms from the vicinity of these stations. The potential toxicity of mercury in river water itself cannot be evaluated with any degree of confidence because, although none was detected, the minimum detection limit of 0.2 µg/L is too high to be certain that Utah water quality standards for the protection of aquatic life (Utah Administrative Code R317-2) and known toxic levels (Suter and Tsao 1996 are not exceeded.

Because mercury has not been monitored in tailings leachate or groundwater downgradient of the pile, a series of ten DOE reports on groundwater contamination at other uranium mill tailings sites (DOE 1994a-d, 1995a-e, and 1996) in the western United States were reviewed for evidence of mercury contamination in ground or surface waters. Although these sites have undergone some level of remediation, contaminated groundwater plumes still exist, and it is instructive to examine mercury concentrations in these plumes. Of 123 samples from contaminated groundwater plumes taken among the 10 tailings sites, only eight samples yielded mercury concentrations equal to or greater than the limit of detection (0.1 to 0.2 µg/L). All but one of these eight samples contained from 0.2 to 0.4 µg/L, equal to or just slightly exceeding the limit of detection. One sample, however, contained 2 µg/L. Natural (unpolluted) background concentrations of mercury in water, and especially groundwater, have been difficult to find because of the inadequacy or unavailability of sampling and analytical techniques. Generally, however, where contamination or mercury-bearing minerals are absent, dissolved concentrations in ground or surface water are likely to be less than 10 ng/L (0.010 µg/L) (Krabbenhoft and Babiarz 1992). Based on the data from 10 different DOE tailings sites as well as the data provided by Atlas and the Utah DEQ, it is unlikely that the Moab tailings pile is a significant contributor to mercury levels in the Colorado River beyond the discharge plume. However, because fish adjacent to the pile and at one

sampling station downstream of the pile exhibited relatively high levels of mercury relative to upstream samples, leachate and/or groundwater in the vicinity of the pile may contribute to mercury uptake by fish in the mixing zone. A possible alternative explanation for the elevated mercury levels in fish near and downstream of the pile is the presence of relatively high concentrations of ammonia in the river near the pile (see the earlier discussion of ammonia originating from the pile). Ammonia is known to form cationic complexes with mercury which "... are generally considered to be more toxic than anionic or neutral species because they are better able to compete for sites on cell surfaces . . ." of biota (Farrell et al. 1990). Thus, even if the pile contributes no mercury at all to the river, it is possible that ammonia from the pile could enhance uptake (and toxicity) of ambient mercury in the river by fish.

Selenium. At 42 mg/kg dry weight in fathead minnows, the selenium concentration at the most downstream station (Station 10) was about 6 times the average upstream concentration (WestWater 1995). Sediment selenium concentrations (all less than 1.0 mg/kg) did not reflect this disparity, and river water concentrations at Station 4 were below the detection limit of 5 μg/L (this compares to a mean basin-wide river concentration of 10 μg/L as reported by Dvorak et al. 1978). The other downstream stations yielded selenium concentrations in fathead minnows comparable to those for the upstream stations.

The geometric mean and 85th percentile concentrations (0.42 and 0.73 mg/kg wet wt, respectively; the ratio of wet to dry weight is approximately 4:1) of selenium reported by Schmitt and Brumbaugh (1990) for whole fish from 109 stations located around the country were considerably lower than at any of the Colorado River stations reported on here (ranging from about 2.6 to 25 times the national mean concentration). Moreover, the selenium concentration reported for Station 10 fish (42 mg/kg dry weight) is comparable to the concentration in red shiners (9.6 mg/kg wet wt) experimentally fed to striped bass in a 1989 study by Coughlan and Velte. They reported that striped bass feeding on contaminated shiners showed modified behavior, very slow growth, reduced condition factor, elevated muscle selenium, damage to liver and kidney tissues, and death of all fish within 78 days. Based on studies summarized in Eisler (1985) showing reduced growth and reproduction in mallard ducks fed diets containing 25 mg/kg selenite, and teratogenic effects in mallard ducklings fed diets containing as little as 10 mg/kg selenite (6.2 mg/kg as selenium), fish from Station 10 may be toxic to birds preying on these fish or other selenium-contaminated aquatic organisms. Ducks fed up to 5 mg/kg selenite (3.1 mg/kg as selenium) for 3 months showed no adverse effects.

Fish selenium burdens as determined by the FWS ranged from 1.9 to 6.2 mg/kg dry weight, considerably less than the maximum of 42 mg/kg at Station 10 reported for the WestWater study.

The FWS were unable to collect any fish upstream of the pile during their sampling effort. Except for measurements of 0.16 mg/kg selenium (dry weight) at upstream Station 3 and 0.20 and 0.19 mg/kg dry weight at downstream Station 8 and 9 respectively, all sediment selenium concentrations upstream and downstream of the pile were below the limits of detection of 0.09 to 0.16 mg/kg dry weight, whereas the WestWater data averaged about 0.6 mg/kg downstream of the pile (nearly the same as upstream).

As was generally true for the Utah State data presented in Table 2, concentrations of selenium in river water were below the minimum detection limit of 5 µg/L for the analytical techniques used. Thus ambient concentrations in water were well below the National Ambient Water Quality Criterion of 35 µg/L and the lowest reported chronic toxicity value for aquatic organisms of 88 µg/L (Suter and Tsao 1996, and even the mean concentrations for the Colorado River basin-wide cited by Dvorak et al. (10 µg/L; 1978) and Eisler (30 µg/L; 1985). Peterson and Nebeker (1992), however, estimated that as low as 1 µg/L of selenium dissolved in water could, through bioaccumulation, possibly prove toxic to some piscivorous birds and mammals. Whether the relatively high ambient concentrations reported by the State and published by others in the literature are truly representative of natural selenium levels in the Colorado River basin, or are at least partially the result of anthropogenic activities, is not clear at this time. If representative of natural conditions, then native species of fish and wildlife are presumably adapted to these levels of selenium; if concentrations are artificially enriched, some species possibly are adversely affected by these selenium levels, even to the point of extirpation from entire river reaches having elevated selenium.

These results, in concert with (1) the already high background selenium concentrations measured in Colorado River fathead minnows, and (2) the unusually high concentration measured for Station 10 fish downstream of the pile, suggest that Colorado squawfish and other predators on fathead minnows and other prey organisms could accumulate potentially toxic levels of selenium, at least for individual predators consuming contaminated prey as a large fraction of their diet. There are several factors, however, that make it unlikely that the tailings pile is the source of the selenium or that fish are unduly stressed by existing selenium levels. First, high background concentrations are certainly not an effect of the pile and may be largely natural or the result of agricultural runoff upstream; native aquatic species may have developed tolerance of such concentrations (Note, however that, based on their study of elevated selenium in milt and eggs of razorback sucker in the Green River, Hamilton and Waddell (1994) suggest that selenium-induced reproductive problems may be a factor in the decline of this endangered fish). Second, the unusually high selenium concentration reported for fish at Station 10 by WestWater Engineering (1995) is based on a single measurement—no replicate measurements were made. Third, Station 10

is well downstream of at least two other possible sources of selenium, the wastewater treatment plant outfall from the city of Moab, and Mill Creek. Fourth, Station 4 (adjacent to the pile) and downstream Stations 8 and 9 (but upstream of Station 10) did not exhibit elevated selenium concentrations. Fifth, instream sediment, seep, and surface water quality analyses do not show any trend toward selenium enrichment in any of these media (Tables 2, 3, and 5). Finally, the analysis of possible selenium contributions from the pile summarized in Table 7 indicates that post-dilution selenium contributions from the pile are negligible.

Vanadium. Although a few samples have been taken by the USGS far upstream at its Cisco monitoring station, vanadium has not been monitored downstream of the site. However, the sum of the post-dilution vanadium concentration increment due to the tailings pile (<0.036 μg/L at record low river flow) and the USGS river concentrations of <6 μg/L still results in a total concentration far below the aquatic life toxicity benchmark of 80 μg/L, a vanadium benchmark for aquatic life shown in Table 8. Recent water data collected much closer to the pile by the Utah DEQ produced no values above the detection limit of 40 μg/L (Table 3).

