Attachment 3 Final Highland Pit Lake Ecological Assessment: Tetra Tech, Inc. and Redente Ecological Consultants, LLC, January 2011

FINAL
HIGHLAND
PIT LAKE-SPECIFIC ECOLOGICAL RISK ASSESSMENT

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BCF	Bioconcentration Factor
BTRV	Baseline Toxicity Reference Value
CSM	Conceptual Site Model
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
HQ	Hazard Quotient
LOAEL	Lowest Observed Adverse Effects Level
NOAEL	No Observed Adverse Effects Level
QAPP	Quality Assurance Project Plan
SAP	Sampling and Analysis Plan
HASP	Health and Safety Plan
SOW	Scope of Work
TRV	Toxicity Reference Value
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

Concentrations of Se, U, Ra-226, TDS, Ca, Mg, Na, Cl, SO4, and HCO3 in surface water from Highland Pit Lake, north of Douglas Wyoming in Converse County, were evaluated to identify those constituents that exceeded relevant State of Wyoming or Federal water quality standards. Selenium and uranium were the only constituents in Pit Lake water that exceeded applicable water quality standards of 0.005 ppm for Se and <1.4 ppm for U (WDEQ, 2005). Geochemical modeling results for selenium and uranium in the Pit Lake water (MFG, 2004) suggest that current concentrations of these elements will remain the same or rise slightly over the next several decades as concentration of these elements occurs as surface water evaporation takes over as the dominant hydrologic process in the lake.

Extensive Pit Lake sampling and surveying was conducted to support the risk assessment. Samples of water, sediment, soil, aquatic and terrestrial vegetation, aquatic and terrestrial invertebrates, and rodents were collected several times between September 2004 and August 2005 and analyzed for selenium and total uranium. Concentration data were used to establish the level of chemical exposures to selected biota that utilized the Pit Lake for various purposes. Observations on bird and terrestrial wildlife were made during 25 separate visits to the lake to record the presence of passerine birds, hawks, owls, waterfowl, shorebirds, and mammals such as pronghorn and mule deer.

A large number of waterfowl and other wildlife species use the Pit Lake during spring and fall migration and as summer range. Nesting by avifauna during the summer of 2005 were very limited and consisted mostly of cliff swallow that nest on the steep cliffs that surround most of the lake and one nest each by a pair of Canada geese and red-winged blackbirds. Both of the latter nests were destroyed by predators.

During planning of the Highland Pit Lake chemical risk assessment, the potential for unacceptable risks from selenium and uranium to aquatic and nearby terrestrial biota were of primary interest. A tiered approach was used to assess risks from selenium and uranium to Pit Lake biota via several exposure pathways. These pathways included aquatic, avian, herbivore, and carnivore receptors.

The Tier 1 evaluation was done by comparing maximum measured concentrations with highly conservative, lower limit TRVs that were highly protective of the more sensitive individuals of a species group such as benthic invertebrates. Results of this screen, using calculated hazard quotients (HQs), showed that some concentrations in Pit Lake samples exceeded the conservative TRVs such that HQs exceeded 1.0.

The Tier 2 evaluation used the less conservative 95UCL exposure concentrations and less conservative NOAEL and LOAEL TRVs that were still protective of individuals or populations of a species. Evaluation of results against assessment endpoints produced the following results:

Aquatic Assessment Endpoints- Under less conservative assumptions of exposure and NOAEL and LOAEL TRVs, only 3 of 18 exposure scenarios resulted in HQs >1.0. For selenium, copepod tissue concentrations very slightly (HQ = 1.2) exceeded the acceptance criteria while, for uranium, tissue concentrations for benthic invertebrates (HQ = 1.6), algae (HQ = 1.5) and leopard frogs (HQ = 1.1) also slightly exceeded calculated acceptance criteria. The conclusion drawn about this assessment endpoint was that current exposures to aquatic organism from selenium and uranium in the Pit Lake were slightly above acceptance criteria for one exposure pathway for selenium and three for uranium. However, for most exposure scenarios for benthic invertebrates, copepods, or aquatic plants, measured concentrations in source media were below levels that would negatively impact aquatic biota.

Waterfowl and Bird Life Assessment Endpoint- Assessment endpoints for waterfowl and bird life, taken as shorebirds feeding on benthic invertebrates, were to ensure that selenium and uranium concentrations did not limit viable populations of waterfowl or shorebirds. Risks based exclusively on conservative chronic screening-level TRVs and maximum concentrations of selenium in benthic invertebrates yielded HQs in the 30-35 range suggesting that some level of potential risk to aquatic biota from selenium would exist if waterfowl and shorebirds were chronically exposed to these upper range concentrations of these chemicals. The HQ for uranium for the benthic invertebrate-waterfowl pathway was about 50 but was less than 1.0 for the benthic invertebrate-shorebird pathway. Results of the baseline assessment suggested that under the less conservative assumptions of exposure and NOAEL and LOAEL TRVs for selenium, chronic exposures to waterfowl and shorebirds from a diet of benthic invertebrates still resulted in HQs >1.0. Under these less conservative conditions, uranium exposures to waterfowl and shorebirds through a benthic invertebrate diet, were within the acceptance criteria of HQ<1.0. The conclusion drawn from evaluation of the waterfowl and shorebird assessment endpoint was that chronic exposures to selenium through a benthic invertebrate diet pathway were slightly to moderately (i.e. HQs from 1.2-7.8) above the acceptance criteria of HQ>1.0. In contrast, chronic uranium exposures to birds through a benthic invertebrate diet were well below the acceptance criteria of HQ<1.0. When evaluated against the assumptions of chronic consumption of Pit Lake benthic invertebrates and year round occupancy, risks to waterfowl and shorebirds to both selenium and uranium, were judged to be insignificant.

Terrestrial Herbivore Assessment Endpoint- The assessment endpoint for herbivores, taken as meadow voles, mule deer or pronghorn was to ensure that chronic selenium and uranium exposures through a grass and drinking water **exposure pathway** were protective of those herbivores. Results of the conservative screening analysis indicated the drinking water exposure pathway for deer or pronghorn was not significant as HQs were less than 1.0. The dietary pathway, which assumed chronic ingestion of shoreline grass, resulted in very slight exceedences of TRVs for dietary selenium in meadow voles (HQ =1.9) and for dietary uranium in deer (HQ =1.2). Results of the baseline assessment only identified the grass to meadow vole pathway as still slightly exceeding the hazard quotient acceptance criteria of 1.0. The conclusion drawn about the herbivore assessment endpoint was that chronic exposures of meadow voles, deer or pronghorn to selenium and uranium in drinking water and a grass diet was of little significance to the maintenance of viable populations of these organisms. When evaluated against the assumptions of chronic consumption of Pit Lake grass and water and year round occupancy, risks to herbivores as represented by deer, pronghorn and meadow voles, to both selenium and uranium, were judged to be insignificant.

Terrestrial Carnivore Assessment Endpoint- The assessment endpoint for carnivores, taken as red-tailed hawk, was to ensure that chronic exposures to selenium and uranium through a dietary pathway were protective of these species. The red-tailed hawk was assumed to consume only meadow voles and consumption of this diet was assumed to be chronic and to consist entirely of voles. Results of the conservative screening analysis indicated that a meadow vole diet containing selenium resulted in exposures above the acceptance criteria of HQ = 1.0 (HQ = 10) while those for uranium were well below HQs of 1.0. Results of the less conservative baseline assessment still resulted in a meadow vole to red-tailed hawk HQ of 1.7 while uranium levels in the diet remained below acceptance criteria. The conclusion drawn about this carnivore assessment endpoint was that chronic exposures to a meadow vole diet resulted in exposures to red-tailed hawks that were very slightly above acceptance criteria only for selenium. When evaluated against the assumptions of chronic consumption of Pit Lake meadow voles and year round occupancy, risks from both selenium and uranium to predators, as represented by red-tailed hawks, were judged to be insignificant.

Finally, the lack of suitable and abundant littoral zone habitat and food sources greatly limit the potential of the Pit Lake as a source of selenium and uranium to avian and mammalian insectivores. In addition, current resident populations of aquatic species have developed under existing and prior chemical conditions at the lake, including selenium and uranium in surface water and sediments. Therefore, these invading species have tolerated chronic exposures to Pit Lake selenium and uranium. Based on projected final lake levels, and the configuration of the landscape to be covered by the water, the amount of habitat and biological productivity is not expected to increase over the next few decades (Figure 3.3). As a consequence, risks to aquatic and terrestrial biota from selenium and uranium are not expected to change dramatically from present conditions.

In summary, results of this site specific risk assessment show that:

1. Concentrations in Pit Lake samples exceeded regional background by at least an order of magnitude;
2. In some cases, HQs for a conservative screening of measured concentrations against conservative TRVs exceeded 1.0 by as much as 100;
3. HQs for a more realistic screening of measured concentrations against higher, but still protective TRVs generally are less than or just slightly above 1.0, implying a low level of risk to biotic populations; and
4. Integrating habitat and biomass estimates into the interpretation of the chemical data, including food availability and frequency of use of the lake by migratory species, leads to the conclusion that risks to resident and migratory biota at Highland Pit Lake are very low.

1.0 INTRODUCTION

1.1 Project Background

In the late 1960s, Humble Oil and Refining discovered a uranium deposit in the southern Powder River Basin, Wyoming, and initiated mining activities, which subsequently became known as the Highland Uranium Operations. Multiple mining techniques were employed to extract uranium ore, including surface mining from a series of four open pits, beginning in 1970 and continuing through 1984 (Water Waste and Land [WWL], 1989). The final two pits (pits 3 and 4) were not completely backfilled and, beginning in March 1984, groundwater from the surrounding aquifer was allowed to discharge into the two pits, forming the Highland Pit Lake (Figure 1.1). At this stage of formation of the lake, aquatic biota were very likely not present.

Figure 1.1 **Highland Pit Lake showing steep shoreline and general ecology of the area surrounding the lake**

While there is a relatively good understanding of the regional hydrology and geology of the Pit Lake, very little was known about the biological resources of the area including a catalog of aquatic fauna and flora that live in the lake or of avian and mammalian species that use the lake environs. Likewise, there was a complete lack of information on the concentrations of chemicals in Pit Lake biota and on current ecological relationships, including standing crops of biota and the amount and quality of habitat available to sustain biota.

The need for an environmental assessment of Highland Pit Lake is largely source-driven (Suter, 1993) since lake water contains elevated levels of selenium and uranium relative to Wyoming Department of

Environmental Quality (WDEQ) water quality standards for protection of aquatic life. WDEQ water quality standards for selenium and uranium are 0.005 ppm and <1.4 ppm, respectively. Current selenium and uranium concentrations in Pit Lake water exceed those standards by a factor of about 20 and 2 times, respectively. Computer modeling of the geochemical evolution of the Pit Lake water indicates that selenium and uranium concentrations will remain above WDEQ standards.

The presence of the lake has resulted in open water habitat that is not naturally abundant in the region. As a result, waterfowl, wading birds, and other wildlife may be attracted to the area. Prior to this study, anecdotal information based on casual observations suggested that waterfowl, raptors, and passerine birds might nest in the area. Consequently, a major data gap relative to the Pit Lake was the level and kinds of use of the lake environs by aquatic and terrestrial wildlife.

This report describes the results of a study initiated in September 2004 and completed in September 2005 to characterize some of the fauna, flora, and habitat associated with the Pit Lake and to assess, using toxicity based reference (i.e. safe) values, whether aquatic biota and visiting wildlife were exposed to unacceptable risk from chemicals in the Pit Lake. The technical approach to this assessment was to 1) characterize physical and biological relationships at the Pit Lake, including type and amount of habitat, species composition, and biomass production associated with aquatic fauna and flora, and 2) measure selenium and natural uranium in water, soil, sediment and selected biota from the Pit Lake and compare these concentrations to values considered safe for the particular exposure pathway. This two-pronged approach provided a means of evaluating the effects of selenium and uranium on Pit Lake biota within the context of the ecological relationships that exist at the lake.

The sampling design for the study focused on answering the following questions:

1. What are the ecological compartment sizes at the lake, including amount and types of habitat, biomass of major aquatic fauna and flora, and inventories of avifauna and terrestrial wildlife using the Pit Lake environs through time?
2. What are the Se and U concentrations with time in water, sediments, and some of the major aquatic biota that use the Pit Lake?
3. Do measured levels of Se and U in biota pose unacceptable risks to aquatic and terrestrial biota when compared to toxicity reference values, and relative to existing ecological relationships at the Pit Lake?

Field data collected to answer these questions consisted of 1) surface water temperature, dissolved oxygen, pH, conductivity, and turbidity, 2) habitat and biomass of aquatic plants and invertebrates, 3) Se and U concentrations in water, sediment, aquatic plants and invertebrates, amphibians, and shoreline soil, vegetation, insects and rodents, and 4) seasonal use of the lake by nesting and migratory birds and mammals. Measurements were replicated when possible to characterize variation in biomass and chemical concentrations within and between species and with time.

1.2 Approach to Risk Assessment

U.S. EPA (USEPA, 1998) describes three primary phases in conducting a risk assessment: 1) Problem Formulation, 2) Risk Analysis, and 3) Risk Characterization. The problem formulation phase describes the goals, scope, focus, and data needed for conducting the risk analysis. This includes the development of a conceptual site model (CSM) to identify complete exposure pathways between site-related chemicals and ecological resources at the site, selection of constituents of potential ecological concern (COPECs), and selection of assessment and measurement endpoints (i.e. the ecological resources at the site that require protection and the metrics that will be used to assess potential adverse effects). The analysis phase consists of an exposure assessment, an effects assessment and the integration of these two components by comparing estimates of exposure based on the measured chemical concentrations in various media to background concentrations or published toxicity benchmarks or reference concentrations that are considered safe levels for ecological receptors.

The analysis of the ERA is conducted using a tiered approach. In the first tier, highly conservative estimates of exposure and effects were used to estimate potential risk. As a first step in the Tier 1 risk analysis, maximum concentrations of selenium and uranium were screened against concentrations obtained from a small pond in Box Creek about 2 km west of the Pit Lake. Box Creek is an ephemeral spring fed stream with intermittent surface water expressions and eventually drains into the Cheyenne River and then the North Platte. No true background or control site for the Pit Lake exists that closely duplicates the lake environment in all respects except for the selenium and uranium concentrations. However, samples from the pond were considered to represent general area selenium and uranium levels in an aquatic environment that could be expected to represent regional background. While we expressly state that the Box Creek pond was not intended to serve as a background for the Pit Lake, we do consider the comparison of data from the pond with that from the Pit Lake as useful for scaling Pit Lake concentration data to regional levels[1]. In addition to this comparison, the Tier 1 analysis includes a comparison of maximum concentrations of selenium and uranium to toxicity thresholds based on lower limits of the range of no adverse effect levels (NOAELs).

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[1] Comparisons of the Box Creek and Pit Lake data were not used to screen out any exposure pathways prior to conducting additional risk analysis.

Any COPEC/receptor pair for which the maximum detected concentration exceeded the NOAEL-based threshold was carried forward for a more site-specific and focused analysis in Tier 2. The Tier 2 analysis includes a more realistic exposure estimate (i.e. based on 95% upper confidence limits) and effects thresholds (e.g. based on mid range NOAEL and lowest observed adverse effect levels when available).