As shown in Figure 4 of the BA, at up to 1.8 mg/kg dry weight, the body burdens of vanadium in fathead minnows collected in the WestWater effort were two to three times higher at downstream Stations 8 and 9 than at upstream stations. The fish vanadium level was back down to the upstream (or background) concentration at Station 10 (furthest downstream) and not detected at all (MDL = 0.5 mg/kg) at Station 4 adjacent to the pile. Downstream fish vanadium burdens as determined in the FWS effort ranged from 1.6 mg/kg dry weight to 5.9 mg/kg, compared to the maximum of about 1.8 mg/kg reported in the WestWater study. Concentrations in both upstream and downstream fish exceeded the 0.14 mg/kg dry weight reported for fish by Jorgensen, Nielsen, and Jorgensen (1991).

Water concentrations at Station 4 (25–34 μg/L) were elevated compared to the very limited USGS (1986) concentrations for Colorado River water upstream of the pile (< 6 μg/L) but not for the mean basin-wide concentration of 105 μg/L (Dvorak et al. 1978). Moreover, given that the Station 4 analyses were on whole water samples, it is likely that much of the vanadium is bound to suspended mineral particles (soils may contain around 100–170 mg/kg vanadium; Bowen 1979; Salomons and Förstner 1984) and not readily bioavailable to aquatic organisms. Sediment concentrations of vanadium (14–22 mg/kg) did not show obvious enrichment downstream of the pile and were far below published values for soils. In the FWS study, vanadium concentrations in sediment tended to be slightly higher upstream (14 mg/kg dry weight) than downstream (9.7 mg/kg dry weight). Based on the above, and the fact that even under lowest flow conditions (as discussed earlier) post-dilution vanadium contributions from the pile are calculated to be minuscule, it is

unlikely that aquatic biota of the Colorado River in the vicinity of the tailings pile would be adversely affected by existing levels of vanadium.

Other Nonradioactive Contaminants. As with most of the above contaminants, post-dilution molybdenum and nickel concentrations are estimated to be well below published toxicity benchmarks for aquatic life (see Table 8). In the FWS study, molybdenum concentrations in downstream fish were all below the detection limit of about 2.0 mg/kg dry weight, and no sediment samples upstream and downstream exceeded the detection limits ranging from 6 to 9 mg/kg dry weight. Similarly, WestWater reported that all molybdenum concentrations for both fish and sediments were less than the minimum detection limit of 0.5 mg/kg. The WestWater (1995) study reported that all nickel concentrations in fish were below the limit of detection (2 mg/kg). The FWS study on the other hand, reported 17 mg/kg nickel dry weight for a single sample at Station 7B. This is roughly 5 times the levels reported for the other downstream stations as well as about 5 times the levels reported for marine fish by Bowen (1979).

Although uranium is radioactive, it also can induce chemical toxicity as well as radiotoxicity, but the levels of uranium in the river expressed in pCi/L (1 μg natural uranium = 0.69 pCi) are well below both the concentrations known to produce toxic effects in aquatic organisms, and the State of Colorado chronic toxicity standard (1500 μg/L) as well. For example, even the maximum concentration of natural uranium in pCi/L reported downstream of the pile (12 pCi/L) is equivalent to only 17 μg/L uranium [(12 pCi/L)/(0.69 pCi/μg uranium)]. This compares to the lowest estimated chronic value of 142 μg/L and the estimated lowest test EC20 value of 455 μg/L (Suter and Tsao 1996). Note also that the mean uranium concentration is lower downstream than upstream.

Radiological and not chemical effects of natural thorium, radium-226, radium-228, lead-210, and polonium-210 are addressed below because chemical effects on biota are extremely unlikely at the listed concentrations. With respect to chemical toxicity, thorium is relatively inert (Sittig, 1985). This fact, coupled with the very low chemical concentrations observed in the river (5 μg/L), strongly argues against the possibility of toxic effects on aquatic biota. Chemical toxicity from the other radionuclides is even less likely. At the radio-concentrations shown in Tables 4 and 9, for example, the chemical concentrations of lead-210 and polonium-210 would be measured in ag/L (attograms/L or 10^{-18} g/L), if methods able to measure these substances at such low concentrations existed.

Table 9. Estimated Internal Radiological Dose to Fish in the Colorado River Assuming Record Minimum Flow (558 cfs)[a]

Contaminant	Ambient Concentration [pCi/L[g] (range)]	Dose[h] to fish (mrad/day)
Uranium (natural)[b]	8.3 (1.6–12)	0.018
Thorium-230	0.9 (0.1–5.1)	0.021
Lead-210[c]	2.7 (1.1–4.6)	0.0017
Polonium-210[b]	3.7 (0.9–5.7)	0.052
Radium-226[c]	1 (< 0.5–3)	0.012
Other Ra-226 progeny (total)[d]	—[d]	0.016
Total	24	0.12
Percent of interim limit[e]		0.012
Gross alpha	14 (< 1–83)	

[a]Based on dose assessment methodology described in IAEA (1976) and Blaylock et al. (1993).

[b]Calculated by adding post-dilution concentration contributed by contaminated groundwater (3,100 pCi/L of uranium) to the ambient concentration in the river.

[c]Ambient concentration based on six samples by Atlas Corporation over a three-year period.

[d]Assumes bioconcentration of radium-226 followed by escape of 70 percent of radon-222 and its short-lived daughters from organisms (Blaylock et al. 1993).

[e]Interim limit set forth by the U.S. Department of Energy at DOE Order 5400.5.

[f]Not applicable.

[g]1 pCi - 0.037 Bq

[h]1 rad = 0.01 Gy

Radionuclides. A dose assessment for a generic fish was performed because (1) ambient gross alpha levels are typically near the State standard and (2) tailings leachate under current conditions contributes a potentially significant fraction of the alpha activity in the form of uranium-238 and its daughters (at least at extremely low river flow). To determine whether or not the reported radionuclide concentrations in the river could be harmful, the dose, D, to fish from each of the alpha-, beta-, and gamma-emitting radionuclides was estimated from the following model for approximating internal dose in aquatic organisms of the size of most fish (IAEA 1976, Blaylock 1993):

$$D = 2.13\ \Sigma\ E_{av} \bullet n \bullet \Phi \bullet C_{water} \bullet B\ \mu\text{rad/hr} = 51\ \Sigma\ E_{av} \bullet n \bullet C \bullet B\ \mu\text{rad/day}$$

where:

E_{av} = the average energy in MeV of each alpha and beta particles and gamma rays emitted per disintegration of a radionuclide;

n = the proportion of transitions producing an alpha or beta particle or gamma ray of energy E_{av} (dimensionless);

Φ = the fraction of photon or particle energy absorbed (dimensionless);

C_{water} = the radionuclide concentration in water in pCi/ml; and

B = bioaccumulation factor for the radionuclide in an organism (fish, invertebrate, plant) given by Killough and McKay (1976).

For all practical purposes, Φ, the fraction of alpha- or beta-particle energy absorbed, can be taken to be one (i.e., 100 percent) because of the relatively large size of even the smallest fish and the low energies of beta-particles emitted by the radionuclides of concern. For gamma photons, on the other hand, Φ is typically about 0.1 (i.e., 10 percent). For additional details and discussion of this methodology, see Blaylock et al. (1993). Doses to organisms from external exposure to these radionuclides were also calculated.

Results of the dose assessments are presented in Table 9. Because the radionuclides of concern are primarily alpha emitters, the calculated external doses were so small that they did not materially affect overall dose. Therefore, external doses were not included in the table. It should be noted that the ambient concentrations of lead-210, polonium-210, and radium-226 (all

daughters of uranium-238) used in this analysis are averages of only six samples from two stations (one immediately upstream, the other downstream of the tailings pile) over a three year period. Thorium-230 concentrations in the water column are based on estimated concentrations in the tailings leachate.

This analysis indicates that thorium-230, followed by polonium-210, contributes more to total dose incurred by fish than do all of the other radionuclides combined. Total dose to fish is estimated at 0.31 mrad/day [3×10^{-6} gray per day (Gy/day)], while invertebrates incur a much higher dose of 22 mrads/day (0.00022 Gy/day).

To place these values in perspective, the total doses were compared to an interim dose limit for the protection of native aquatic animals set forth in DOE Order 5400.5. This interim dose limit is based on the opinion of many researchers that aquatic populations are not significantly affected at doses below 0.01 Gy/day (1 rad/day) (IAEA 1992, National Research Council of Canada 1983). The calculated doses for all three organism types are well below DOE's interim dose limit of 0.01 Gy/day (1 rad/day) or 3.65 Gy/yr (365 rads/yr).