As a final step in the assessment, overall risks were characterized by integrating ecological factors with the results of the quantitative Tier 2 risk analysis in order to evaluate any potential risk in the context of available habitat, species present over time, and species biomass.

1.3 Report Organization

This report presents the results of the habitat, biota, chemical measurements, and assessment of impacts selenium and uranium on the Highland Pit Lake aquatic ecosystem. The report supplements earlier documents on the Pit Lake including: Scope of Work (MFG, 2004) in which the Sampling Analysis Plan, Quality Assurance Project Plan, and Health and Safety Plan are inserted. Other important background documents addressed long-term groundwater and Pit Lake hydrology (MFG, 2003) and, long-term geochemical evolution of Highland Pit Lake (MFG, 2004). These earlier documents provided background information for this aquatic life assessment, including sampling methods, quality control procedures in the SOW, and a detailed description of the geology and current and future predicted states of the hydrology and water chemistry of the Pit Lake in MFG (2003; 2004). This report is a revision of the "Final Draft, Highland Pit Lake, Pit Lake-Specific Ecological Risk Assessment" dated March 2006. The revision was prepared by Redente Ecological Consultants in January 2011 in order to present an updated version of this assessment. The remaining sections of this report are organized as follows:

Section 2.0 is PROBLEM FORMULATION and is a key chapter defining the nature and extent of the assessment problem.

Section 3.0 is FIELD DATA and presents the findings of the field sampling to measure the physical, biological, and chemical characteristics of the Pit Lake.

Section 4.0 is RISK ANALYSIS and compares chemical data to Toxicity Reference Values that are known to be protective of aquatic biota or with other types of acceptance criteria. Comparisons are also made between habitat quality parameters and previously documented quality indices.

Section 5.0 is RISK CHARACTERIZATION and evaluates the impact or ecological significance of selenium and uranium on the Pit Lake ecosystem. The section on Uncertainties discusses sources of uncertainty, including contributions from sampling, analytical, Pit Lake model, and TRV derivation. The section on Conclusions summarizes results of the evaluation.

2.0 PROBLEM FORMULATION

Problem formulation defines the goals and objectives of the risk assessment. This is a formal process to develop and evaluate preliminary hypotheses concerning the likelihood and causes of ecological effects that may have occurred, or may occur, from human activities (USEPA, 1998). The problem formulation for this ERA includes a description of the Pit Lake and the surrounding area, a description of the ecological setting, selection of COPECs, the CSM, the selection of assessment and measurement endpoints, and the selection of representative receptors. The following sections provide details of each step in the problem formulation.

2.1 Pit Lake Description

In the late 1960s, Humble Oil and Refinery discovered a uranium deposit in the southern Powder River Basin, Wyoming, and initiated mining activities, which subsequently became known as the Highland Uranium Operations. The uranium occurred as a roll front deposit trending roughly northwest in the area of the Highland property (Langden and Kidwell, 1973). Multiple mining techniques were employed to extract uranium ore, including surface mining from a series of four open pits, beginning in 1970 and continuing through 1984 (WWL, 1989). Overburden and waste rock removed during stripping operations were initially stockpiled and were then used to backfill previously opened pits. The final two pits (pits 3 and 4) were not completely backfilled and, beginning in March 1984, groundwater from the surrounding aquifer was allowed to discharge into the two pits, forming the Highland Pit Lake. As mentioned, a functioning aquatic community did not exist in the lake during this period.

Open-pit mining at the Highland project followed the general strike of the roll-front. The current shape of the Pit Lake represents the final extent of open pit mining. Therefore, portions of the pit-wall in the ore body exposed the mineralized roll-front. Even though portions of the pit-walls were covered with backfill (EPRC, 1983), groundwater flowing from up gradient in the ore body leached uranium, radium, and selenium from mineralized zones and transported the metals into the Highland Pit Lake.

Other sources of water flowing to the Highland Pit Lake include: (1) surface runoff, (2) direct precipitation, (3) discharge from a perched aquifer, and 4) seepage from the tailings impoundment. Outflow of water from the Highland Pit Lake is limited to evaporation based upon the current hydrological model. A more complete discussion of lake and groundwater hydrology can be found in a previous report (MFG, 2003).

2.2 Ecological Description

The Highland Pit Lake environs experiences a dry continental climate, typical of the Northern Rockies, with prevailing winds and weather patterns moving from west to east. The mountain ranges to the west of the Highland site cause Pacific storms to drop much of their moisture before they reach the Pit Lake area, resulting in low precipitation of about 12 inches (~ 300 mm) annually. The most abundant rainfall occurs in the spring and early summer. In the winter months, total snowfall averages 44 inches, and snow cover remains on the ground through much of November to March or April. July temperatures in the region are mild, ranging from 44° to 82° F, while January temperatures fall to a range of 4 to 28° F.

In undisturbed areas, the temperate climate and low precipitation support primarily grasses and forbs with shrubs and trees occurring on steep north facing slopes and along water courses. However, most of the vegetation surrounding the Pit Lake reflects species used for past reclamation activities. Currently, the vegetation around the lake is dominated by western wheatgrass, crested wheatgrass, thickspike wheatgrass, Great Basin wild rye, and smooth brome. A limited amount of vetch (possibly *Astragalus cicer* that was seeded in the area) occurs near the shore line at the Pit Lake. This species is known as a hyperaccumulator of selenium (Sors et al., 2005).

A number of faunal species are associated with the lake environs (Appendix F). Terrestrial species include Rocky Mountain mule deer, which are abundant in the area during the summer and use the lake for drinking water. In addition, muskrats, meadow voles, deer mice, and a variety of insects, inhabit the shore area. Some of the mammalian predators include the coyote, red fox, skunk, badger, and raccoon.

Avian predators are very abundant during the summer nesting season. Many species of terrestrial birds occur in the general area, including several species of raptors, owls, and a variety of passerine birds.

Waterfowl species have been observed at the lake from Spring through the Fall (Section 4.3). During the study period, most waterfowl used the lake for resting and or loafing. Canada geese that were observed on the lake appeared to be acclimated to human presence suggesting that they likely were a resident population that had flown from Douglas Wyoming to rest on the Pit Lake during the day. At the beginning of this study, some species were thought to nest around the lake including Canada geese, blackbirds, and western grebes.

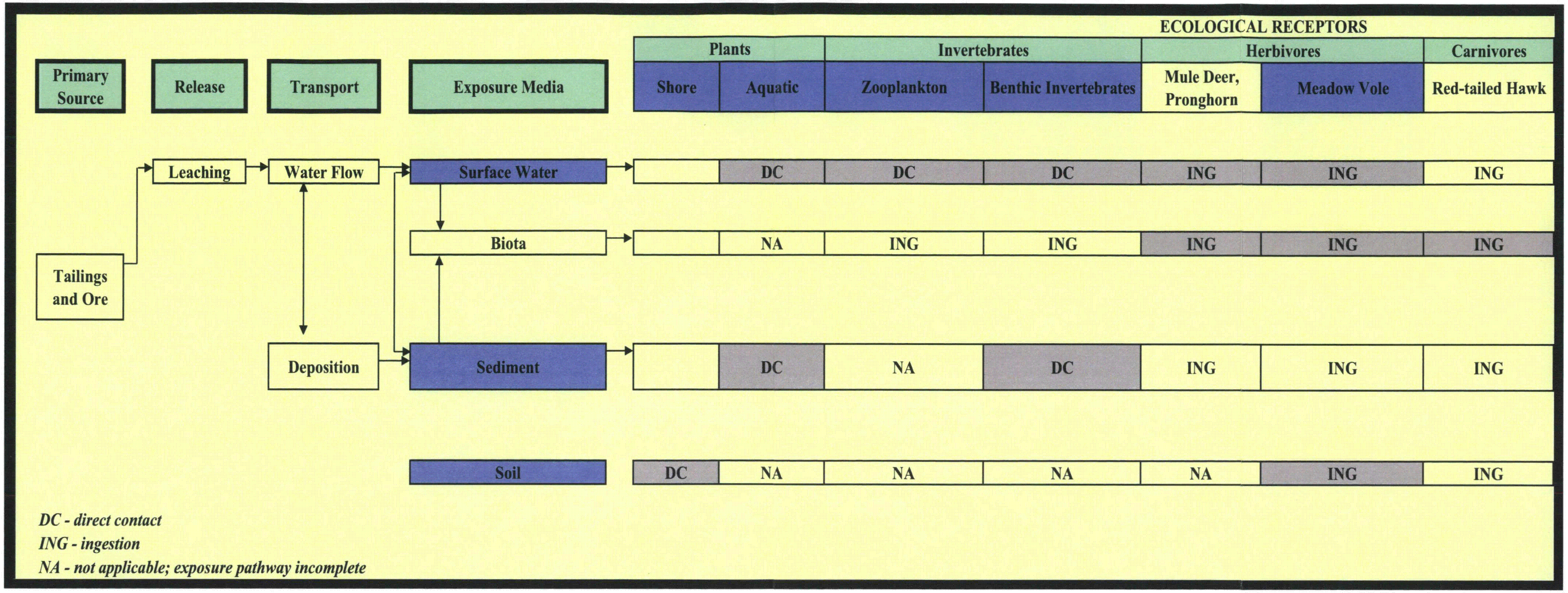
Benthic invertebrates of several species occupy a small, shallow water area in the Pit Lake. Amphibian species that are thought to occur in the Pit Lake area are the tiger salamander (*Ambystoma tigrinum*), leopard frog (*Rana pipiens*), and a toad (*Bufo* sp.). Only the leopard frog and toad were observed during the 2004 and 2005 field investigations (Appendix F).

A total of about 45,000 rainbow, cutthroat, and hybrids of the two species were planted in the Pit Lake on 2 occasions in the 1990's in an attempt to establish a fishery in the lake. However, fish have never been caught from the lake leading to the conclusion that the stocked fish did not survive. Repeated attempts to catch fish using gill nets, cast nets and tackle during a prior survey and during this study were unsuccessful.

While no listed species were recorded in Wyoming Natural Diversity Database (1/23/06) as occurring in the township containing the Pit Lake, two of these were observed in the general area of the Pit Lake. The short-eared owl (*Asio flammeus*) and golden eagle (*Aquila chrysaetos*) were both observed on several occasions in the general area of the Pit Lake. The short-eared owl, a ground nester, was assumed to have nested in the area based on repeated observations of the bird/s in the same general area. A meadow vole-owl pathway was evaluated using toxicity reference values for a diet to bird exposure pathway.

2.3 Pit Lake Conceptual Site Model

A simplified conceptual site model (CSM) of the Pit Lake ecosystem was developed to visually represent some of the biological components of the Pit Lake potentially at risk from chemicals (Figure 2.1). Conceptualization of the structural and functional relationships, including chemical exposure pathways, is used to identify data needed to evaluate the potential risks from chemicals to Pit Lake receptors. From the model, identified data needs include: 1) specific Pit Lake chemicals that are of interest, 2) applicable standards for chemicals of interest, 3) biota that might be exposed to the chemicals, 4) concentration of chemicals in biota, 5) physical and biological attributes of the lake habitat including size of the various physical and biological compartments, and 6) a methodology for integrating the physical, chemical, and biological information to estimate risks to biota associated with the Pit Lake. Blue shaded boxes in the model were sampled to estimate selenium and uranium concentrations. The gray-shaded boxes depict pathways which were examined in the risk analysis.



	ECOLOGICAL RECEPTORS						
	Plants		Invertebrates		Herbivores		Carnivores
Exposure Media	Shore	Aquatic	Zooplankton	Benthic Invertebrates	Mule Deer, Pronghorn	Meadow Vole	Red-tailed Hawk
Surface Water		DC	DC	DC	ING	ING	ING
Biota		NA	ING	ING	ING	ING	ING
Sediment		DC	NA	DC	ING	ING	ING
Soil	DC	NA	NA	NA	NA	ING	ING

DC - direct contact
ING - ingestion
NA - not applicable; exposure pathway incomplete

Figure 2.1 **Conceptual Site Model for Highland Pit Lake. Media sampled for this assessment are shaded purple while pathways evaluated are shaded in gray.**

2.4 Chemicals of Potential Ecological Concern

Long term monitoring of Pit Lake water for a variety of chemicals identified only selenium and uranium as exceeding State of Wyoming surface or groundwater standards for protection of aquatic life in 2004 (Table 2.1). Surface and groundwater monitoring data for Ra-226, TDS, Ca, Mg, Na, Cl, SO_4, and HCO_3 were all less than applicable Wyoming or Federal water quality standards in 2005 (WDEQ, 2005). The WDEQ water quality standard for selenium and uranium for use by livestock is 0.05 mg/l and 5 mg/l, respectively. New EPA regulations for selenium, which have been adopted by WDEQ, stipulate a maximum tissue concentration in fish or benthic invertebrates of 7.9 mg/kg dw in order to protect avian life that forages for fish or benthic invertebrates in the subject water body.

Table 2.1 Wyoming Department of Environmental Quality water quality standards for selenium and uranium compared with measured and predicted concentrations.

SELENIUM (mg/l)	URANIUM (mg/l)
Measured at Pit Lake = 0.11	Measured at Pit Lake = 3.12
Predicted Long Term = 0.15	Predicted Long Term = 3.5
WDEQ Stock Water = 0.05	WDEQ Stock Water = 5
WDEQ Aquatic Life = 0.005	WDEQ Aquatic Life = <1.4

The exposed ore body and intrusion of groundwater into the lake are considered to be the two sources of selenium and uranium in surface water and sediment (MFG, 2004). Based on surface and groundwater monitoring data and computer modeling studies (MFG, 2004), groundwater was considered to be secondary to the exposed ore body as a direct source of selenium and uranium in lake water under current conditions.

Monitoring data show that concentrations of selenium and uranium in Pit Lake water have decreased with time following an initial pulse probably due to a release of soluble constituents from the exposed ore bodies covered by the rising water. However, over the long term, the modeling studies (MFG, 2004) predict that groundwater will become a more important source of Se and U in the lake with time as the exposed ore body in the pit becomes depleted in soluble selenium and uranium. The modeling studies also predict that selenium and uranium concentrations over the long term may increase slightly as evaporation from the lake concentrates chemicals in the water (MFG, 2004; Table 2.1).

The analytical protocols and reported detection limits for selenium and uranium in sampled media are presented in Table 2.2.

Table 2.2 Sample Analytical Methods and Reporting Limits

Sample Media	Analyte	Method	Required Reporting Limit	Units*
Surface water	Selenium (Se)	A 3114 B -hydride	0.0005	mg/l
	Uranium (Unat)	EPA 200.7/EPA 200.8	0.0003	mg/l
Sediment	Selenium (Se)	EPA 3050B, M7742-hydride	0.1	mg/kg
	Uranium (Unat)	EPA 3050B, M6020	0.01	mg/kg
Benthic Invertebrates, Plankton, Vegetation	Selenium (Se)	EPA 600 (4-81- 55)/M7742-hydride	0.1	mg/kg
	Uranium (Unat)	EPA 600 (4-81-055)/M6020	0.01	mg/kg

*mg/kg reporting limit on solid samples on dry weight basis

2.5 Potential Receptor Types and Assessment Endpoints

For this assessment, sediment and surface water are considered to be the primary sources of selenium and uranium to biological components of the Pit Lake environs (Figure 2.1). Through transport processes involving ingestion and direct contact, some chemicals in water and sediment could be transferred to aquatic and terrestrial fauna and flora. While the conceptual model in Figure 2.1 illustrates potential exposure pathways, no measurements were made to quantify individual pathways such as ingestion or direct contact. Evaluation of exposures and exposure pathways was made by direct measure of concentrations in selected biota and by using published or calculated TRVs specific to those pathways.

There are essentially two types of primary producers (produce biomass through photosynthesis) to be considered for the Pit Lake exposure pathways. The first is vascular and non-vascular aquatic plants such as rooted emergent and submerged vegetation, algae, and diatoms. The second type is vegetation growing along the lake margin. As mentioned, this is primarily grasses planted during past reclamation activities along with some weedy species that have invaded the site.

Primary consumers, which convert plant biomass to animal biomass, include some benthic invertebrates, some waterfowl, and terrestrial herbivores such as rodents, mule deer, and pronghorn. Secondary consumers, which convert animal biomass to animal biomass, include amphibians, some waterfowl, and terrestrial predators such as coyotes, and raptors. Of course, there are some species that consume both plant and animal material including some waterfowl, shoreline rodents, and benthic invertebrates. Whatever the trophic relationships, ingestion of food and water are potentially important mechanisms whereby lake and terrestrial biota can be exposed to selenium and uranium.

Goals, objectives, and data needs for the impact assessment (USEPA, 1997; 1998) were developed by integrating management goals, assessment endpoints, risk questions, and measurement endpoints for evaluating impacts from selenium and uranium on Pit Lake biota (Table 2.3). The primary management goal was to protect aquatic and terrestrial biota from harmful impacts of Pit Lake selenium and uranium.

Assessment endpoints are expressions of the actual environmental value that is to be protected. The assessment endpoint is generally a neutral statement of the ecological entity and is usually coupled with a corresponding management goal, which expresses the desired condition of the ecological resource (USEPA, 1998).

Measurement endpoints (Table 2.3) were developed to reflect specific data and information needs to support the evaluation of the assessment endpoints. The assessment endpoints were used to judge the potential toxic effects of selenium and uranium on aquatic and terrestrial life associated with the Pit Lake.

The questions this assessment attempts to answer relate to whether or not assessment endpoints are likely to be adversely affected by exposure to selenium or uranium. These questions form the basis for identifying the specific analyses to be conducted and the data needed to perform the analysis.

What is not apparent from Table 2.3 is that ancillary measurements were made on the composition and biological productivity of the Pit Lake ecosystem along with the chemical measurements. The types and amount of habitat and plant and animal biomass production formed was a key ingredient in the interpretation and eventual significance of the chemical data. For example, high selenium or uranium concentration in benthic invertebrates becomes relatively unimportant if benthic invertebrate biomass production is low and provides a very limited potential food supply to organisms that consume benthic invertebrates.

2.6 Risk Analysis Procedure

The USEPA (1998) identifies three types of measures that are used to assess ecological risk:

- Measures of Ecosystem and Receptor Characteristics – Measures of ecosystem and receptor characteristics that influence the potential for contact between the receptor and stressor.
- Measures of Exposure – Measures of stressor concentrations and movement in the environment.
- Measures of Effect – Direct measures of changes in an attribute of the assessment endpoint that can be attributed to exposure for the stressor in question.

Table 2.3 **Selenium and uranium assessment and measurement endpoints for biological receptors at Highland Pit Lake**

Management Goal	Assessment Endpoint	Measurement Endpoints	Questions
Protect Pit Lake aquatic macroinvertebrate and zooplankton communities from harmful impacts of selenium and uranium.	Maintain viable benthic macro-invertebrate, aquatic vegetation, and zooplankton populations.	Comparison of chemical concentrations in surface water sediment, and tissues against safe levels for benthic macroinvertebrates and zooplankton populations.	Are there chemical limitations to surface water that affect the survival, growth, and reproduction of benthic macroinvertebrates and zooplankton populations?
Protect Pit Lake waterfowl and bird life populations from harmful impacts of uranium and selenium in water and food.	Maintain conditions protective of waterfowl and bird populations	Comparison of chemical concentrations in surface water, sediment and food against safe levels for waterfowl and bird life. Observations on nesting success.	Are there chemical limitations to the Pit Lake that affect waterfowl and bird life?
Protect terrestrial herbivores associated with the shoreline of the Pit Lake from harmful impacts of uranium and selenium in water and food.	Maintain conditions protective of herbivore populations.	Comparison of chemical concentrations in surface water, soil, and food against safe levels for rodents, deer, or pronghorn.	Are there chemical limitations to the Pit Lake water and forage that affect herbivore populations?
Protect terrestrial carnivores associated with the Pit Lake from harmful impacts of uranium and selenium in water and food.	Maintain conditions protective of carnivores populations	Comparison of chemical concentrations in surface water, soil, and food against safe levels for red-tailed hawk	Are there chemical limitations to the Pit Lake that affect carnivore populations?

2.6.1 Measures of Ecosystem and Receptor Characteristics

A important part of this risk assessment was an evaluation of the physical and biological characteristics of the Pit Lake that influence the significance of selenium and uranium exposures to the different plants and animals. Factors that can influence the exposure frequency and duration include seasonal and daily patterns of habitat usage by the receptors, availability of food items, quantity of available food, feeding behaviors, and population structure of the exposed receptors.

Both formal and informal means were utilized to characterize the physical and biological composition and biomass in the Pit Lake ecosystem. Information from the literature on migration and nesting behavior, home range, and other behavior were used as appropriate but the primary method was to observe and keep detailed field notes during each of the 25 visits to the lake. Evidence of usage included visual observations of individual receptors, the presence of scat or tracks, and evidence of feeding and nesting behavior. Because field sampling was conducted during more than one season, these observations provide insight into seasonal patterns of usage of the Pit Lake by the different receptors.

The species, abundance and behavior of waterfowl were monitored from September 2004 through September 2005 at about 2 week intervals during the study period. In addition, the area around the lake was surveyed for dead or dying birds (or other wildlife). Results of these surveys are summarized in Appendix F.

Habitat mapping was done using a combination of a computerized bathymetric map and field reconnaissance with a GPS. The littoral zone was delineated from the limnetic zone based upon water depth, secchi visibility, presence of macrophytes, and presence of benthic invertebrates. Frequent water quality measurements were also made with a Hydrolab fitted with probes for temperature, pH, conductivity, dissolved oxygen, and oxidation-reduction potential.

2.6.2 Measures of Effect

Direct measures of effects of selenium and uranium on receptors, such as reduced productivity or reproduction, were not made for this Pit Lake assessment. Part of the reason for not making measurements of direct effects is that variables such as reproduction or biomass production can be influenced not only by selenium and uranium but by non-chemical factors such as season and food availability. As will be mentioned repeatedly in this document, an appropriate background site that duplicated the Pit Lake in all aspects but selenium and uranium concentrations, does not exist. If such a site did exist, then measure of effects would be possible.

2.6.3 Measures of Exposure

In lieu of direct measures of effects of selenium and uranium on biota, our approach was to measure concentrations of these chemicals in aquatic and terrestrial components and to compare those concentrations to ecotoxicological toxicity reference values derived from the scientific literature or were calculated from Pit Lake specific bioconcentration factors. Published TRVs represent known levels of effects for specific exposure ranges based upon dose-response studies conducted primarily in the laboratory. In this assessment, both conservative and less conservative no-observed-adverse-effects-level (NOAELs) TRVs were utilized to evaluate the potential risk. NOAELs for a given exposure pathway encompass a range of concentrations at which no toxic effects are expected and are generally understood to be safe to individual organisms. In some cases, low observed adverse effects level TRVs (LOAELS) were used in the less conservative baseline assessment to represent conditions that were protective of populations of organisms instead of individuals as is inferred from the use of NOAELS.

Most of the TRVs for biological components of the aquatic and terrestrial habitat were derived from published studies for water or soil as the exposure media since the quantity and quality of the toxicity data for exposure pathways involving those media are generally available. Calculated safe concentrations in tissues of Pit Lake biota used ~ bioconcentration factors derived from either water or soil as the exposure media. For example, the BFC for benthic invertebrates was calculated by dividing the measured selenium or uranium concentration in benthic invertebrates by the concentration of those chemicals in water. Likewise, the BCF for grass was obtained by dividing the measured chemical concentrations in grass by the concentration in underlying soil. We consider BCFs based on site specific data as the most reliable way (i.e. better than published TRVs) to evaluate chemical risks to Pit Lake biota. The reason for this is that a BCF based on site specific data represents the net transfer of selenium and uranium and that single number integrates all the physical, chemical, and biological factors that affect the total transfer of selenium and uranium to Pit Lake biota.

Extensive sampling of biological components of the Pit Lake was conducted periodically from September 2004 to June, 2005 to determine species composition, biomass, and concentrations of Se and U in selected aquatic and terrestrial species, surface water, sediment, and soil. Benthic invertebrate and vegetation samples from the Pit Lake were collected using quantitative methods so that biomass could be estimated. An Ekman Dredge was used to collect benthic invertebrates and sediments in order to convert mass to mass/unit area. A 0.5 m^2 quadrat was used to collect rooted aquatic and terrestrial vegetation. Zooplankton were collected with a 30 cm diameter net towed behind a boat. The net was towed over the entire lake behind a motor boat to obtain representative zooplankton samples. The tow net was also used to estimate zooplankton biomass by lowering it to the lake bottom and then hauling it vertically to sample zooplankton from a given volume of water. Special studies were done to determine the vertical distribution of zooplankton in the water column. That information was used to develop an estimate of the amount of lake volume to use in the calculation of zooplankton biomass

Background concentrations of selenium and uranium were measured in a small pond in Box Creek about 2 km west of the Pit Lake. As mentioned, the Box Creek location cannot be considered as a control site for the Pit Lake because the two sites differ dramatically in physical characteristics. However, the pond in Box Creek contains most of the biological components sampled at the Pit Lake and also lies outside the influence of the Highland mine and mill site. As such, we consider Box Creek to represent regional levels of selenium and uranium in aquatic and terrestrial component that that can be used to scale the concentration data obtained from the Pit Lake. Aquatic samples collected from the Box Creek pond included benthic invertebrates, leopard frogs, submerged and emergent vegetation, sediment, and surface water. Terrestrial samples included soil and vegetation.

Summary statistics for the biomass and chemical concentration data that follow were based on normal statistics. Sample size limitations and, in some cases, the need to lump data (i.e. means based on lumping concentrations for individual benthic invertebrate species together), precluded an analysis of the sampling distributions of the data. Therefore, the arithmetic mean, standard deviation and 95th upper and lower confidence limits were all based on normal statistics. The 95th % UCLs and LCLs reported later were calculated as follows:

$$95UCL = \text{Mean} + \frac{1.96}{2}\left[\frac{SD}{\sqrt{n}}\right]$$

In addition, none of the time series measurements of selenium and uranium concentrations in Pit Lake samples qualified for repeated measures statistical analysis (RMSA) as several assumptions for the RMSA were violated. For example, sampling locations were not exactly duplicated in time due to rising water levels (e.g. benthic invertebrate sampling) and copepod, water, and sediment sampling was conducted in a general region of the Pit Lake (e.g. north end of lake) rather than exactly duplicating previous sampling locations. Consequently, differences in chemical concentrations with time were influenced by other factors in addition to time.

3.0 FIELD DATA

The data used to support this ERA was collected based on the approach developed by MFG and presented in the Scope of Work (MFG, 2004). The field study to collect data for the ERA was initiated in September 2004 and completed in September 2005 to characterize some of the fauna, flora, and habitat associated with the Pit Lake. In addition to biological data, chemical data were collected for selenium and uranium for various environmental media and biota tissue from in and around the lake. This section presents a summary of the data collected for and used in the ERA.

3.1 Physical Description of Pit Lake

The Pit Lake is oriented roughly southwest-northeast, covers about 110 acres (46 ha), is approximately over 130 ft (41 m) deep, and has a water level that was rising about one foot per year during the study period. The current elevation of the lake surface is about 5,030 feet (1,533 m). Due to the relatively recent age of the lake (~ 20 yrs) and the cold NE Wyoming climate, the lake would be expected to exhibit a limited biological component as is typical of cold water, low productivity oligotrophic lakes.

There are two distinct zones, or habitats, in the Pit Lake (Figure 3.1). The first is an open water or limnetic zone, and the second, a near shore, shallow water or littoral zone. This near shore littoral zone (i.e. foreground in Figure 3.1) with its associated flora and fauna has formed recently as water levels 6-8 years ago would not have covered this shallow water area.

In many deep, cold, freshwater lakes, most aquatic biological activity is associated with the littoral zone, where water temperatures rise during summer months allowing for the establishment of rooted and submerged vegetation, including periphyton, that contributes organic matter to bottom sediments. This organic matter serves as the basis of the food web that supports benthic invertebrates and other aquatic biota including amphibians.

The shore around the perimeter of the lake is primarily comprised of very steep slopes ranging from near vertical to a very limited area with more gentle slopes of about 10% (Figure 3.1). These slopes consists of exposed soil and rock with sparse grass on the very steep areas and, on the more gentle slopes, a heavier grass cover consisting of western wheatgrass (*Pascopyrum smithii*), crested wheatgrass (*Agropyron cristatum*), thickspike wheatgrass (*Elymus lanceolatus*), Great Basin wildrye (*Leymus cinereus*), and smooth brome (*Bromus inermis*) are associated with past reclamation work on the tailing and waste rock areas around the Pit Lake.

Note: The foreground shows the shallow littoral zone along with the deep water, limnetic, zone in the background.

Figure 3.1 **Pit Lake shore showing steep slopes and cliffs that comprise most of the shoreline**

The steepness of the shore slopes limits areas that can be easily accessed by larger terrestrial species that might use the lake for drinking water or forage. Consequently, nearly all of the mule deer seen utilizing the lake for drinking water (Appendix F) did so in the small area that supported rooted aquatic vegetation and had relatively gentle slopes (foreground in Figure 3.1).

The area around the lake within at least a kilometer from shore completely lacks trees and shrubs (Figure 3.1) that might provide lake side nesting and hunting habitat for avian species. Trees do grow along drainages associated with the Box Creek drainage south-south west of the lake. These trees are used by nesting hawks and owls. Several locations in Box Creek and stock watering ponds on private land provide surface water for livestock and wildlife such that the Pit Lake is not the only surface water source in the area.

For this study, the littoral zone in the Pit Lake was defined as the zone from shore to a maximum water depth of 5 ft (1.5 m)(current extent of littoral zone shown by the blue contour line in Figure 3.2). This definition is based upon the fact that maximum water depths increase dramatically beyond the 5 ft (1.5 m) depth in the littoral zone owing to the vertical walls associated with the pit shaped configuration of the lake. As mention previously, as little as 6-8 years ago, none of the area defined herein as littoral zone would have existed because of the rising lake water levels.