Total uranium concentrations in fathead minnows collected at station 4 adjacent to the pile (0.51 µg/kg dry weight) and at downstream station 10 (0.46 µg/kg) were up to 10 times the concentrations found at upstream and other downstream stations (ranging from 0.035 to 0.098 µg/kg). As with selenium and mercury, no similar trend was evident in the sediment data from this study. However, sediment grab samples taken from the river adjacent to the pile and just upstream of the pile in November, 1994 yielded considerably elevated uranium concentrations in the interstitial (pore) water [0.77 mg/L (530 pCi/L) and 0.28 mg/L (190 pCi/L), respectively] compared to the more typical concentration of the downstream sediment sample [0.016 mg/L (11 pCi/L). The high concentrations probably represent partially diluted leachate (groundwater) from the tailings pile which is diluted to near background concentrations on entering the river proper. Moreover, the FWS study found elevated uranium-238 (52 pCi/g) and uranium-234 (51 pCi/g) in the sediments at Station 4A. Other stations upstream and downstream of the pile had concentrations of these uranium isotopes on the order of 2 pCi/g.

Both lead-210 (0.24 pCi/g, or more than 3 times concentrations reported for other stations) and polonium-210 (3.0 pCi/g, or 2 to 5 times concentrations reported for other stations) were elevated in fathead minnows collected from station 4 (adjacent to pile) compared to all other stations. Again, except for the FWS data, sediment concentrations did not reflect this apparent enrichment of lead-210 and polonium-210 in fatheads near the pile.

Radium-226, radium-228, and thorium-230 show slight, but again statistically untestable, elevations in concentrations in fatheads collected near the pile at Station 4. No similar trend was evident from the sediment data. Gross alpha and gross beta were higher in fatheads but not in sediments from station 4 and at one or more downstream stations (BA, Figure 14).

To determine whether or not the reported radionuclide concentrations in fathead minnows could be harmful, the dose, D, to fish from each of the alpha- or beta-emitting radionuclides was estimated from a slightly modified version of the equation presented above for approximating internal dose in aquatic organisms of the size of most fish (IAEA 1976):

$$D = 2.13\ \Sigma\ E_{av} \bullet n \bullet \Phi \bullet C_{fish}\ \mu rad/hr = 51\ \Sigma\ E_{av} \bullet n \bullet C\ \mu rad/day$$

where E_{av} = the average energy in MeV of each alpha and beta particles and gamma rays emitted per disintegration of a radionuclide; n = the proportion of transitions producing an alpha or beta particle or gamma ray of energy E_{av} (dimensionless); Φ = the fraction of particle or photon energy absorbed (dimensionless); and C_{fish} = the radionuclide concentration in fish in pCi/g. Because this model uses the concentration of radionuclides in fish tissue itself, rather than in water, a bioaccumulation factor, B, is unnecessary. The results are summarized in Table 10.

Interestingly, the estimated total dose to fathead minnows based on actual measured body burdens of radionuclides (0.27 mrad/day; Table 10) was found to be very close to the dose calculated independently from water quality data (0.31 mrad/day; Table 9). Even allowing for additional contributions from the thorium-232 decay series and radionuclides in water and sediments (which would, at most, triple the total dose presented in Table 10), the total dose to fish of 0.5 to 0.9 mrad/day is clearly well below the 1 rad/day threshold considered potentially capable of producing adverse effects in fish populations. It should be noted that about 77 percent of the total dose from the uranium-238 decay series is attributed to polonium-210, most of which may originate from upstream of the pile.

A few weeks before the collection of fish by WestWater, the FWS had also collected fathead minnows for analysis of radionuclide burdens from some of the same stations used by WestWater (Mizzi 1996). The resulting data indicated that fish at Station 7A had about twice the body burdens of uranium-238, uranium-234, and thorium-230 reported above for Station 4. If radium-226 concentrations in fish are assumed to be a like multiple of radium-226 concentration in WestWater's Station 4 fish, and daughters are in equilibrium with the parent radium-226, then the total dose from uranium-238 and its daughters still would be no more than 550 µrad/day (0.550 mrad/day), again far below the 1 rad/day threshold for concern. The FWS data also

Table 10. Internal Dose to Fathead Minnows Collected May 1995 at Station 4 Located at the Mouth of Moab Wash Next to Tailings Pile[a]

Radionuclide	Concentration (pCi/g wet wt)	Dose (μrad/day)[b]
Uranium-238	0.043	9.5
Thorium-234	0.043	0.15
Protactinium-234m	0.043	1.8
Uranium-234	0.043	11
Thorium-230	0.13	31
Radium-226	0.018	4.3
Radon-222[c]	0.0053	1.5
Polonium-218[c]	0.0053	1.6
Lead-214[c]	0.0053	0.085
Astatine-218[c]	0.0053	0.00037
Bismuth-214[c]	0.0053	0.2
Polonium-214[c]	0.0053	2.1
Thallium-210[c]	0.0053	0.00016
Lead-210	0.060	0.13
Polonium-210	0.75	210
Radium-228	0.40	0.35
Total		270 = 0.00027 rad/day

[a]Fish radionuclide burdens from WestWater Engineering 1995.

[b]Based on dose assessment methodology described in IAEA (1976) and Blaylock et al. (1993).

[c]Not measured. Concentrations and estimated doses based on assumption that these daughters of Ra-226 are in secular equilibrium with parent Ra-226, which was measured, and that 70 percent of the daughter Rn-222 (and consequently Rn-222 daughters) escapes from fish tissues (Blaylock et al. 1993).

suggested an increased body burden of thorium-232 (0.160 ± 0.080 pCi/g) in minnows at Station 7A. Assuming secular equilibrium of daughters with the parent thorium-232, these fish may receive a maximum additional dose from this decay series of about 0.1 mrads/day.

Recently, Atlas provided data from two samples of seep water from the same hole excavated by the Utah DEQ from the bed of Moab Wash near its confluence with the river—one sample from December 1995 and one from January 1996 (Atlas 1996). The analysis of Atlas' samples produced concentrations of a few contaminants far higher than those reported by the Utah DEQ (see Table 4.5-2) or reported for groundwater samples collected by Atlas. Atlas' seep samples produced much higher levels of arsenic (maximum of 145 μg/L, manganese (maximum of 8480 μg/L), vanadium (maximum of 1250 μg/L), zinc (950 μg/L), radium-226 (maximum of 364 pCi/L) and radium-228 (maximum of 19 pCi/L). How much of these contaminants are contributed by the tailings pile is unknown, but it is reasonable to assume that the pile contributes a substantial proportion of these substances, if the analyses are in fact valid. The samples apparently were not filtered prior to analysis—the high metal concentrations may represent total metal content, including those metals adsorbed to or forming part of the matrix of the particulates in the samples. The unusually high concentration of radium-226 exceeds levels reported by the Utah DEQ by a factor of about 50, and levels reported for Atlas's own groundwater reports by a factor of 300 or more. This level is even greater than most estimates of radium-226 concentrations in the pile leachate itself (60–150 pCi/L). Although these samples may prove to be anomalous, if the 364 pCi/L value proves to be more representative of groundwater concentrations, then predicted river concentrations and exposures reported would be considerably higher than those based on other seep data. However, even if a fish were exposed to undiluted groundwater containing 364 pCi/L radium-226 and progeny, absorbed dose would probably be no more than about 10 mrad/day, or about 1 percent of the recommended 1 rad/day dose for protection of aquatic life. A good reason to suspect that these samples are anomalous is that they exhibit much higher levels of contaminants than reported for groundwater downgradient of the pile, or in some cases (e.g., radium-226) the tailings leachate itself.