The total area of the lake is about 5,920,151 yd^2 (4,950,000 m^2) while the total area of the region from shoreline to 5 ft (1.5 m) depth is 321,937 yd^2 (269,180 m^2) or 5.44% of the total lake area (Figure 3.2). The littoral zone, as defined above, comprised only about 0.4% and 5% of the total lake volume and surface area, respectively. About 2% of the total lake area, or approximately 2 ac (0.9 ha) supported emergent vegetation and associated fauna.

The total area of the rooted vegetation in the lake, which is shown as the green shaded areas in Figure 3.2, was estimated at 4,100 m^2 (44,132 ft^2). This means that rooted macrophytes contributed 0.08% to total lake area or about 1.5 % to the 0-5 foot (0-150 cm) region defined as the littoral zone or about 15,300 m^2 (164,820 ft^2). The low contribution of the littoral zone to plant production is expected to decrease as the lake reaches its final level because of the steep nature of the shore area precludes any expansion of the littoral zone (Figure 3.3). The projected area for the littoral zone at the time that the Pit Lake reaches its final level is estimated to be 13,225 m^2 (142,341 ft^2), which represents a loss of approximately 2,075 m^2 (22,335 ft^2).

The open water, or limnetic zone (i.e. water depths > 150 cm or > 5 ft), comprises about 96% and 99+%, respectively, of the lake surface area and volume. The limnetic zone had a maximum depth of about 40m (130 ft) during the study. The lake stratifies during the summer with a thermocline developing at the 55-65 ft depth (17-20 m) (Figure 3.4). The thermocline persists from May through September and begins to dissipate in October. Water temperatures from November through April are cold from top to bottom and reach a minimum of about 2 degrees centigrade throughout the water column in February.

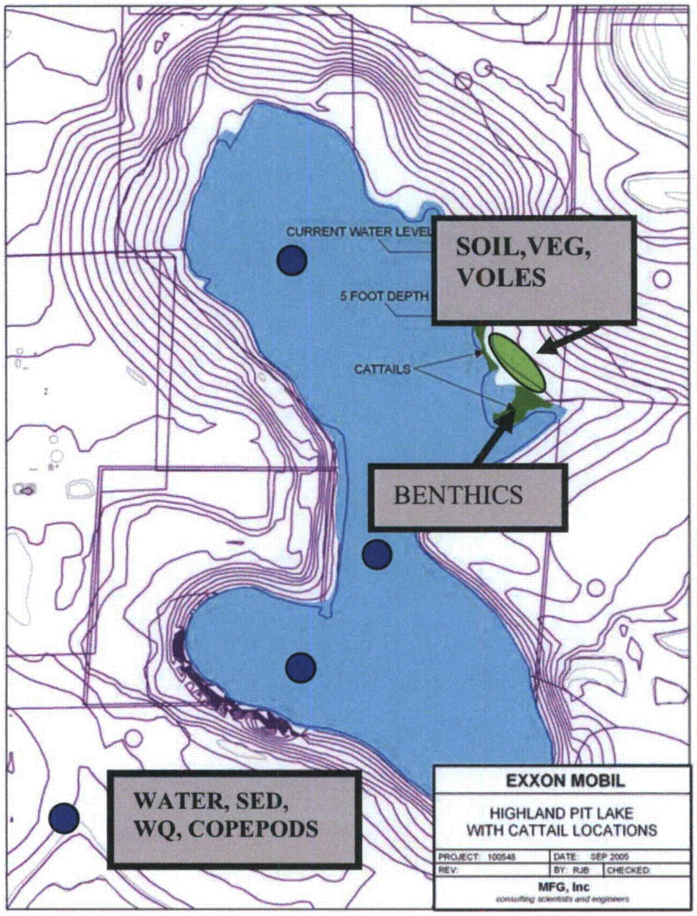
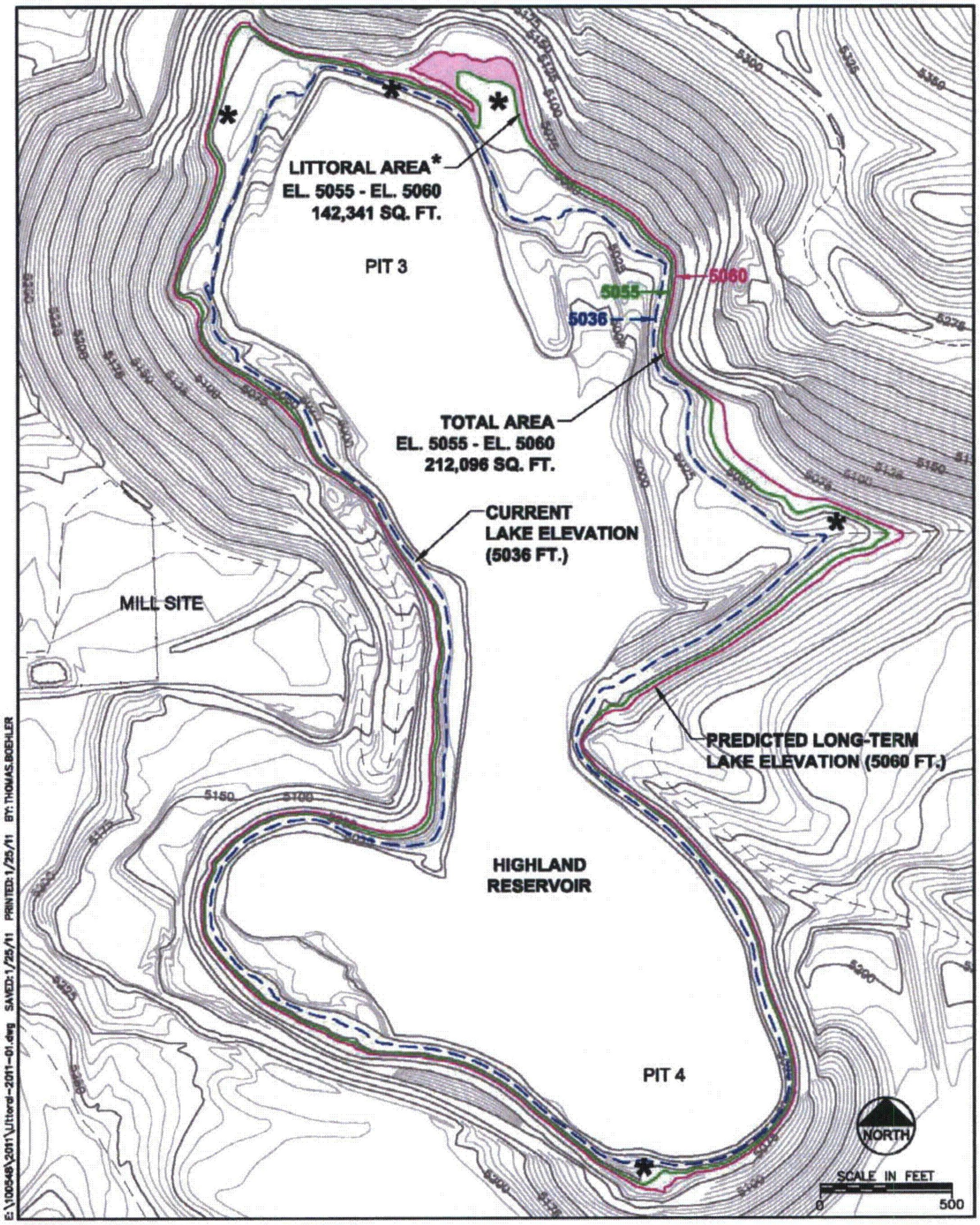


Figure 3.2 Plan view of Highland Pit Lake showing the current extent of littoral zone, cattail beds, and sampling locations.



Project No. 180549/2011

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Figure 3.3
Projected Long-Term Pit Lake Level Showing New Littoral Zone

Figure 3.3 Projected long-term Pit Lake level showing new littoral zone.

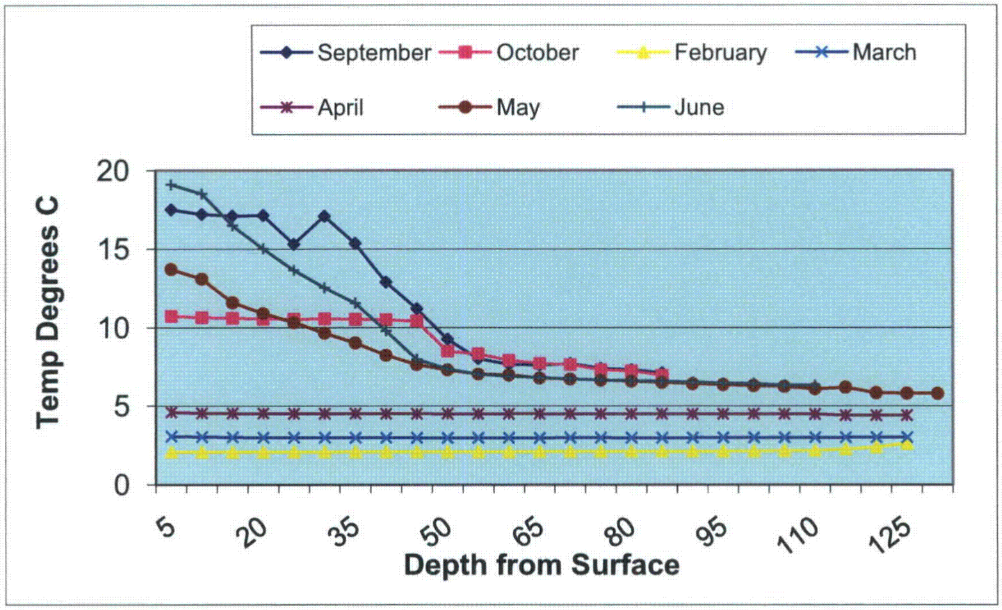

Figure 3.4 **Highland Pit Lake water temperatures, 2004 and 2005.**

The euphotic zone (i.e. lake surface to depth of sunlight penetration) is very limited at the Pit Lake with sunlight penetrating to a maximum of about 6.5 ft (2 m) as measured by Secchi disk visibility (Figure 3.5). Reasons for the turbidity of the lake water are not known at this time but may be related to calcite concentrations in the water.

Saturated oxygen levels in the lake as a function of time and depth ranged from 100% down to about 70% (Figure 3.6). Saturated oxygen levels were highest in the winter months and lowest during the summer months. There was also a consistent decrease in saturated oxygen levels with depth in the lake independent of season. In any case, oxygen levels were sufficiently high to support aquatic life. The pH levels in Pit Lake water (Figure 3.7) were around 8.0 near the lake surface but decreased to as low as 7.65 at depths of 100 feet (30 m) or more.

Water hardness was calculated from the calcium, magnesium, and sulphate levels in Pit Lake water (MFG, 2004). Results show that total hardness as $CaCO_3$ was estimated to be about 200 mg/l.

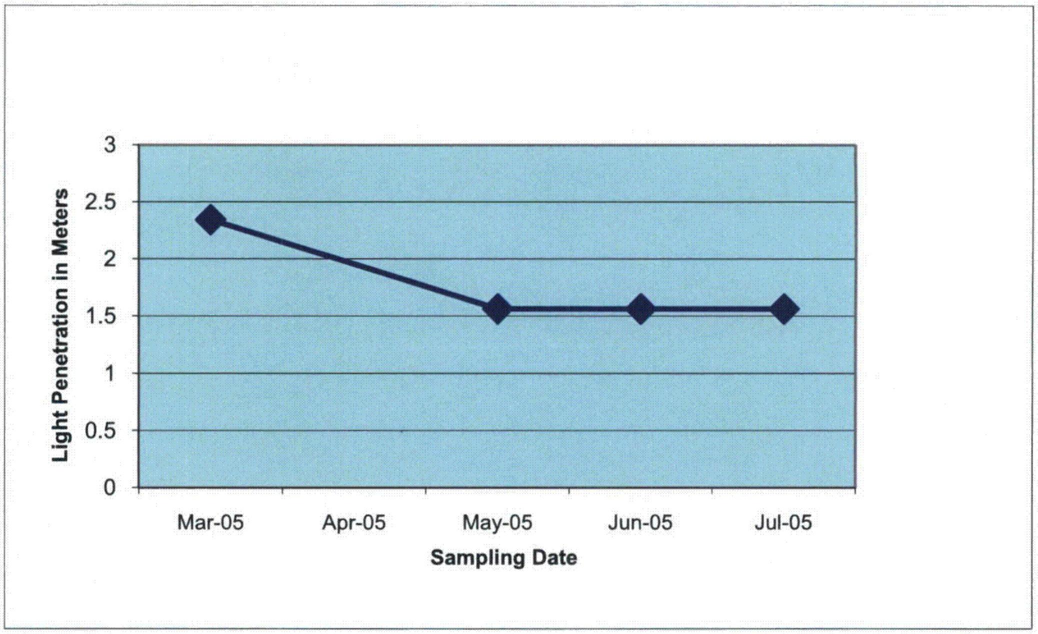

Figure 3.5 Depth of sunlight penetration as measured by Secchi visibility in Highland Pit Lake during 2005.

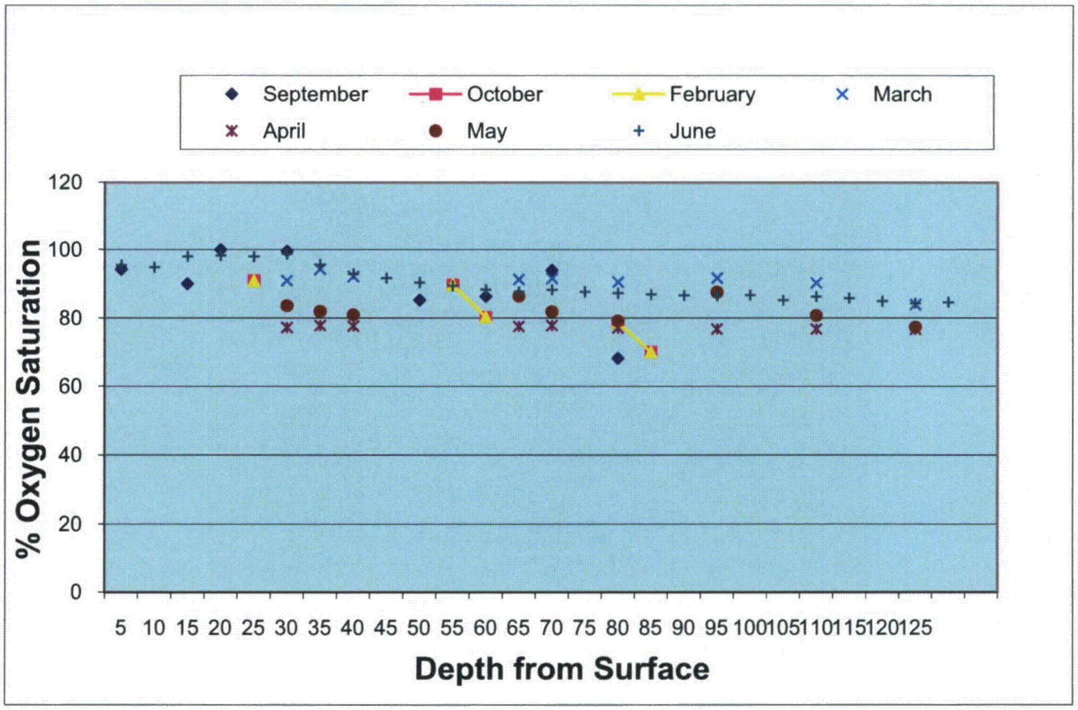

Figure 3.6 Highlands Pit Lake dissolved oxygen levels in 2004 and 2005.

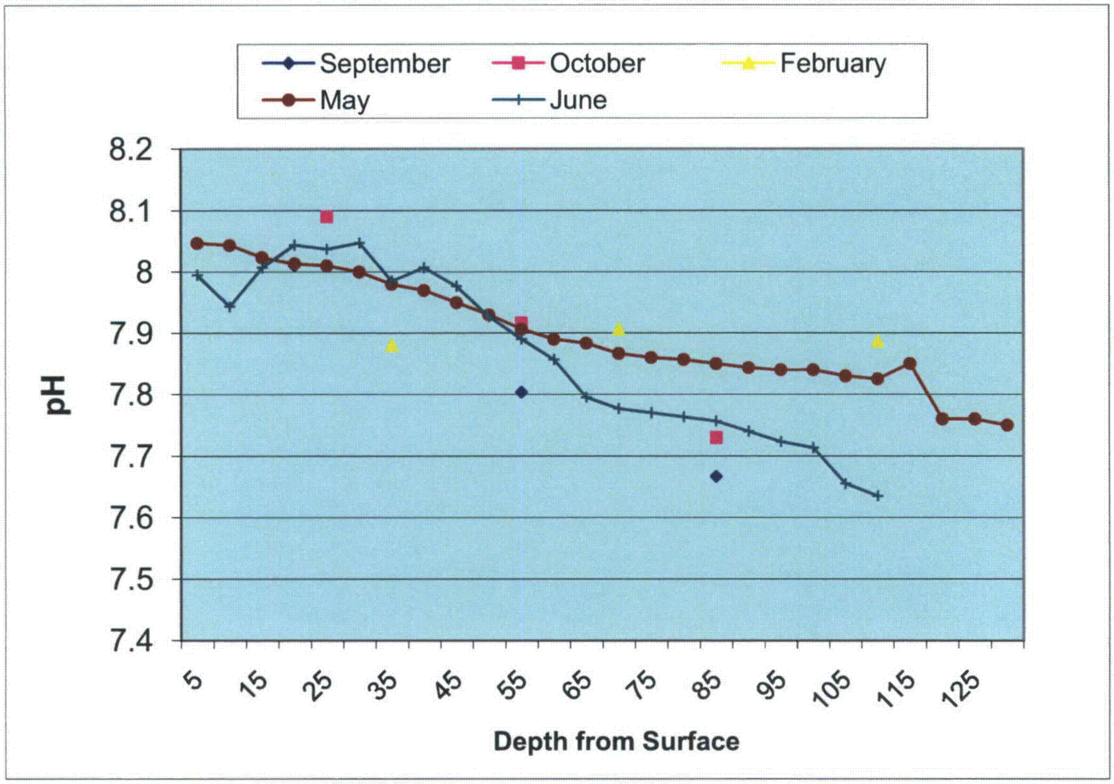

Figure 3.7 **pH in Highland Pit Lake water as a function of depth during 2004 and 2005.**

3.2 Biological Data

The only emergent rooted macrophyte in the Pit Lake (Figures 3.1 and 3.2) was the cattail (*Typha latifolia*). A limited amount of the algae or stonewort, (*Chara* sp.) occurs in the littoral zone and is primarily associated with a narrow band extending from shoreline out to a couple of meters from shore. The 0.9 ha comprising the littoral zone with rooted macrophytes also supports a sparse benthic invertebrate community. In addition to the cattails, the major source of organic in the littoral zone appears to be shoreline grass being inundated by the rising water level of the lake. This narrow band of submerged grass was where most of the benthic invertebrate biomass was concentrated. A copepod of the genus *Cyclops*, is also present in the limnetic zone of the lake. This planktonic species apparently feeds on microscopic plants and animals in the water column although phytoplanktons were never observed in the 150 micron tow net used to collect copepods samples.

Periodic measurements on the biomass of the benthic invertebrate, copepods and rooted macrophyte communities were made throughout the study period using techniques described below. Biomass was obtain on cattails but not algae (*Chara* sp.) as the latter was sparsely distributed in a narrow band close to shore and sampling techniques were inadequate for getting good biomass estimates on this species. In addition, no measurements were made of biomass of terrestrial grass that was covered by the rising water levels.

Copepods (*Cyclops* sp.) were the primary consumers in the limnetic zone. No evidence of phytoplankton was found in net samples taken the water column. While this was not confirmed, it is likely that microscopic organisms such as cyanobacteria, rotifers, and protzoans serve as food sources for the copepods in the Pit Lake. Copepod biomass was estimated using a 150µm haul net retrieved vertically in the water column. Each haul represented a discrete sample. Three locations, distributed across the lake were sampled for copepod biomass on several occasions during the study period. Because the dimensions of the haul net and depth to which it was lowered was known, the mass of copepods in the haul net could be converted to total biomass in the lake by multiplying copepod mass/liter of water sampled by the total liters in the Pit Lake.

Because copepods are phototrophic (shun direct sunlight), they show diurnal patterns in their distribution in the water column. Several samples were taken on separate occasions and light conditions (i.e. cloudy versus direct sunlight) to determine the maximum depth to which copepods are found in the water column. Although several patterns were observed depending on ambient light conditions (Figure 3.8), the conclusion drawn from all of these studies was that copepods were not found below a depth zone of 40-60 ft (12-18 m) and that at 95% of the copepod biomass was confined to the upper 40 ft (12 m) of the lake. Based upon these special studies, the volume of lake water that was used in calculating total copepod mass was that contained in the upper 40 ft (12 m) of the water column. Total copepod biomass was estimated four times during 2005. Summary statistics for copepod biomass estimates by sampling period are shown in Table 3.1.

Mean total copepod biomass for the entire lake varied by about a factor of two from a minimum of about 300 kg to a little over 700 kg. Highest biomass was measure during June as would be expected with the warmer water temperatures. Variation as expressed by the coefficient of variation (i.e. standard deviation/mean) for total copepod biomass on a particular sampling date ranged from about 25% - 50%.

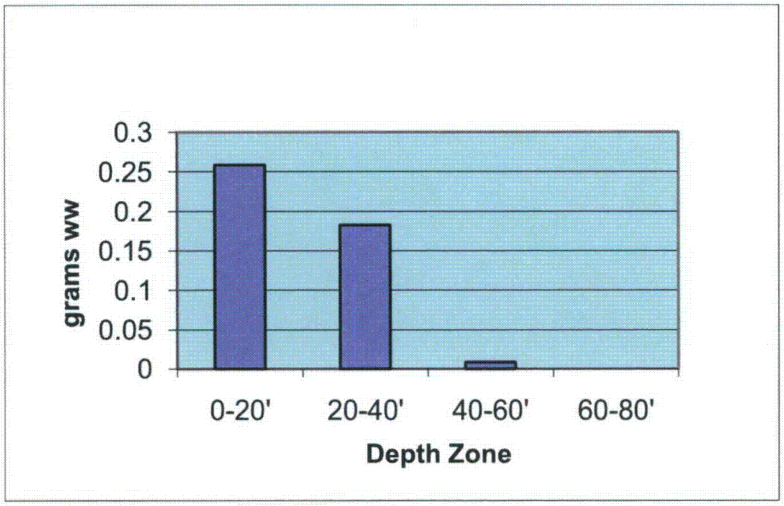

Figure 3.8 Relationship of copepod biomass (g/ 20' depth zone) to sampling depth in Highland Pit Lake

Table 3.1 Summary statistics for total copepod biomass estimates (kg) at Highland Pit Lake

	n	Mean	SD	Mean-95UCL	Mean+95UCL
Feb-05	**6**	298.4	166	**147**	450
Mar-05	**5**	400.0	82	**318**	**482**
Apr-05	**1**	295.0	0	**295**	**295**
Jun-05	**3**	727.7	403	**206**	1249

Benthic invertebrate biomass was obtained using an Ekman Dredge to sample a given area on the sediment surface. The open face of the dredge used in this study had a surface area of 232 cm^2. The dredge was lowered to the sediment surface and the closure jaws activated to collect sediment and any contained benthic organisms. Each sample was transferred to a 60 mesh screen and hand sorted to retrieve benthic invertebrates. Samples were weighed, oven dried and then reweighed. Voucher specimens were also taken to identify the species collected.

Results show that total benthic invertebrate biomass in the 2.2 ac (0.9 ha) of littoral zone containing cattails averaged 25-36 kilograms on 3 different sampling dates and for sample sizes of 14 to 23 depending on sampling date (Table 3.2). Differences in estimates of biomass between sampling dates were not significant ($p \leq 0.05$). The coefficient of variation was about 100% of the mean and the mean plus the 95UCL ranged from 37-59 kg. Samples were taken at many other locations around the lake in the zone from shore to a 5 ft (150 cm) water depth. The only place benthic invertebrates were found was in the small area of littoral zone containing cattails.

Table 3.2 **Summary statistics for benthic invertebrate biomass (kg) estimates in Highland Pit Lake by sampling date.**

	Mean	SD	Mean-95UCL	Mean+95UCL	n
Feb-05	25.0	32.1	13	45	21
Mar-05	20	28	9	37	21
Jun-05	36	36	22	59	23

Cattail biomass was estimated in July 2005 using a 0.5 m^2 quadrat and long handled clippers to provide biomass estimates on a m^2 basis. Plants were clipped at the root crown. The one acre (4100 m^2) of cattail beds in the littoral zone had a total biomass that averaged just over 4000 kg dry weight based on three replicates (Figure 3.9). This value represents total dry weight production of cattails for the entire lake.

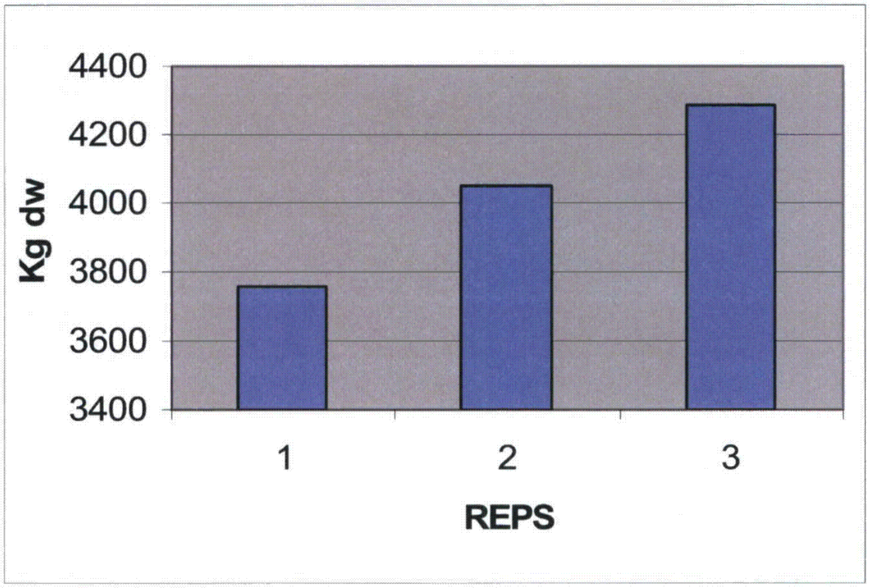

Figure 3.9 **Total estimated cattail biomass in the littoral zone at Highland Pit Lake.**

Biomass estimates for terrestrial vegetation and rodents were not obtained due to the sharp gradient in vegetation biomass with distance away from the shoreline and because of the ever changing conditions of the shoreline due to the rising water level. Ocular estimates of vegetation biomass from locations sampled near shore (i.e. with 10 ft (3 m) of the water) supported from 50-100 g/m^2 of grass (Section 3.1). The abundance of rodents, primarily *Microtus montanus*, was also low as evidenced by a few tunnel systems confined to the narrow band of green shoreline vegetation that had responded to the saturated conditions within 10 ft (3 m) of the shoreline. The changing conditions created by the rising water levels and saturated soil conditions near shore contributed to the low abundance of meadow voles. Trapping over several days caught primarily meadow voles.

3.3 Chemical Data

3.3.1 Surface Water

Concentrations of dissolved selenium and uranium in water samples from the Pit Lake and Box Creek (Table 3.3) were measured in September, 2004 and June, 2005. The means were based on a sample size of six representing 3 locations and 2 depths (1/3 and 2/3 total water column depth). Concentrations of selenium and uranium in Pit Lake water showed very little variation within or between sampling dates suggesting that the lake was well mixed both horizontally and vertically. Mean concentrations of selenium and uranium averaged 0.11 ppm and 3.0 ppm with coefficients of variation (i.e. SD/Mean X 100) was no more than 5% of the mean for both within and between date comparisons. In water samples from Box Creek, concentrations of selenium were non-detectable (<0.0005 ppm) while total uranium averaged about 0.008 ppm (detection limit = 0.0003 mg/l).

Table 3.3 Selenium and uranium concentrations in surface water samples from Highland Pit Lake and Box Creek.

		Selenium (mg/l)						Uranium (mg/l)					
Site	**Date**	**n[2]**	**Min**	**Max**	**Mean**	**SD**	**95UCL**	**n[2]**	**Min**	**Max**	**Mean**	**SD**	**95UCL**
Pit Lake	9/15/04	6 (0)	0.097	0.10	0.11	0.0006	0.10	6(0)	3.0	3.3	3.0	0.11	3.2
Pit Lake	6/22/05	6(0)	0.107	0.11	0.11	0.003	0.11	6(0)	2.9	3.2	3.1	0.13	3.2
Overall Mean		12(0)	0.097	0.11	0.11	0.006	0.11	12 (0)	12	3.3	3.1	0.11	3.1
Box Creek	7/18/05	3(3)	0.00025[1]	0.00025[1]	0.00025[1]	0	0	3 (0)	0.0076	0.008	0.0078	0.00021	0.0076

[1] 0.00025 = ½ the detection limit of 0.0005 mg/l Se

[2] sample size (number of non-detects)

3.3.2 Sediment

Sediment was sampled in the limnetic and littoral zone at the Pit Lake and in Box Creek using an Ekman dredge. Samples were taken at the same 3 general locations as water and copepod biomass samples. Over the course of the study, a total of 16 sediment samples were collected on two different sampling dates in both the limnetic and littoral zones of the lake. The depth to which each sediment sample was taken was variable due to differences in bottom characteristics. In general, sediment depths collected by the Ekman Dredge averaged about 2-3 in (5-7 cm).