3.2 Impacts of Proposed Reclamation

Construction-related activities during actual reclamation of the tailings pile (whether stabilization in place, or removal to the Plateau site) could adversely, but temporarily, affect water quality of the Colorado River, and possibly other streams as well, through accidental spills and the entry of sediment-laden and contaminated runoff. These activities include soil disturbance from earth moving activities, generation of wastewaters from, for example, equipment washing, and leaks and spills of liquids such as oils and fuels for vehicles. Moab Was, a natural, shallow channel along

the east side of the tailings pile that only rarely carries surface water, would be relocated further to the east to reduce the probability of channel migration into the pile. Development and operation of onsite and offsite borrow areas for clay, soil, sand, and rock riprap could adversely affect streams in the vicinity of such operations. Rain-mobilized soils and small amounts of contaminants may occasionally result in temporary increases in stream concentrations of suspended solids and contaminants, but concentrations in the Colorado River (but not necessarily in smaller streams near borrow areas) beyond a small mixing zone would probably be unmeasurable and of no consequence. It should be noted that the Colorado River naturally experiences large swings in suspended solids and averages nearly 700 mg/L just upstream of the tailings pile. Endangered fish and other native aquatic organisms should therefore be adapted to these conditions.

Accidental spills of oils and other liquids could possibly have a noticeable short-term effect on surface water quality in the vicinity of the spill if measures for containment and cleanup are inadequate. In any smaller streams down gradient of borrow areas, impacts on water quality of suspended solids and spilled liquids in the absence of appropriate mitigative measures could be more substantial, and could possibly adversely affect endangered fish if, for example, spills were to enter Mill Creek at a time that an endangered species happen to be utilizing the area around the mouth of the creek for cover, foraging, or as a nursery.

The effects of increased suspended solids and siltation on aquatic biota are well documented and include reduction of light penetration and photosynthesis, impairment of respiration (gill function) and feeding, obliteration of spawning sites and microhabitats such as the interstitial spaces of bottom substrates, smothering of benthos and demersal fish eggs, alterations in species composition, and lowered fish production. Because the Colorado River has enormous dilutive capability, and naturally experiences large swings in suspended solids concentrations and turbidity, adverse effects, if any, of reclamation activities on endangered fish would likely be of short duration and limited to a small mixing zone adjacent to and downstream of the site. As stated earlier, aquatic organisms native to the mainstem of the Colorado River are generally quite tolerant of these conditions. Suspended solids concentrations in this river average nearly 700 mg/L just upstream of the tailings pile. Even these minor impacts, however, could be further reduced through the proper use of runoff control measures including careful grading practices, interception and retention of runoff in adequately sized settling basins, stabilization of soils promptly after disturbance, and use of sediment barriers such as silt fences. Some sediments mobilized by earthmoving operations and rain during reclamation may be contaminated with low levels of trace elements and radionuclides, while accidental spills could introduce oils, cleaning wastes, or other undesirable liquids into the river. Again, dilution in the river would probably

reduce concentrations beyond a small mixing zone to acceptable levels, but to better ensure that these contaminants do not exceed safe levels, runoff control measures such as those listed above would be implemented.

The impacts of implementing the Atlas proposed reclamation plan on aquatic biota in the Colorado River would be a gradual reduction of diluted tailings leachates over time because dewatering operations at the pile will have reduced saturation and hydraulic head, and the cover would retard the movement of water through the pile even further (Section 2.2). Stabilizing the tailings pile in place is likely to reduce any adverse effects on aquatic biota, including endangered species, that may be occurring under existing conditions. Although potentially toxic concentrations of ammonia could continue to be released into the river, the extent of the affected area would be much smaller because the flux of contaminated groundwater would have been substantially reduced, thereby requiring a smaller cross-sectional area of the river to achieve adequate dilution. Additional discussion of impacts to aquatic biota and endangered fish species after reclamation is completed is provided in Section 3.3.

Removal of the entire pile to the Plateau site would involve impacts similar to those described above, but the potential for contamination of the Colorado River would be substantially greater during the period of removal because of the amount of excavation and transportation that would be required. The Plateau site itself has no permanently flowing streams in the area, but, during rare periods of heavy precipitation, a shallow arroyo south of the proposed alternative site could carry some surface flow to Courthouse Wash, an intermittent stream that eventually joins with the Colorado River many kilometers to the southeast.

Proposed offsite borrow areas for cover and riprap materials include alluvial deposits in Spanish Valley and an upland area above the west bank of the Colorado River immediately west of the Potash boat ramp approximately 24 km downstream of the tailings pile (see Sections 2.1.4 and 4.2 for additional discussion of this borrow area). Endangered fish possibly inhabit the reach adjacent to the proposed Potash site, and almost certainly pass by the site on occasion. Although endangered fish are unlikely to enter the small ephemeral-to-intermittent streams near the Spanish Valley borrow operations, the impacts of increased suspended solids and accidental spills on resident aquatic organisms could be more substantial because the dilution capacity is much lower and some streams may have much lower ambient suspended solids concentrations. Consequently, aquatic biota would be more likely to incur illness, injury, or diminished success in respiration, feeding, mating, growth, and many other functions necessary to sustain populations as well as individuals. For these reasons, early and effective mitigative measures such as interception,

retention, and treatment of sediment- and chemical-contaminated runoff would be required to ensure that susceptible streams are adequately protected.

Mining regulations of the Utah Division of Oil, Gas and Coal Mining (Utah R674-4) require that certain measures be taken to mitigate potential adverse environmental effects from borrow operations. It is expected that a National Pollutant Discharge Elimination System permit also will be required for the release of storm water to the river. Compliance with permit conditions will probably require implementation of several mitigative measures. These and other required or recommended measures for protecting water quality and aquatic life of both the Colorado River and smaller streams near borrow areas are outlined in Section 3.4.

3.3 Post-Reclamation Impacts

Once completed, full implementation of the proposed stabilization of the pile in place would substantially diminish the pathways by which contaminants and sediments enter the Colorado River and Moab Wash—that is, (1) surface runoff, (2) leachate transport to groundwater, and (3) wind-blown dusts. Stabilization would effectively isolate tailings contaminants from surface runoff and wind. Only small amounts of uncontaminated soils and dusts would be available for transport to the river by these two pathways. Groundwater transport of contaminant-bearing tailings leachate to the river would likely continue but at a reduced rate (conservatively estimated as less than 20 percent of the existing rate). Consequently, a concomitant reduction in the rate of contaminant migration to the river would be expected.

Because the pile already has such a small effect on post-dilution concentrations of most analytes of concern, only slight improvement in water quality of the river downstream of the site would result from reclamation of the pile. It follows that the existing effects on water quality and endangered fish—already shown earlier and in Tables 7 through 10 (with the exception of ammonia) to be of little consequence beyond a small mixing zone—should be negligible after stabilization in place is completed. Although the limited data available show the levels of mercury and selenium in fish downstream and/or adjacent to the pile to be sufficiently high to indicate contamination from an unknown source, the review of the data on groundwater, seep water, sediments, and surface water presented in this Supplement does not support the conclusion that the pile is the source of this contamination. Although potentially toxic concentrations of ammonia could continue to be released into the river under the proposed reclamation, the extent of the affected area would be much smaller because the flux of contaminated groundwater would have been substantially reduced, thereby requiring a smaller cross-sectional area of the river to achieve adequate dilution.

Within the mixing zone, specifically in the area where leachate-contaminated groundwater from the pile mixes with surface water, pre-dilution concentrations of ammonia and possibly other contaminants may occur at levels sufficiently high to harm local invertebrates and members of any fish species should they reside there for extended periods of time. These contaminants could potentially affect *individuals* of the endangered Colorado squawfish and razorback sucker, if these species actually reside or feed extensively in the mixing zone. However, adverse effects from the proposed action on the Colorado squawfish and razorback sucker at the population level are unlikely.

Although implementation of the proposed action would reduce the release of toxic metals from the reclaimed tailings pile, occasional, temporary increases in the release rates of these materials could result from the rise and fall of groundwater during floods. The amount and rate of water entering the pile during floods would depend on (1) the relatively short period during which flood levels would be high enough to provide sufficient head to drive groundwater back up into the pile (a matter of a few days), (2) the frequency of flood events where water levels are higher than the base of the pile, and (3) the resistance of the materials in the bottom of the pile to movement of water upwards (i.e., the rate would be no greater than the measured rate of seepage out of the pile of 50 gpm). These factors strongly suggest that the amount of water entering the base of the pile during floods would be greatly limited and would result in only very minor additions of contaminants into the groundwater as the flood waters drain from the pile. Such releases could potentially contribute to any effects on *individuals* of the endangered Colorado squawfish and razorback sucker, if these species actually reside or feed extensively in the mixing zone. However, such contributions are considered to be very minor in comparison to the overall flux of contaminants.

Few fish would be likely to spend long periods at the more contaminated interface where groundwater mixes with river water. Detailed site-specific data for these areas are not available to assess effects on biota residing in these areas. However, anomalously high, but very limited, sampling data for mercury and selenium concentrations in fathead minnows are sufficiently high to raise concerns about the possible impacts to predators (e.g., endangered fish) of these and other possibly contaminated organisms (Section 4.3).

Under the alternative to relocate the pile to the Plateau site, contaminated groundwater would continue to migrate into the Colorado River for an unknown period of time. Although the source of contaminants (i.e., the tailings) would be removed under this alternative, the contaminated groundwater and alluvium under site would continue to contribute contaminants to the river. As with the current proposal for onsite stabilization, continued groundwater cleanup at the former

tailings site would be required under the relocation alternative. Under either the Atlas proposal or the relocation alternative, it is uncertain whether the site could ever be cleaned up sufficiently to completely eliminate any impact to the Colorado River or under the relocation alternative to allow future unrestricted use. Effects of the relocated pile on surface water quality in washes and gullies near the Plateau site would be expected to be negligible because precipitation is so low and the clay liner would restrict the escape of leachates.

3.4 Monitoring and Mitigation

The following monitoring and mitigation measures are recommended as requirements for implementing the proposed action to minimize the potential for endangered aquatic species to be affected by the proposed action. Groundwater and Colorado River water and sediments should continue to be monitored for all contaminants that are both (1) known or suspected to enter these media from the tailings pile, and (2) potentially capable of occurring in river concentrations harmful to endangered fish or other aquatic life. Based on the analysis presented in this Supplement, the following contaminants should be monitored at least semiannually in groundwater and river sediments, and quarterly in the Colorado River:

ammonia	arsenic	selenium	mercury
manganese	lead	vanadium	zinc
molybdenum	uranium	thorium-230	radium-226
polonium-210	lead-210	gross alpha	gross beta

This list should not be viewed as excluding other contaminants that may be identified later from the monitoring program or other sources of information as potentially important. Other constituents or characteristics that may be relevant to the behavior or toxicity of these contaminants, and that are normally monitored under similar circumstances, such as pH, alkalinity, temperature, hardness, total dissolved solids, total suspended solids, acid soluble sulfides, and dissolved oxygen, should be included in the monitoring program. Analytical methods should allow for detection at concentrations below established standards or criteria. Sampling stations in the river should be established in at least one upstream area and in several downstream sites (including one well within the mixing zone) to reduce the possibility localized but unusually high levels of contaminants are missed by the sampling program. Evidence of unacceptable levels of contaminants in environmental media (i.e., surface water and river sediments) from the pile would require implementation of measures for reducing contaminant releases to levels safe for aquatic life, and monitoring of contaminant levels in non-endangered fish such as the fathead minnow or, if available, other, better surrogates for endangered fish. If mitigative measures beyond those already proposed for stabilization of the pile in place are found to be necessary for protection of

water quality and aquatic life, other measures would be required. Such measures may include some type of pump and treat operation, chemical treatment, or additional engineered barriers.

The following measures are recommended to mitigate potential adverse effects of construction activities related to either reclamation alternative on water quality and aquatic biota of the Colorado River and smaller streams near borrow areas:

- Development and implementation of an effective spill prevention and response plan (and adequate training of personnel in spill prevention and response);

- Interception and storage of sediment- and contaminant-laden runoff through use of adequate drainage control, retention and treatment ponds, silt fences, and other means as necessary;

- Avoidance of major earthmoving operations (such as the relocation of Moab Wash) during periods of high thunderstorm potential where and when feasible;

- Avoidance of siting potential borrow areas too near streams; and

- Topographic and vegetative restoration of borrow areas as required by the State of Utah Division of Oil, Gas and Coal Mining.

With these measures in place, construction activities associated with either the proposed action nor the alternative action are unlikely to adversely affect Colorado squawfish or razorback suckers at the population level.

3.5 Conclusions

Most of the evidence presently available indicates that the tailings pile as it currently exists, with the exception of ammonia, contributes relatively small amounts of known contaminants compared to the relatively high reported ambient concentrations of contaminants in the river. Limited but recently obtained data on fish contaminant levels indicate that possibly hazardous levels of selenium and mercury occur in fathead minnows collected near the pile. There is little other evidence, however, indicating that the pile contributes significant quantities of these contaminants.

Given minimal dilution at record low flow conditions, uranium, gross alpha (nearly all from uranium and its daughters), ammonia, and molybdenum from tailings under current conditions

could contribute a significant fraction of the river's concentrations of these contaminants in the vicinity of the pile. Nevertheless, under these low flow conditions, only gross alpha and ammonia would be likely to approach or exceed the state water quality standards as a result of contaminant input from the pile. Of these two contaminants, only ammonia at measured river concentrations as high as 11 mg/L in the mixing zone, and calculated post-dilution concentrations as high as 0.56 mg/L at the record low river flow, could pose a toxicity hazard to aquatic animals including endangered fish (see Table 3). If continued monitoring confirms the presence of ammonia or any other contaminant from the pile at levels exceeding water quality standards or criteria, or levels potentially toxic to endangered fish, the need and feasibility of additional measures will be considered.

Completion of the proposed action (stabilization in place) would reduce mobilization and transport of contaminants to the river to approximately one sixth of current levels or less and, therefore, reduce any hazards to endangered fish. Tailings disposal at the Plateau site would eventually eliminate most discharge of contaminated leachate into the Colorado River over the long term because the source of contamination would be largely removed. However, even if the tailings were relocated, the currently contaminated groundwater would continue to slowly discharge into the river for an unknown period.

As noted earlier, to ensure a reasonable degree of conservatism, the analyses of contaminant flux to the Colorado River used in this assessment are based on conservative estimates of vertical liquid transport through the pile, contaminant concentrations in the pile and groundwater flow rates. To place these assessment results in perspective, however, it is recognized that the actual value of contaminant flux (and thus post-dilution concentrations and effects on water quality in the river) could be an order of magnitude lower than calculated here if less conservative flow estimates were used in the analysis. Given these lower values, the mixing zone in the Colorado River and the numbers of aquatic organisms exposed to contaminant concentrations above water quality criteria would also be proportionally smaller.

During reclamation activities, sediment- and contaminant-laden runoff could enter the Colorado River and any small stream present at the clay and riprap borrow sites. Plans for control of water pollution and runoff would be required as discussed in Section 3.4.

Implementation of the proposed Atlas reclamation plan would reduce the area currently affected by potentially toxic levels of ammonia and other contaminants. Assuming that continued monitoring shows that ammonia concentrations decrease to acceptable levels or can be adequately

mitigated, and based on analysis of the limited data currently available, it appears that both the Atlas proposal and the relocation alternative would be unlikely to adversely affect any of the endangered fish at the population level. However, should individual Colorado squawfish or razorback suckers reside or feed extensively in the mixing zone (see Section 3.1.6), it is possible such individuals could be adversely affected under either current conditions or those expected to occur under the proposed action.

4. IMPACTS TO THREATENED AND ENDANGERED PLANTS AND BIRDS

Sections 3.2, 3.3, 4.2, and 4.3 of the BA provide background information and assessment of impacts on threatened and endangered plants and birds. The following section of this Supplement provides additional information and analysis on impacts to endangered plants and birds from quarry construction and operations at the newly proposed Kane Creek Borrow Area (Section 2.1.4 above) and from disturbance caused by relocation of Moab Wash under the Atlas proposed reclamation plan. In addition, additional information and analysis is provided on impacts to the southwestern willow flycatcher (*Empidonax traillii extimus*) to address concerns raised by the FWS (Section 1). The status of two plant species, *Astragalus sabulosa* and *Oreoxis trotteri*, has changed since the BA was prepared. These species were formally identified as Category 2 species, indicating that they were candidates for listing under the Endangered Species Act, but insufficient information was available to propose them for listing. Recent changes in regulations has dropped the Category 2 designation, so that these species are no longer formally considered candidate species.

4.1 Impacts from Relocation of Moab Wash

Surface water drainage at the Atlas site is primarily via Moab Wash, an ephemeral tributary to the Colorado River (Section 2.1.3). Moab Wash is approximately 8 km (5 miles) in length and has a drainage area of about 12.9 km^2 (5 square miles) (Smith Technology Corporation 1996). On the Atlas site, the current channel runs along the eastern side of the pile and discharges into the Colorado River due east of the middle of the pile (DEIS, Figure 2.1-1). Vegetation along the channel near its discharge point is dominated by dense growths of tamarix. Away from the river, the Wash is primarily a rocky channel that does not support much plant growth.