Table 3.4 lists the minimum, maximum, mean, standard deviation, total number of samples w/undetects in parenthesis (n), and the 95th UCL for selenium and uranium concentrations in sediment samples. Selenium and uranium in sediments collected from the limnetic and littoral zone were not significantly different ($p<0.05$). Selenium averaged about 21 mg/kg while uranium averaged 145 mg/kg. Selenium concentrations averaged 50-150 times higher and uranium 20-40 times higher in Pit Lake sediments than corresponding samples from Box Creek. Concentrations of selenium and uranium in Pit Lake sediments were moderately variable with coefficients of variation (SD/mean x 100) ranging from about 50-100% of the mean.

Table 3.4 Selenium and uranium concentrations in sediment from Highland Pit Lake and in Box Creek

			Se mg/kg Dry						U mg/kg-Dry					
Site	**Location**	**Sampling Date**	**Min**	**Max**	**Mean**	**SD**	**95 UCL**	**n[1]**	**Min**	**Max**	**Mean**	**SD**	**95 UCL**	**n[1]**
Pit Lake	Limnetic	9/14/04	3.7	59.3	27.1	28.8	64.4	3 (0)	21.3	178.0	94.3	78.9	196.4	3 (0)
		7/8/05	8.4	19.0	12.2	5.9	19.8	3 (0)	28.6	193.0	116.2	82.7	223.3	3 (0)
	Littoral	9/14/04	2.5	32.3	18.4	9.7	26.6	7 (0)	28.7	273.0	210.1	84.8	281.9	7 (0)
		7/8/05	1.7	84.0	30.2	46.6	90.5	3 (0)	17.3	107.0	69.9	46.8	130.5	3 (0)
Grand Mean			1.7	84.0	21.1	22.0	33.4	16 (0)	17.3	273.0	144.5	93.2	196.7	16 (0)
Box Creek		7/18/05	0.1	0.28	0.2	0.076	0.281	4 (0)	2.26	5.34	3.75	1.33	5.19	4 (0)

[1] sample size (number of undetects)

3.3.3 Soil

Soil samples at the Pit Lake were collected on two occasions within 10ft (3 m) of the shoreline adjacent to the littoral zone area supporting cattails (Figure 3.1 and 3.2). Soil samples were restricted to this area as it was the primary area of use by mule deer which periodically use the lake for drinking water and forage. Access to the water by deer was very limited due to the very steep banks around most of the shoreline. Soil samples from Box Creek were also taken around the shore of the pond. Samples at both locations were taken with a step coring tool to a depth of 6in (15 cm).

Summary statistics for selenium and uranium concentrations in soil samples are presented in Table 3.5. Mean concentrations of selenium between Pit Lake and Box Creek samples were within a factor of about 2 and, in the case of Pit Lake soil, were 10-30 times lower than concentrations in Pit Lake sediment. Uranium concentrations in Pit Lake soil averaged about 5-8 times higher than those in soil from Box Creek while Pit Lake soil uranium averaged 10-20 times lower than that in Pit Lake sediments.

Table 3.5 **Concentrations of selenium and uranium in shoreline soil at Highland Pit Lake and the Box Creek.**

Location	Sampling Date	Se (mg/kg-Dry)						U (mg/kg-Dry)					
		Min	Max	Mean	SD	95UCL	n[1]	Min	Max	Mean	SD	95UCL	n[1]
Pit Lake	2/24/05	0.5	1.3	0.82	0.30	1.09	6(0)	2.0	28	6.8	12	19.4	6(0)
	6/22/05	1.3	3.6	2.4	1.2	3.9	3(0)	4.0	21	12	8.6	2.3	3(0)
	Grand Mean	0.5	3.6	1.3	0.97	2.0	9(0)	2.0	28	8.2	9.41	15.2	9(0)
Box Creek	7/18/05	0.18	0.32	0.27	0.07	0.34	4 (0)	1.37	1.42	1.39	0.02	1.41	4 (0)

[1] sample size (number of undetects)

3.3.4 Biota

3.3.4.1 Aquatic and Terrestrial Vegetation

Grab samples of aquatic and shoreline vegetation from the Pit Lake (Figure 3.2) and Box Creek pond were collected by clipping plants at the root crown. As mentioned, biomass sampling of terrestrial vegetation was not done because of the sharp gradient in biomass with distance from the shoreline. However, occular estimates, based on past experience in estimating plant biomass, suggested that 50-100 g/m^2 of vegetation were present in sampled areas.

Grass samples from the Pit Lake consisted of a mixture of the perennial species used to revegetate the reclaimed areas around the lake (Section 3.1) while the aquatic vegetation was primarily cattail (*Typhus* sp.). Some algae or stonewort (*Chara* sp.) was also collected but this species was very sparsely distributed and occurred only in a narrow band with 10ft (3 m) of shore. No estimates of algal biomass were obtained. As mentioned, no trees or shrubs occurred at the Pit Lake or Box Creek.

Pit Lake vegetation samples were taken on three dates in 2004 and 2005. Box Creek samples were taken on one occasion in July 2005. Box Creek aquatic vegetation was more diverse than that in the Pit Lake. Species sampled included cattail (*Typha* sp) and stonewort (*Chara* sp.), which also occur at the Pit Lake, but also bulrush (*Scirpus* sp.), sedge (*Carex* sp.) and pondweed (*Potamageton* sp.). Tables 3.6 presents the minimum, maximum, mean, standard deviation, 95th UCL, and total number of samples (including number of nondetects in parenthesis) for the concentrations of the selenium and uranium in vegetation samples.

Concentrations of selenium and uranium in vegetation were a function of species sampled and sampling location. Highest concentrations in aquatic vegetation were measured in stonewort. This algal species had concentrations of both selenium and uranium that were 2-30 times higher than that measured in cattails. With the exception of *Astragalus*, near-shore terrestrial vegetation had concentrations of selenium and uranium that were in the lower range of the cattail concentration data. The high levels of selenium in *Astragalus* were due to the fact that this species is a known hyperacculmulator of selenium.

Background levels of selenium in vegetation from Box Creek were generally non-detectable. Uranium concentrations in background vegetation averaged at least an order of magnitude lower than that measured in vegetation from the Pit Lake.

Table 3.6 Selenium and uranium concentrations in vegetation from Highlands Pit Lake and the Box Creek

Location	Date	Species	Min	Max	Mean	SD	95UCL	n[2]
Aquatic- Selenium (mg/kg dry weight)								
Pit Lake	Sep-04	Cattail	5.2	16.2	11.2	3.5	14.2	7 (0)
	Oct-04	Cattail	5.4	8.5	6.6	1.3	8.1	4(0)
	Jul-05	Cattail	7.0	20.0	13.3	6.5	21.8	3(0)
	Jul-05	Stonewort	36.0	50.0	40.7	8.1	51.1	3(0)
Box Creek	Jul-05	Cattail	0.05[1]	0.05[1]	0.05[1]	0		4(4)
	Jul-05	Bulrush	0.05[1]	0.05[1]	0.05[1]	0		4(4)
	Jul-05	Sedge	0.05[1]	0.05[1]	0.05[1]	0		4(4)
	Jul-05	Pondweed	0.18	0.52	0.05[1]	0.16	0.49	4(0)
Terrestrial- Selenium (mg/kg dry weight)								
Pit Lake	Jun-05	Milkvetch	1300	4400	2850	2192	6324	2(0)
	Jun-05	Grass	6.80	9.70	9.83	3.10	13.85	3(0)
Box Creek	Jul-05	Grass	0.05[1]	0.13	0.07	0.04	0.12	4(3)
Aquatic- Uranium (mg/kg dry weight)								
Pit Lake	Sep-04	Cattail	15.1	129.0	55.4	40.0	89.3	7(0)
	Oct-04	Cattail	22.4	53.8	35.2	14.9	51.9	4(0)
	Jul-05	Cattail	4.7	10.2	7.3	2.8	10.9	3(0)
	Jul-05	Stonewort	168.0	325.0	221.3	89.8	337.5	3(0)
Box Creek	Jul-05	Cattail	0.03	0.12	0.06	0.04	0.11	4(0)
	Jul-05	Bullrush	0.21	1.10	0.58	0.43	0.73	4(0)
	Jul-05	Bulrush	0.04	0.71	0.32	0.32	0.68	4(0)
	Jul-05	Pondweed	1.4	1.8	1.6	0.25	1.9	4(0)
Terrestrial- Uranium (mg/kg dry weight)								
Pit Lake	Jun-05	Milkvetch	3.3	6.1	4.7	1.9	7.8	2(0)
	Jun-05	Grass	1.9	18.5	7.5	9.5	19.8	3(0)
Box Creek	Jul-05	Grass	0.06	0.08	0.07	0.0082	0.0792	4(0)

[1] 0.05 = ½ the detection limit of 0.1 mg/kg Se

[2] sample size (number of non-detects)

3.3.4.2 Aquatic Biota

Aquatic macroinvertebrates inhabiting the littoral zone in the Pit Lake were sampled on several occasions during the study using an Ekman dredge in the littoral zone area containing cattails (Figure 3.2). Because the dredge sampled a defined area on the sediment surface, it provided biomass estimates for organisms contained in the sediment samples. Individual samples were hand sorted to remove individual species for selenium and uranium analysis.

Taxonomic groups collected were primarily comprised of Notonectids and Hemiptera with minor contributions from species (<10%) such as Ephemeroptera, Tricoptera, Odonata, Amphipoda, Coleoptera, and Diptera (Table 3.7). Most of the benthic invertebrate species sampled at Box Creek were also occurred at the Pit Lake. As mentioned previously, the aquatic plants and invertebrates occurring in the littoral zone (Figure 3.2) represent recently introduced species groups because 6-8 years ago, the current littoral zone, as defined by shoreline out to a 5 ft (150 cm) water depth, was dry land.

Table 3.7 Benthic invertebrate taxa present in Highland Pit Lake and the Box Creek.

Location	Order	Family	Genus	Species	Common name	Life stage
Pit Lake	Coleoptera	Dystiscidae	*Dytiscus*	sp	Predaceous diving beetle	Adult
Pit Lake	Hemiptera	Notonectidae	*Notonecta*	*undulata*	Groused backswimmer	Adult
Pit Lake	Hemiptera	Corixidae	*Sigara*	*alternata*	Water boatman	Adult
Pit Lake	Diptera	Stratiomydae	*Stratiomys*	sp	Aquatic soldier fly	Larva
Pit Lake	Trichoptera	Rhyacophilidae	*Rhycophila*	sp	Free living caddisfly	Larva
Pit Lake	Diptera	Syrphidae	*Eristalis*	sp	Rattailed maggot	Larva
Pit Lake	Ephemeroptera	Heptaganiidae	*Stenacron*	*interpunctatum*	Flat-headed mayfly	Larva
Pit Lake	Odonata	Libellulidae	*Libellula*	sp	Common skimmer	Larva
Box Creek	Odonata	Gomphidae	*Gomphus*	*vastus*	Desolate clubtail	Adult
Box Creek	Coleoptera	Dytiscidae	*Coptotomus*	*interrogatus*	Predaceous diving beetle	Adult
Box Creek	Hemiptera	Corixidae	*Sigara*	*alternata*	Water boatman	Adult
Box Creek	Hemiptera	Notonectidae	*Notonecta*	*undulata*	Groused backswimmer	Adult
Box Creek	Ephemeroptera	Heptaganiidae	*Stenacron*	*interpunctatum*	Flat-headed mayfly	Larva
Box Creek	Araneae	Tetragnathidae	*Tetragnatha*	sp	Long jawed spider	Adult
Box Creek	Orthoptera	Acrididae	*Melanoplus*	sp	Grasshopper	Adult

Concentration data for benthics in the Pit Lake are shown in Figure 3-10 and Table 3.8 to illustrate the relationship of selenium and uranium concentrations between species. There were no non-detects of either selenium or uranium in Pit Lake or Box Creek samples. Pit Lake concentrations were at least a factor of 50 higher than corresponding data from Box Creek. Highest mean concentrations of selenium were measured in predators including leopard frogs, dragon/damsel fly larvae, and terrestrial spiders. Highest mean concentrations of uranium were measured in copepods, snails, caddis fly larvae, and algae. Pit Lake samples containing Summary statistics for individual species of aquatic organisms are presented in Appendix A.

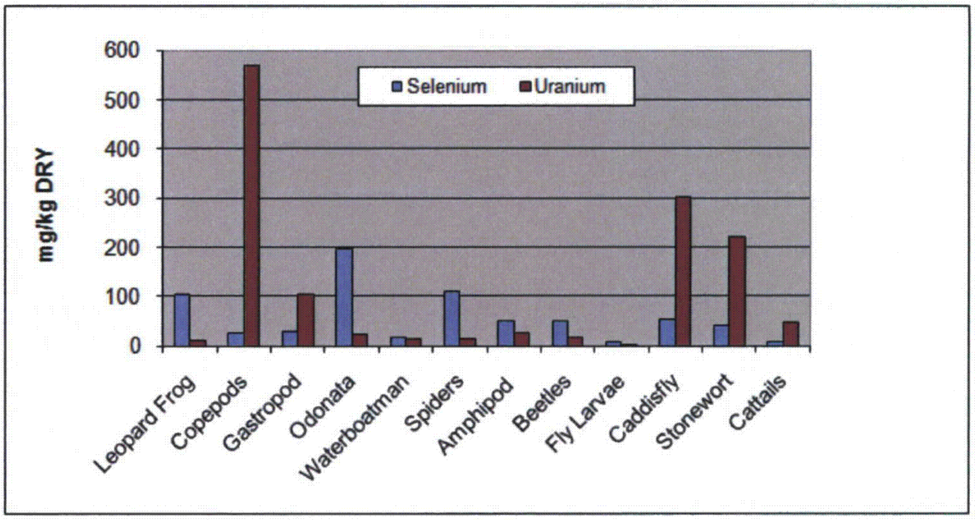

Figure 3.10 **Relationship of selenium and uranium in biota from Highland Pit Lake.**

Table 3.8 **Summary statistics for selenium and uranium concentrations (mg/kg dry weight) in aquatic biota at Highland Pit Lake and Box Creek.**

Benthic Inverts	Min	Max	Mean	SD	95UCL	n[1]
Pit Lake Se	6	287	53	70	78	40(0)
Box Creek Se	0.45	1.5	0.93	0.37	1.31	5(0)
Pit Lake U	1	1170	170	286	271	40(0)
Box Creek U	0.14	1.04	0.41	0.36	0.77	5(0)
Leopard Frog						
Pit Lake Se	20	136	105	35	118	5(0)
Box Creek Se	0.3	3.7	1.9	1.57	3.7	4(0)
Pit Lake U	3	15	12	3	14	5(0)
Box Creek U	0.08	0.32	0.21	0.12	0.34	4(0)

[1] sample size (number of non-detects)

3.3.4.3 Rodents

Meadow voles (*Microtus montanus*) were collected on two occasions in 2005 in the same area where soil and vegetation were collected (Figure 3.2). Meadow voles are primarily herbivores that consume herbaceous vegetation, seeds, plant roots. A few deer mice (*Peromyscus* sp.) were caught but the very small sample size precluded their use in this assessment.

The entire meadow vole carcass was analyzed for selenium and uranium. Results (Table 3.9) show that selenium levels in rodents were in the range of those measured in terrestrial vegetation (Table 3.6). In contrast uranium levels in rodents were about 10-15% of those measured in terrestrial vegetation.