According to the Flood Hazard Boundary Map for Grand County Utah, (FEMA 1981), the lowest reaches of Moab Wash where it discharges into the river and possibly a small portion of the eastern base of the tailings pile are located on the 100-year floodplain of the Colorado River. On

several occasions, flood waters have risen from 0.9 to 1.2 m (3 to 4 ft) above the base of the pile, which has an elevation of 1,209.4 m (3,968 ft). Although the floodplain of Moab Wash has not been mapped in detail, the 100-year Colorado River floodplain extends up the wash at least several hundred meters (yards). Flooding and its effects on floodplains at the Atlas site are discussed in Sections 3.5.1.2 and 4.5.1 of the DEIS.

For the Atlas proposal or the relocation alternative, water for dust control would be pumped from the Colorado River. Atlas retains very senior water rights to obtain water from the Colorado River. Consumptive use of Colorado River water would be much less than when the mill was processing ore and would have minimal impact on depletion of Colorado River water.

The reconfiguration of Moab Wash near the tailings pile is designed to allow the PMF discharge to pass and to minimize the potential for floodplain encroachment. Impacts of reconfiguring Moab Wash and the tailings pile, and excavation of contaminated and cover materials would affect small areas of the 100-year floodplain, possibly about 2 hectares (5 acres). These activities on the floodplain may require Atlas to obtain a Section 404 permit under the Clean Water Act from the U.S. Corps of Engineers.

The potentially affected floodplain areas are along the eastern edge of the former mill site and the tailings pile, and currently support degraded riparian habitat dominated by dense growths of tamarix. As discussed in Section 3.2.1.3 of the BA, such habitat is common along this stretch of the river and is not considered to be prime habitat for the southwestern willow flycatcher; however, flycatchers have been known to nest in tamarisk habitat. Loss of habitat by construction of the reconfigured Moab Wash inner channel would be limited to a relatively small area near the discharge point. It is reasonable to assume that similar tamarisk habitat would develop over time at this new discharge point and also in the area of the former discharge. Therefore, the amount of tamarisk-dominated riparian habitat on the site should not be reduced significantly under the Atlas proposal.

4.2 Impacts from Development and Use of Kane Creek Borrow Area

Although a detailed survey of plants and animals on this site has not been made, general information from the soil survey of Grand County (USDA 1989) indicates that soils on the site would fall within the general Soil Map Unit 35 (Moenkopie-Rock outcrop complex which is primarily derived from sandstone) A more specific description of the local terrace area which is the proposed source of limestone is that for Soil Map Unit 40 (Hoskinnini very gravelly fine sandy loams) which forms on structural benches along the Colorado River (USDA 1991). These soils

form in residuum derived dominantly from limestone and shale. Land uses for these soil types include rangeland, wildlife habitat, and recreation areas. A site visit by staff in August 1996 indicated that the proposed site included large limestone rock outcrops. The area immediately adjacent to the boat ramp has been used in the past as a quarry area and has not been reclaimed. Vegetation cover observed by staff included a mixture of such species as bunch grasses, sagebrush, four-wing saltbush, yucca, and prickly pear. Evidence of cattle grazing was present. Development of the area would be subject to permit requirements of the Utah State Division of Oil, Gas, and Coal Mining.

Information provided by the FWS on listed threatened or endangered terrestrial species that may occur in the vicinity of the proposed Atlas project include the American peregrine falcon (*Falco peregrinus*), the southwestern willow flycatcher, and Jones cycladenia (*Cycladenia humilis* var. *jonesii*) (DEIS and BA). The proposed Kane Creek quarry site is in an area where the peregrine falcon is known to occur and may be foraging on birds or other small animals on the site. The site itself does not include nesting habitat for peregrine falcons, but high cliffs where peregrines may nest are in the general vicinity on both sides of the river. Quarry operations are unlikely to have any significant impact on foraging activities of any peregrines, but noise from the operations could disturb nesting peregrines in the general area. Therefore, quarry operations should be scheduled to avoid the nesting season for peregrine falcons.

The proposed quarry site is several hundred feet above the river and does not provide any riparian habitat that would support southwestern willow flycatchers. There is some riparian vegetation including willows along the river banks near the boat ramp and up and down the river. This area is not extensive and would not be removed by development of the quarry. However, quarry operations occurring during winter months are unlikely to affect the use of this area by southwestern willow flycatchers.

No surveys have been done to determine if Jones cycladenia is present at the Kane Creek site or adjacent areas that could be affected by quarry operations. Since the distribution of Jones cycladenia is associated with arkosic sandstones (BA, Section 3.3.1), it is unlikely that the species will be present on the limestone quarry area. However, it is possible that the species might occur in the vicinity of the proposed quarry site where the Moenkopie-Rock outcrop complex occurs, and if present, the species could be affected by dust or other activities associated with operations. Therefore, a survey by a qualified botanist to determine if Jones cycladenia is present in the vicinity of the proposed quarry site would be required before any activities are initiated at the site. If the species is present, the licensee would be required to develop appropriate mitigative measures in consultation with the FWS to ensure that populations are protected from disturbance.

4.3 Impacts of Proposed Reclamation on Endangered Birds

Concerns have been raised by the FWS about bioaccumulation of contaminants from the pile on the southwestern willow flycatcher. As discussed in Section 3.2.1 of the BA, the Atlas site is near the northern limits of this endangered subspecies of the willow flycatcher. Recent breeding bird surveys in the period 1994–1996 in the Moab area have identified willow flycatchers to be present both upstream and downstream of the Atlas pile (Fagan 1997). Identification was made by recording the birds songs, and it is not certain if the records are for the southwestern willow flycatcher nesting in the area or a northern subspecies moving through the area. In either case, however, the observed bird(s) were probably feeding on insects along the river.

Because the flycatchers could eat aquatic insects that reside a significant part of their life cycle in the river adjacent to the pile and would be potentially influenced by contaminants from the pile, the concern is that the birds could concentrate mercury, selenium, or other contaminants through the foodchain and experience effects that could jeopardize their continued survival. In addition, there are no data to indicate whether aquatic insects are accumulating any contaminants that might originate from the tailings pile.

Contaminants present at levels capable of causing ecological problems in the aquatic system could move to and cause ecological problems in the terrestrial system. As discussed in Section 3.3 above, one-time sampling at stations in the vicinity of the pile found elevated levels of two such contaminants, selenium and mercury, in fish. These selenium and mercury levels could be potentially toxic to predatory birds feeding on fish and other aquatic organisms in the vicinity of the pile (Eisler 1985, 1987) through bioaccumulation in the foodchain.

For example, the fish at Stations 4 and 8 of the May sampling program (WestWater 1995) could produce toxic body burdens of mercury for some predatory birds and mammals that feed largely on fish and other contaminated organisms from the vicinity of these stations. Similarly, selenium concentrations in fish from Station 10 are sufficiently high that they could be toxic to birds preying on these fish or other aquatic organisms. However, this possibility is based on few data points from unreplicated samples; and it appears unlikely that the tailings pile is a significant contributor to mercury or is the source of the selenium (see discussion in Sections 3.1.6 and 3.3). The limited data available are therefore not sufficient to conclude (1) that the elevated levels observed reflect actual conditions, or (2) that the tailings pile is the source of the elevated levels that were observed.

The selenium and mercury data from the WestWater (1995) sampling program can also be used as the basis of a screening risk assessment to determine whether these contaminants, at the levels observed, have the potential to cause toxicological problems to the endangered peregrine falcon and southwestern willow flycatcher. In a screening risk assessment concentrations of the contaminants in the environment are compared to no observed adverse effects level (NOAEL)-based toxicological benchmarks. The benchmarks represent concentrations of chemicals in the environmental media (water, sediment, soil, food, etc.) that are presumed to be nonhazardous to a species of interest (Sample et al. 1996). Similarly, lowest observed adverse effects level (LOAEL)-based toxicological benchmarks represent threshold levels at which adverse effects are likely to become evident. Generally, when contaminant exposures are below a toxicological benchmark, significant effects would not be expected, and the contaminant can be excluded from further consideration. For contaminant concentrations that exceed benchmarks further investigation may be appropriate.