Table 3.9 Selenium and uranium concentrations (mg/kg dry weight) in meadow voles from Highland Pit Lake Shoreline

Selenium							Uranium					
Date	**Min**	**Max**	**Mean**	**SD**	**95UCL**	**n[1]**	**Min**	**Max**	**Mean**	**SD**	**95UCL**	**n[1]**
Feb-05	5.8	36.0	16.4	9.7	23.6	9 (0)	0.26	4.34	1.06	1.26	2.00	9 (0)
Jun-05	13.0	48.0	25.5	15.4	37.0	4 (0)	0.09	1.58	0.77	0.71	1.29	4(0)
Grand Sum	5.8	48	19.2	11.9	26.6	13(0)	0.09	4.3	0.97	1.1	1.65	13(0)

[1] sample size (number of non-detects)

3.4 Wildlife Surveys

Bird surveys were conducted at the Pit Lake from September 18, 2004 to August 26, 2005 on 25 different occasions (Table 3.10). A total of 1054 individual birds of 26 different species were observed over the 10 month period in the Pit Lake environs. Of that total, 393, or 37% were waterfowl species of 7 different species. Of the 544 birds that were not raptors or waterfowl, 55% were cliff swallows. The total number of bird species observed during each visit ranged from 1 to 14. As would be expected, most birds were present in the lake environs only during the summer months although some species were observed year round in the lake environs, especially Canada geese, owls, and golden eagles.

Waterfowl reproduction at the lake was also noted during the field surveys (results shown in Appendix F). Only four bird species were observed to nest at the Pit Lake during this study and they were a pair of Canada geese, one of blue winged teal, one of red-winged blackbirds, and numerous cliff swallows. The goose and red-winged blackbird nests were destroyed by predators before egg hatching and the nests were not re-established. Both of these nests were exposed due to a lack of good nesting cover. The blue winged teal nest produced two young that were alive two weeks after hatching. It is believed that the teal nest was in a small wetland located in an upland area several hundred yards (250-350 m) above and to the west of the Pit Lake as numerous intensive bird surveys failed to find the teal nest around the lake shore. Upon hatching, the teal likely brought her young from the small wetland to the Pit Lake for protection against mammalian predators. The cliff swallow nests were constructed on the vertical walls above the south end of the lake and were not accessible, so records were not maintained on this species. With the exception of the cliff swallows, a total of three birds were observed to nest in the Pit Lake area during the 2005 season and only one was successful in producing young. Predation was responsible for the loss of the other two nests based on direct evidence.

Detailed field notes from each individual survey recorded not only the presence of birds but also all other wildlife that were seen during visits to the study site (Appendix F). The dominant large mammalian species observed during the study was the Rocky Mountain mule deer (*Odocoileus hemionus*) (204 observed) along with a limited number of pronghorn (*Antiolcapra americana*) (7 observed) in the Pit Lake environs.

Table 3.10 Catalog of avian species observed at Highland Pit Lake over a 10 month period in 2004 and 2005

	2004						2005																		
Species	**9/13**	**9/14**	**9/15**	**10/25**	**10/26**	**10/27**	**2/21**	**2/22**	**2/23**	**2/24**	**3/23**	**3/24**	**4/6**	**4/11**	**4/12**	**4/29**	**5/24**	**6/2**	**6/9**	**6/17**	**6/22**	**7/1**	**7/7**	**7/14**	**8/26**
Blue-winged teal		X	X	X	X	X											X		X		X				
Canada geese	X						X	X		X	X	X	X	X	X	X									
Cliff swallow																	X	X	X	X	X	X	X	X	X
Falcon			X																						
Franklin's gull		X	X		X																				
Golden eagle		X	X	X	X				X		X														
Great-horned owl											X		X		X		X	X	X						
Herring gull						X																			
Eared grebe	X	X	X		X	X																			X
Horned lark	X	X	X	X	X	X							X				X	X	X	X	X	X	X	X	
American destrel													X												
Killdeer															X		X		X	X	X				
Lesser scaup														X			X								
Mallard					X						X		X	X			X		X						
Marshhawk	X	X	X	X	X	X					X		X				X	X	X	X	X	X	X	X	
Pintail							X				X				X			X							
Prairie falcon																									
Red-tailed hawk													X				X	X	X	X	X	X	X		
Red-winged blackbird																	X	X	X	X	X	X	X	X	
Rough-legged hawk													X		X										
Scaup											X														
Short-eared owl											X	X	X		X		X		X		X				
Northern shoveler			X																						
Spotted sandpiper																	X								
Vesper sparrow																	X		X	X					
Western meadowlark													X				X	X	X	X	X			X	
Yellow-headed blackbird	X	X																							
Total Observed	**16**	**16**	**46**	**55**	**97**	**105**	**1**	**45**	**1**	**18**	**30**	**6**	**29**	**9**	**24**	**1**	**109**	**52**	**45**	**63**	**118**	**84**	**61**	**31**	**5**

4.0 RISK ANALYSIS

4.1 Roadmap for Risk Analysis

Comparison of measured concentrations of selenium and uranium in Pit Lake and Box Creek samples in Section 3.0 showed that levels of these two chemicals in aquatic plants and animals in Pit Lake samples were generally at least an order of magnitude higher than those from Box Creek. In addition, concentrations of selenium and uranium in soils and biota from the Pit Lake exceeded by at least a factor of 10 those measured in Box Creek samples. While Box Creek samples do not represent a true background site for the Pit Lake, they do represent regional concentrations in aquatic and terrestrial samples from an area unaffected by the Pit Lake and associated mill. Thus, the Box Creek data are useful for scaling Pit Lake data against concentrations representative of background.

Given that Pit Lake samples exhibited elevated concentrations of selenium and uranium relative to those in samples from a distant area not influenced by the mine and mill site, a risk analysis was done to compare measured selenium and uranium concentrations with toxicity reference values (TRVs), developed from dose-response studies, that were considered to be safe exposures for aquatic and terrestrial biota. The risk analysis was conducted in a phased approach beginning with a very conservative analysis, designated as a screening level assessment, and ending with a less conservative analysis, designated as a baseline assessment. In both cases, the underlying criteria for judging whether risks to biota were acceptable were the choice of TRVs used in the assessments.

Consequently the first step in the risk analysis was to review published TRVs which represent known levels of toxicity (or non-toxicity). For this assessment, these values were compiled from State of Wyoming Department of Environmental Quality regulations as well as the scientific literature and other sources of toxicological data, such as governmental and NGO documents and databases. In cases where relevant TRVs could not be found, they were calculated using Pit Lake specific bioconcentration factors (BCFs) as described later in this document.

TRVs for a particular source and receptor combination usually span a range of values, all of which are protective of either the individual receptor or the receptor population. Most State and Federal regulations use TRVs at the low end of the range of concentrations considered safe for a particular exposure pathway in order to provide protection to the most sensitive species. These low TRV standards are often used generically across a wide range of site and source conditions. As such, they are highly protective but do not take into account local conditions and species that may be much less sensitive to the receptors under study. Therefore, in developing TRVs for the Highlands risk assessment, we used TRVs representative of two levels of conservatism. The first level, and most conservative approach, used TRVs for selenium and uranium that were recommended by the State of Wyoming and other regulatory agencies. In the risk analysis tables which follow, we have designated these TRVs as conservative TRVs (CTRVs).

The second level of TRVs used in the risk assessment were less conservative and were based on a review of published toxicity studies establishing a range of safe levels of selenium and uranium for various source-receptor combinations. These less conservative TRVs were designated as baseline TRVs (BTRVs) in the baseline risk assessment. As mentioned above and described in detail below, where relevant TRVs could not be found, they were calculated using Pit Lake specific BCFs.

For screening level assessment, a highly-conservative approach was used including the use of the *maximum* detected concentrations as exposure point concentrations and the most conservative (i.e. lowest reported effect) TRV value. If this comparison indicated low potential for adverse effect, the selenium and/or uranium was not considered further. If this was not the case, a more realistic evaluation of exposure and effects were conducted using 95th percentile upper confidence limits (95thUCL) as the exposure point concentration and the less conservative BTRV that is still protective of individual receptors or , in all cases, receptor populations.

While a risk analysis may indicate a potential for adverse effects, based on numerical comparisons, it is important to interpret the significance of the risk analysis within the context of the physical and biological characteristics of the Pit Lake. This final step in the assessment evaluates the significance of selenium and uranium concentrations in biota with respect to the type and amounts of habitat, biological productivity, and recorded use of the Pit Lake by wildlife. These physical and biological attributes of the Pit Lake determine the potential magnitude and significance of food chain transport of selenium and uranium to aquatic and terrestrial consumers.

Assessment endpoints for this risk analysis all derived from a comparison of measured selenium and uranium concentrations with TRVs specific to a particular exposure pathway. Exposure pathways included water, soil, and diet as exposure media and direct comparison of measured tissue concentrations with those based on TRVs. Exposure pathways included major trophic levels including plants, herbivores, omnivores, and carnivores. The specific endpoints for these comparisons were that measured levels of selenium and uranium in Pit Lake samples were protective of individual organisms or populations of organisms. In the absence of T&E species, the primary endpoint goal was to ensure protection of exposed populations rather than individuals.

4.2 Components of the Risk Analysis

4.2.1 Evaluation Method

The sequence of comparisons that were made using TRVs and measured concentration data are described in Section 4.1, Roadmap to Risk Analysis. A two step approach was used, with an initial screening level analysis using very conservative assumptions of exposure and effects. The CTRVs included the WDEQ water quality and tissue standards for selenium and uranium (Table 2.1). The screening level assessment also used the maximum concentrations of selenium and uranium in the various sample types as the estimated concentrations to which biota were exposed. Overall, this greatly overestimates exposure since the maximum concentration is only representative of a single location, rather than the average conditions of exposure. The maximum concentrations in samples were then compared to the lowest CTRV for the particular sample media. The follow-on baseline risk assessment used the 95UCL as the exposure point concentration and less conservative TRV's (BTRV) that were still protective of individuals or biological populations. CTRVs as used in this assessment are equivalent to no-observed-adverse-effects levels (NOAELs) and BTRVs include some NOAELS and low-observed-adverse-effects-level (LOAEL) TRVs.

Estimating effects based on exposure involves comparing measured selenium and uranium concentrations with the media specific TRVs. Results are expressed as a Hazard Quotient (HQ) (USEPA, 1997) where:

$$\text{Hazard Quotient (HQ)} = \text{Exposure Point Concentration (EPC)} \div \text{TRV}$$

If the HQ is less than 1.0 (indicating the exposure concentration or dose is less than the TRV), the occurrence of adverse effects is very unlikely. If the HQ is equal to or greater than 1.0 (indicating the exposure is equal to or greater than the TRV), there is some potential for adverse effects to occur (USEPA, 1997). However, there is no clear consensus from either USEPA guidance or the scientific literature concerning the significance of the level of departure from 1.0. The Tri-Services Procedural Guideline for conducting ecological risks assessment (Wentsel et al., 1996) cites Menzie et al.'s (1992) HQ interpretation:

- $HQ < 1$: No Significant Risk
- $1<HQ<10$: Small Potential for Adverse Effects
- $10<HQ<100$: Significant Potential for Adverse Effects
- >100: Expected Adverse Effects

While Wentsel et al. (1996) points out that no statistical analysis supports this interpretation; this convention is widely used and accepted based on best professional judgment. One further complicating issue is that an HQ greater than one by itself does not indicate the magnitude of effect nor does it provide a measure of potential population-level effects (Menzie et al., 1992). For instance, a high sediment HQ for a chemical may be the result of a small, isolated area of high concentration rather than widespread contamination. Therefore, a high HQ may not indicate potential population/community-level effects because, no matter how high the HQ is above 1.0, the risk is limited to receptors in the vicinity of the high-concentration area. For this reason, the concentrations of selenium and uranium at levels above TRVs were interpreted with respect to the type and amount of habitat and biological productivity to provide information about the potential spatial extent of adverse effects.

4.2.2 Development of Toxicity Reference Values

Toxicological reference values for ecological components are concentrations of chemicals that are reasonably considered to be the highest acceptable concentration at or below which there are adverse effects on individual species (CTRVs) or populations of species (BTRVs). The assumptions inherent in TRVs are that exposures to target organisms are continuous (i.e. chronic), that bioavailability of the chemicals of interest is 100%, and that they represent concentration limits that are protective of an individual organism or a population of that organism under chronic exposure.

Sources of published TRVs include WDEQ standards for water quality (WDEQ, 2005), databases such as that available from Oak Ridge National Laboratories, Cal Ecotox, USEPA (draft) Ecological Soil Screening Level (EcoSSL) document (USEPA, 2000) and Risk Assessment Information Services. As a point of reference, applicable Wyoming Department of Environmental Quality (Wyoming DEQ) TRVs for selenium and uranium concentrations in surface water that are protective of aquatic biota and livestock are presented in Table 2.1. Current standards for selenium and uranium in surface water that are protective of aquatic life are 0.005 mg/l and <1.4 mg/l, respectively while the selenium concentration protective of livestock is 0.05 mg/l (Table 4.2).

A thorough review of published toxicological data for selenium and uranium also appears in MFG (2004). The literature review on selenium and uranium toxicology and accompanying summary tables of TRVs are presented in Appendices B-E. Computer databases and literature reviews also present comprehensive summaries of toxicology and risk information for a wide range of chemicals and exposure pathways. TRVs for surface water, soil, and to a lesser degree, sediment are well established since these media are most often used as the source media in toxicity studies with biota. Less information is available on tissue concentration TRVs for biota, particularly when the exposure pathway involves movement of chemicals from one biological component to another.

For cases where published TRV data were not available, TRVs were estimated using site specific concentration data to calculate Pit Lake-specific bioconcentration factors (BCFs). BCFs relate concentrations in a receptor to that in a source compartment (i.e. concentration in benthic invertebrates to that in surface water). Site specific TRVs , based on BCFs, are considered to be the best source of TRVs for biota at the Pit Lake in that they use well researched, published data on TRVs for water, sediment, or soil, and site specific selenium and uranium BCFs. As mentioned, BCFs integrate all Pit Lake specific physical, biological, and chemical conditions that could affect selenium and uranium behavior in the Pit Lake ecosystem. Although it is accepted practice, the use of published TRVs has the distinct disadvantage of not necessarily representing site specific conditions, including site specific physical, biological and chemical characteristics of the site, while site specific BCFs exactly represent those site conditions.

The procedure for calculating BCFs from the Pit Lake chemical data is as follows:

$$\text{BCF} = \frac{\text{Se or U in biological component in mg/kg dry weight}}{\text{Se or U in water (mg/l for aquatic biota) or soil (mg/kg dry for terrestrial biota).}}$$

Mean calculated BCFs for Highland Pit Lake biota are presented in Table 4.2

Table 4.1 **Mean bioconcentration factors for various aquatic and terrestrial biota at Highland Pit Lake**

Organism	BCFSe[1] (dw)	BCFU[1] (dw)
Benthic Invertebrates	482	53
Leopard Frog	954	4
Copepods	235	178
Algae	370	69
Cattail	90	14
Rodents	15	0.12
Grass	7.5	0.92
Milkvetch	2166	0.58

[1] BCF = concentration of chemical in biota/ concentration of chemical in water (for aquatic species) or soil (for terrestrial species), BCFs in dry weight units.