Sample et al. (1996) compiled toxicological benchmarks for 85 chemicals, including mercury and selenium, for 11 representative avian wildlife species. Of these species, Cooper's hawk and rough-winged swallow are most representative of peregrine falcon and southwestern willow flycatcher, respectively, in size and food preferences.

For Cooper's hawk, the selenium NOAEL, expressed on a dry weight basis (dry weight concentrations are approximately 4 times wet weight levels; all concentrations in the following analyses are expressed on a dry weight basis) is 11.6 mg/kg for food. The LOAEL is 23.1 mg/kg. This means that a peregrine falcon eating a steady diet of food containing more than 23.1 mg/kg of selenium could show toxicological effects. Conversely, if diet were the only source of selenium, this contaminant could be excluded from further consideration at levels below 11.6 mg/kg. The selenium level measured in fish at Station 10 was 42 mg/kg, a level more than three times greater than the NOAEL. It also exceeds the LOAEL. The primary food of peregrine falcons is not fish, but other birds, including those that eat fish and aquatic insects. Because selenium can bioaccumulate in the food chain it could transfer from fish and insects to the birds on which falcons prey, possibly resulting in levels exceeding the benchmark concentrations.

For rough-winged swallow (representative of southwestern willow flycatcher), the selenium NOAEL for food is 2.7 mg/kg; the LOAEL is 5.3 mg/kg. The fish from all of the stations sampled had concentrations of selenium that exceeded the NOAEL, and most also exceeded the LOAEL. The primary food of flycatchers is insects, and not fish. Concentrations of selenium in aquatic insects, however, may be roughly equal to levels in fish from the same body of water (Ohlendorf et al. 1986). If this is the case in the reaches of the stream that were sampled, southwestern

willow flycatchers, if any are present, could possibly consume selenium from insects of aquatic origin at greater than benchmark concentrations.

Toxicological benchmarks for mercury depend on its chemical form. The organic species methyl mercury is much more toxic than inorganic forms. Although the form of mercury analyzed in fish in the WestWater (1995) sampling program was not determined, mercury tends to be accumulated up the foodchain in the methylated form (Eisler 1987), and it is likely that most of the mercury in the fish sampled was methyl mercury (George Southworth, ORNL, personal communication to Harry Quarles, ORNL, November 20, 1996).

For Cooper's hawk (representative of peregrine falcon), the methyl mercury (as methyl mercury dicyandiamide) NOAEL for food is 0.15 mg/kg; the LOAEL is 1.48 mg/kg. Mercury concentrations in fish from four of the stations sampled exceed the NOAEL, and concentrations at Stations 4 and 8 approach the LOAEL. Because mercury can bioaccumulate through the food chain it could transfer to piscivorous or insect-eating birds, and in turn to peregrine falcons at levels exceeding benchmark values. This would be less likely to occur with an inorganic species such as mercuric chloride: NOAEL for food 2.6 mg/kg.

Similarly, for rough-winged swallow (representative of southwestern willow flycatcher) the methyl mercury (as methyl mercury dicyandiamide) NOAEL for food is 0.032 mg/kg; the LOAEL is 0.34 mg/kg. Mercury concentrations in fish from all the stations sampled exceeded the NOAEL; the LOAEL was exceeded at four stations. If mercury is present in aquatic insects at concentrations similar to fish, they could contribute enough of this contaminant to the diet of any southwestern willow flycatchers present along the stream to exceed benchmark values.

The results of this baseline risk assessment do not demonstrate that any toxicological effects are being caused by the concentrations of selenium and mercury observed in the WestWater (1995) sampling program. Rather, they suggest that further investigation would be required to resolve the issue.

Under the proposed action, installation of a permanent cover on the tailings pile would reduce any leaching of these metals from the pile. Under the alternative of moving the pile to the Plateau site, the potential source of these metals from the pile would be eliminated, although contaminated groundwater would continue to enter the river for an unknown period.

5. REFERENCES

Atlas Corporation, 1990–1996, *Corrective Action Program Review Reports*, Reports Submitted to U.S. Nuclear Regulatory Commission, 1990-96.

Atlas Minerals Corporation, 1996, *Analyses of Water Quality Samples for Moab Wash and the Colorado River*, Data provided by Barringer Laboratories in December 1995 and January 1996, to Atlas Corporation, Denver, Colorado.

Barringer Laboratories, Inc., 1996, *Analytical Report Package*, Data provided to Dale Edwards, Atlas Minerals Corporation, Moab, Utah (July 12, 1996).

Blaylock, B. G., M. L. Frank, and B. R. O'Neal, 1993, *Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment*, ES/ER/TM-78. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Blubaugh, Richard, 1996, Letter to Joseph J. Holonich, Office of Nuclear Material Safety and Safeguards, from Richard Blubaugh, Atlas Corporation, concerning Moab rock source (November 19, 1996).

Bowen, H. J. M., 1979, *Environmental Chemistry of the Elements*, Academic Press. New York, 334 pp.

Canonie Environmental Services Corporation, 1994, *NRC Technical Information Request, Atlas Corporation Ground Water Corrective Action Plan, Uranium Mill and Tailings Disposal Area, Moab, Utah*, Project 88-067, Report prepared for Atlas Corporation, Denver, Colorado (July 1994).

Carlson, C.A., and R.T. Muth, 1989, "The Colorado River: Lifeline of the American Southwest," pp. 220-239, In D.P. Dodge, ed., Proceedings of the International Large River Symposium, *Can. Spec. Publ. Fish. Aquat. Sci.*, No. 106.

Coughlan, D.J., and J.S. Velte, 1989, "Dietary toxicity of selenium-contaminated red shiners to striped bass," *Trans. Am. Fish. Soc.*, 118 (4), pp. 400-408.

Dvorak, A.J. et al., 1978, *Impacts of Coal-fired Power Plants on Fish, Wildlife, and Their Habitats*, U.S. Fish and Wildlife Service Report FWS/OBS-78/29.

Edwards, D. L., 1994, "Colorado River Water and Sediment Samples," Memorandum from D.L. Edwards to R.E. Blubaugh, Atlas Corporation, Denver, Colorado (December 28).

Efroymson, R., and G. Suter, 1995, *Body Burden Measurements as Indicators of Toxicity in Fish Populations*, Presentation at the Second SETAC World Congress, November 5-9, 1995, Vancouver, British Columbia, Canada.

Fagan, D., 1997, Telephone conversation between Dameon Fagan, Moab Utah, and R. M. Reed, Oak Ridge National Laboratory, January 28, 1997.

Farrell, R.E., J.J. Germida, and P. Ming Huang, 1990, "Biotoxicity of Mercury as Influenced by Mercury (II) Speciation," *Applied and Environmental Microbiology* **56**(1).

Eisler, R., 1985, *Selenium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service Biological Report 85 (1.5), October.

Eisler, R., 1987, *Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service Biological Report 85(1.10), April.

Eisler, R., 1988a, *Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service Biological Report 85(1.12), January.

Eisler, R., 1988b, *Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service Biological Report 85(1.14), April.

Eisler, R., 1994, *Radiation Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*, U.S. Fish and Wildlife Service Biological Report 26, December.

EnecoTech, Inc., 1988, *Technical Response For Ground Water Detection Monitoring Program*, Report prepared for Atlas Corporation, Denver, Colorado.

Federal Emergency Management Agency (FEMA), *Flood Hazard Boundary Map, Grand County, Utah, Unincorporated Area*, Panel 33 of 40, Community-Panel Number 4902320033A, effective date, October 6, 1981.

Hamilton, S.J., and B. Waddell, 1994, "Selenium in eggs and milt of razorback sucker (*Xyrauchen texanus*) in the middle Green River, Utah," *Arch. Environ. Contam. Toxicol.* 27(2), pp. 195–201.

Harding Lawson Associates. 1996a. *Draft Compilation of Analytical Data Associated with the Atlas Uranium MIll Tailings Site in Moab, Utah*, Report prepared for Atlas Corporation, Denver, Colorado (October 17, 1996).

Harding Lawson Associates, 1996b, *In-Progress Draft Work Product, Potential Groundwater Influences on the Colorado River, Atlas Uranium Mill and Tailings Site, Moab, Utah.* Report prepared for Atlas Corporation, Denver, Colorado (November 11, 1996).

International Atomic Energy Agency (IAEA), 1976, *Effects of Ionizing Radiation on Aquatic Organisms and Ecosystems*, IAEA Technical Report Series, No. 172. Vienna.

International Atomic Energy Agency (IAEA), 1992, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*," IAEA Technical Report Series, No. 332, Vienna.

Jorgensen, S.E., S.N. Nielsen, and L.A. Jorgensen, 1991, *Handbook of Ecological Parameters and Ecotoxicology*, Elsevier. New York.

Killough, G.G., and L.R. McKay, 1976, *A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment*, ORNL-4992, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Krabbenhoft, D.P., and C.L. Babiarz. 1992. The Role of Groundwater Transport in Aquatic Mercury Cycling. Water Resources Research, Vol. 28, No. 12, pp. 3119 - 3128.

Mizzi, Janet, 1996, Written Cmmunication from J. Mizzi, FWS, Salt Lake City, to Myron Fliegel, NRC, Washington D.C., Concerning Sediment and Biological Samples Collected in 1995 from the Colorado River, May 22, 1996.

Morton, Loren B., 1996, *Report Update of State Water Quality Results from Vicinity of Atlas Uranium Tailings Pile near Moab, Utah*, Utah Department of Environmental Quality.

Mussetter, R. A., and M. D. Harvey, 1994, *Geomorphic, Hydraulic, and Lateral Migration Characteristics of the Colorado River, Moab, Utah* (Final Report), MEI Reference No. 94-02, prepared for Canonie Environmental and Atlas Corporation by Mussetter Engineering, Inc., Fort Collins, Colorado (May 1994).

National Research Council of Canada, 1983, *Radioactivity in the Canadian Aquatic Environment*, NRCC 19250, Ottawa, Ontario.

Nature Conservancy, undated, *The Bright Edge; A Campaign for Utah's Colorado Plateau*, Pamphlet Published by The Nature Conservancy, Moab Project Office, Moab, Utah.

Ohlendorf, H. M., D. J. Hoffman, M. K. Saikri, and T. W. Aldrich, 1986, *Embryonic mortality and abnormalities of aquatic birds: apparent impacts of selenium from irrigation drain waters*, Sci. Total Environ., 52, 49-63.

Parr, J.F.; Marsh, P.B., Kla, J.M. (Eds.), 1983, *Land Treatment of Hazardous Wastes*, Noyes Data Corporation, Park Ridge, New Jersey.

Peterson, J.A., and A.V. Nebeker. 1992. Estimation of waterborne selenium concentrations that are toxicity thresholds for wildlife. Arch. Environ. Contam. Toxicol. Vol. 23, No. 2, pp. 154-162.

Salomons, W., and U. Förstner, 1984, *Metals in the Hydrocycle*, Springer-Verlag, New York. 350 pp.

Sample, B. E., D. M. Opresko, and G. W. Suter, II, 1996, *Toxicological Benchmarks for Wildlife: 1996 Revision*, ES/ER/TM-86/R3, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Schmitt, C.J., and W.G. Brumbaugh, 1990, "National Contaminant Monitoring Program: Concentrations of Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, and Zinc in U.S. Freshwater Fish 1976-1984," *Arch. Env. Contam. Toxicol.*, **19**(5), pp. 731-747.

Shacklette, H.T., and J. Boerngen, 1984, *Element Concentrations in Soils and Other Surficial Materials of the Coterminous United States*. U.S. Geological Survey Professional Paper 1270, U.S. Government Printing Office, Washington, D.C.

Smith Technology Corporation, 1996, *Final Reclamation Plan Volume 1 - Text, Tables, Drawings, Atlas Corporation Uranium Mill and Tailings Disposal Area*, Prepared for Atlas Corporation, Denver, Colorado, October 1996.

Suter, G. W. II, and C. L. Tsao, 1996, *Toxicological Benchmarks for Screening of Potential Contaminants of Concern for Effects on Aquatic Biota on Oak Ridge Reservation: 1996 Revision*, ES/ER/TM-96/R2, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 104pp.

Suter, G.W., II, M.A. Futrell, and G.A. Kerchner, 1992, *Toxicological Benchmarks for Screening of Potential Contaminants of Concern for Effects on Aquatic Biota on the Oak Ridge Reservation, Oak Ridge, Tennessee*, ORNL/ER-139, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Upper Colorado Region State-Federal Interagency Group, 1971, *Upper Colorado Region Comprehensive Framework Study, Appendix XV: Water Quality, Pollution Control and Health Factors*, Pacific Southwest Interagency Committee Water Resources Council.

U.S. Department of Agriculture (USDA), 1989, *Soil Survey ofGrand County, Central Part*, Soil Conservation Service in cooperation with U.S. Department of the Interior, Bureau of Land Management; and Utah Agricultural Experiment Station, Natural Resources Conservation Service, Salt Lake City, Utah.

U.S. Department of Agriculture (USDA), 1991, *Soil Survey of Canyonlands Area, Utah, Parts of Grand and San Juan Counties*, Soil Conservation Service in cooperation with U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; and Utah Agricultural Experiment Station, Natural Resources Conservation Service, Salt Lake City, Utah.

U.S. Department of Energy (DOE), 1994a, *Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Gunnison, Colorado*, DOE/AL/62350-57D, UMTRA Project Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), 1994b, *Baseline Risk Assessment of Groundwater Contamination at the Monument Valley Uranium Mill Tailings Site, Cune Valley, Arizona*, DOE/AL/62350-43, UMTRA Project Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), 1994c, *Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Shiprock, New Mexico*, DOE/AL/62350 48F, UMTRA Project Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), 1994d, *Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site at Grand Junction, Colorado*, DOE/AL/62350 104, UMTRA Project Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), 1995a, *Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Salt Lake City, Utah*, DOE/AL/62350-134, UMTRA Project Office, Albuquerque, New Mexico.

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

U.S. Department of Energy (DOE). 1995c. Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Durango, Colorado. DOE/AL/62350-175. UMTRA Project Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE). 1995d. Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Naturita, Colorado. DOE/AL/62350-195. UMTRA Project Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE). 1995e. Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Riverton, Wyoming. DOE/AL/62350-65. UMTRA Project Office, Albuquerque, New Mexico.

U.S. Department of Energy (DOE). 1996. Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Lakeview, Oregon. DOE/AL/62350-145. UMTRA Project Office, Albuquerque, New Mexico.

U.S. Environmental Protection Agency (EPA). 1986. Quality Criteria for Water 1986. EPA 440/5-86-001. Washington, D.C.

U.S. Geological Survey (USGS), 1986, *Water Resources Data: Utah, Water Year 1989,* U.S. Geological Survey Water-Data Report, UT-86-1.

U.S. Nuclear Regulatory Commission (NRC), 1979, *Final Environmental Statement Related to Operation of Moab Uranium Mill, Atlas Minerals Division, Atlas Corporation,* NUREG-0453, Office of Nuclear Material Safety and Safeguards, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC), 1980, *Final Generic Environmental Impact Statement on Uranium Milling*, NUREG-0706. Office of Nuclear Material Safety and Safeguards, Washington, D.C., September.

U.S. Nuclear Regulatory Commission (NRC), 1996a, *Draft Environmental Impact Statement Related to Reclamation of the Uranium Mill Tailings at the Atlas Site, Moab, Utah.* NUREG-1531, Office of Nuclear Material Safety and Safeguards, Washington, D.C., January.

U. S. Nuclear Regulatory Commission (NRC), 1996b, *Draft Technical Evaluation Report for the Proposed Revised Reclamation Plan for the Atlas Corporation Moab Mill*, NUREG-1532, Office of Nuclear Material Safety and Safeguards, Washington, D.C., January.

Utah Department of Environmental Quality, Division of Radiation Control, 1995-96. Report on Colorado River Water Quality to M. Fliegel, NRC April 17, 1996.

WestWater Engineering, 1995, *Atlas Corporation Moab Mill Site Colorado River Sampling and Literature Review*, Report prepared for Atlas Corporation by WestWater Engineering in consultation with Miller Ecological Consultants, Inc., and SENES Consulting, Ltd., Grand Junction, Colorado, July 1995.

ATTACHMENT A

CORRESPONDENCE FROM THE U.S. FISH AND WILDLIFE SERVICE