4.2.2.1 Surface Water TRVs

Table 4.2 presents various surface water TRVs, including Wyoming Department of Environmental Quality standards, as well as literature values that were used in this assessment. The TRVs in Table 4.2 are considered safe to individuals and/or populations of various Pit Lake biota as per the cited references.

Table 4.2 Chronic Surface Water TRVs Protective of Various Biota

Parameter	Pathway	Chronic TRVs (mg/L)	Reference
Selenium, dissolved	Aquatic Life	0.005 (NOAEL)	WDEQ, 2005, USEPA (2004)
	Daphnia magna	0.15 (NOAEL)	Dunbar et al. 1983
	Aquatic Invertebrates	0.15(NOAEL)	Foe and Knight (1986)
	Hamsters	3 (NOAEL) 9 (LOAEL)	Hadjimarkos 1970 Beath, 1962
	Humans	0.05 (NOAEL)	Safe drinking water USEPA (2000) MCL
	Bird and Mammals	0.5 (NOAEL)	Llobet et al. (1991)
	Livestock Use	0.05 (NOAEL)	WDEQ, 2005
	Aquatic Plants	0.01 (NOAEL)	Bowen (1979)
	Aquatic Plants	0.05 (NOAEL)	Foe and Knight (1986)
	Deer Deer	0.86 (NOAEL) 1.4 (LOAEL)	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
Uranium	Aquatic Life	3.22 (NOAEL)	@ 200 mg/l hardness[1]
	Aquatic Life	<1.4 (NOAEL)	WDEQ, 2005
	Daphnia	0.01 (NOAEL)	Hyne et al. 1993
	Mammals and Birds	13 (NOAEL)	Llobet et al. (1991)
	Humans	0.03 (NOAEL)	Safe drinking water USEPA (2000) MCL
	Cladoceran	0.01(NOAEL)	Hyne et al. 1993
	Pond Lily	0.08-0.7(NOAEL)	Mahon and Mathewes (1983)

[1] Estimated hardness of surface at Highlands Pit Lake is 200 mg/l

4.2.2.2 Sediment TRVs

The propensity of selenium to cycle through the food web, and its ability to cause reproductive impairment in fish and wildlife has long been considered its primary environmental risk (Van Derveer and Canton, 1997). As a result, no threshold effects values based on sediment exposure effects to benthic invertebrates are available. Van Derveer and Canton (1997) developed sediment toxicity thresholds, based on bird and fish tissue and egg residue values and direct observations of deformities, using the ERL and ERM approach of Long and Morgan (1991). A value of 2.5 mg/Kg was derived based on the 10th percentile of predicted effects data, and a value of 4 mg/Kg was derived based on the 10th percentile of observed effects data. This suggests that there is little if any potential for adverse effects on fish or birds at sediment selenium concentration below 4 mg/Kg. The uranium benchmarks values are derived from the Priority Substances List Assessment Report on Releases of Radionuclides from Nuclear Facilities≅ (Environment Canada, 2000).

Table 4.3 lists two levels of sediment quality guidelines for selenium and uranium defined as CTRV (NOAEL) and BTRV (NOAEL and LOAEL). The BTRVs often range from metal concentrations in the sediment above which adverse effects on sensitive species or life stages are expected to occur to metal concentrations above which effects can be expected to occur frequently. The CTRV level represents either the background level that is not expected to cause an adverse effect or a concentration above which effects are expected to rarely occur.

Specific TRVs for U were developed in northern Saskatchewan in the location of Canada's operating uranium mines (Environment Canada, 2000). Environmental monitoring data for sediment contaminant concentrations and co-occurring benthic invertebrate monitoring data in northern Saskatchewan lakes near operational and pre-operational uranium mines were used to calculate no effect level (CTRV) and the low effect level (BTRV).

Table 4.3 **Sediment TRVs protective of individual species or populations of species.**

Metal	Pathway	CTRV mg/kg dw (NOAEL)	BTRV mg/kg dw (NOAEL & LOAEL)	Reference
Selenium	Fish and Birds	2.5 (NOAEL)	4 (NOAEL)	Van Derveer & Canton (1997)
Uranium	Benthic Invertebrates	17 (NOAEL)	29.5 (LOAEL)	Environment Canada (2000)
	Aquatic Plants	15 (NOAEL)		Mahon and Mathewes (1983)

4.2.2.3 Soil TRVs

The TRVs for soil were derived from the literature as shown in Table 4.4. All of the values presented represent NOAEL concentrations and represent soil to invertebrate or to plant exposure pathways.

Table 4.4 Soil TRVs protective of individual species or populations of species

Pathway	Selenium (mg/kg dw)		
Soil-Earthworm	70	NOAEL	RAIS
Soil-Plants	1	NOAEL	RAIS
Soil-Invertebrates	70	NOAEL	RAIS
	Uranium(mg/kg dw)		
Soil-Plants	2-176	NOAEL	Dreesen and Marple (1979)
Soil-Plants	50-5000	NOAEL	Meyer and McLendon (1997)
Soil-Plants	5	NOAEL	RAIS

4.2.2.4 Biota TRVs

TRV's for biota for a variety of exposure scenarios and tissue concentrations, including sources of the data, are presented in Table 4.5 for selenium and Table 4.6 for uranium. Reported toxic dietary Se levels were fairly uniform across species. Literature toxic values were 4 ppm for cattle (Underwood, 1977), 5 ppm for dogs (Munsell et al., 1936), rats (NAS, 1976) and swine (Moxon and Mahan, 1981), and 8 ppm for sheep (Pierce and Jones, 1968). Pronghorn antelope, however, are reported to have a NOAEL level of 15 ppm (Raisbeck et al. 1996). Hapke (1991) reported a general safe level of 2 ppm, while Davis et al. (1978) listed an upper critical level of 5 ppm. Toxic levels in birds are similar to mammals, with a reported 2 ppm NOAEL level for chickens (Arnold et al. 1973) and a 10 ppm NOAEL level for mallards. To be conservative, a safe dietary level of 2 ppm was set for all birds and mammals.

No toxic tissue-Se levels in grasses were available in the literature. The safe level of 30 ppm is equal to the upper critical concentration for barley (Davis et al. 1978). Toxic levels reported for forbs were between 5-18 ppm (Fergusson, 1980; Kloke et al., 1984; Kabata-Pendias and Pendias, 1992). Tolerant species were not affected by levels of 4000-14920 ppm Se (Knott and McCay, 1959). The 2 ppm NOAEL (Fergusson, 1990) value for general plant tissue was used as the safe level for forbs, shrubs, trees and aquatic plants. The safe water level of 0.05 ppm for aquatic plants equals the general algae NOAEL level (Foe and Knight, 1986).

The safe dietary level of uranium of 478 ppm for rodents is equal to the rat NOAEL value (NAS, 1980). Growth depression in rats is reported at >500 ppm (Venugopal and Luckey, 1975; NAS, 1980). The hare safe level of 28 ppm is 50% of the LOAEL (renal damage) value for rabbits (IRIS, 1999; Maynard and Hodge, 1949). The reported safe level for ruminants of 0.4 ppm was used for cattle, elk, and deer (Dreesen and Marple, 1979). The average of the rodent, rabbit, and ruminant levels (167 ppm) was used for all other mammals. The dietary safe level for birds of 1600 ppm equals the NOAEL level in American black ducks (Haseltine and Sileo, 1983). No dietary U levels toxic to birds are reported. Both aquatic and terrestrial insects were assigned a safe dietary level of 100 ppm U based on the NOAEL concentration for earthworms (Sheppard and Evenden, 1992). Reported safe tissue levels in terrestrial insects range from 2.85-22 ppm (Swanson, 1985).

The safe tissue levels of 36 ppm in grass and 12 ppm for forbs are NOAEL levels reported by Dreesen et al. (1982). The 3 ppm level for shrubs and trees is the NOAEL level for the shrub- *Atriplex canescens* (Dreesen and Marple, 1979). The safe soil-U concentration for grasses of 5000 ppm is from Meyer and McLendon (1997). While Stoklasa and Penkava (1928) reported twisted leaves and thin roots in forbs at soil-U concentrations of 476 ppm, NOAEL levels of 300 ppm in *Brassica rapa,* and 500 ppm for *Geranium* spp. are also reported (Sheppard and Evenden, 1992; Free, 1917). A safe soil level of 300 ppm U was chosen to be protective of forbs. The safe soil level of 176 ppm for shrubs and trees is the highest reported NOAEL level for *Atriplex canescens* (Dreesen and Marple, 1979). Mahon and Mathewes (1983) reported NOAEL levels for the aquatic plant-*Nuphar lutea* of 0.7 ppm in tissue, 15 ppm in sediment, and 0.34 ppm in water; no toxic levels were given.

As mention previously, when literature estimates of TRVs were not available, they were estimated using bioconcentration factors (BCF) derived from the Pit Lake data (Table 4.2). The calculation procedure was to take the mean measured concentrations of selenium or uranium in biota and divide it by either mean Pit Lake surface water concentrations (in the case of aquatic biota) or by mean terrestrial soil concentrations in the case of terrestrial biota. The BCF based TRVs were calculated by multiplying the TRV for either surface water or soil by the appropriate BFC. For example, the TRV for selenium in benthic invertebrate tissue was estimated by taking the TRV for water of 0.005 mg/l (this is the Wyoming DEQ standard for surface water protective of all aquatic life) and multiplying by the benthic invertebrate BCF of 482, the BCF derived from water and benthic invertebrate selenium concentrations data for the Pit Lake. The results of the calculation (Table 4.7) yielded an estimate of TRV for selenium concentration in benthic invertebrates of 2.5 mg/kg dw. Because the TRV for water of 0.005 mg/l is protective of all aquatic life, the calculated TRV for benthic invertebrates must by definition be protective of all benthic invertebrates.

Table 4.5 **Selenium TRVs for a variety of biota under different exposure scenarios derived from the literature.**

Species	Se (ppm)	Effect	Reference
Mammals-dietary			
General	0.1	Safe limit	Kabata-Pendias and Pendias (1992)
Swine	0.13	NOAEL	Lindberg (1968)
General	2	Safe limit	Hapke (1991)
Swine	2.5	NOAEL	Moxon and Mahan (1981)
Rat	3.75	Increased reproduction	Halverson (1966)- DW=WW/0.2
General	4.5	Critical conc.	NAS (1980a), Underwood (1977)
General	5	Upper critical conc.	Davis et al. (1978)
General	5	Safe limit	NAS (1980)
Pronghorn antelope	15	NOAEL	Raisbeck et al. (1996)
Mammals-dietary water			
Human	0.05	Safe drinking water	USEPA MCL
Hamster	3	NOAEL	Hadjimarkos (1970)
Hamster	9	LOAEL	Beath (1962)
Avifuana-dietary			
Chicken- juvenile	2	NOAEL	Arnold et al. (1973)
Mallard- juvenile	10	NOAEL	O'Toole and Raisbeck (1997)
Chicken- juvenile	3	Min. toxic level	Munsell et al. (1936)
Invertebrates dietary aquatic			
Daphnia magna	295	NOAEL	Foe and Knight (1986)
Invertebrates-water aquatic			
Daphnia magna	0.15	NOAEL	Foe and Knight (1986)
Plants / Grass-tissue			
General	0.032	NOAEL	Fergusson (1990)
General	0.033	NOAEL	Kabata-Pendias and Pendias(1992)
Wheat	0.7	NOAEL	Zook et al. (1970)
Wheat	0.7	NOAEL	Lindberg (1968)
Wheat	0.8	NOAEL	Scott and Thompson (1971)
General	1	NOAEL	Bennett (1983)
Wheat	2.2	NOAEL	Fergusson (1990)
Barley	30	Upper critical concentration	Davis et al. (1978)
Plants / forb tissue			
Astragalus_racemosus	14920	NOAEL	Knott and McCay (1959), highly tolerant
Plants / Aquatic-water			
Algae			
Green	0.01	NOAEL	Bowen (1979)
General	0.05	NOAEL	Foe and Knight (1986)
Blue-green			
Lemna minor	2	LOAEL->10% growth decrease	Zayed et al. (1998)

Table 4.6 **Uranium TRVs for a variety of biota under different exposure scenarios derived from the literature.**

Species	U(ppm)	Effect	Reference
Mammals-Dietary			
Ruminants	0.4	Max. recommended level	Dreesen and Marple (1979)
Mice	2-237	NOAEL	NAS (1980)
Rats	474	NOAEL	NAS (1980)
Rats	500	Tolerated	Venugopal and Luckey (1978), soluble U salts
Rats	200000	Tolerated	Venugopal and Luckey (1978), insoluble U salts
Rabbit	56	LOAEL- renal damage	IRIS (1999), Maynard and Hodge (1949)
Mammals-Dietary-Water			
Human	0.035	Safe limit	NAS (1983)
Avifauna-Dietary			
Am. black duck	25-1600	NOAEL	Haseltine and Sileo (1983)
Invertebrates-Soil-Terrestrial			
Lumbricus terrestris	3-100	NOAEL	Sheppard and Evenden (1992)
Invertebrates-Tissue Terrestrial			
Blackflies	2.85	NOAEL	Swanson (1985), DW=WW/0.2
Dragonflies	4.75	NOAEL	Swanson (1985), DW=WW/0.2
Caddisflies	22	NOAEL	Swanson (1985), DW=WW/0.2
Invertebrates-Water Aquatic			
Cladoceran- *Moinodaphnia macleayi*	0.01	NOAEL	Hyne et al. (1993)
Plants / Grass-Tissue			
Corn	0.008	NOAEL	Laul et al. (1979)
Sporobolus airoides	0.05-0.17	NOAEL	Dreesen and Marple (1979)
Calamagrostis rubescens	0.06	NOAEL	Mahon and Mathewes (1983)
General	36	NOAEL	Dreesen et al. (1982)
Plants / Grass-In Soil			
Sporobolus airoides	2-176	NOAEL	Dreesen and Marple (1979)
Aristida purpurea	50-5000	NOAEL	Meyer and McLendon (1997)
Buchloe dactyloides	50-5000	NOAEL	Meyer and McLendon (1997)
Schizachyrium scoparium	50-5000	NOAEL	Meyer and McLendon (1997)
Plants/Aquatic-Water			
Nuphar lutea	0.2-0.34	NOAEL	Mahon and Mathewes (1983)
Nuphar lutea	0.08-0.7	NOAEL	Mahon and Mathewes (1983)
Plants/Aquatic-Sediment			
Nuphar lutea	14-15	NOAEL	Mahon and Mathewes (1983)

4.2.3 Results of Tier 1 Screening Level Risk Analysis

The purpose of the Tier 1 screening level exposure assessment was to evaluate whether selenium and uranium contributed unacceptable risk to biota associated with the Pit Lake. Consistent with the USEPA guidance (USEPA, 1997), the most conservative assumptions of exposure and effects were used including the maximum concentrations of selenium and uranium in soil, sediment, surface water, and biota, depending on the exposure scenario, and very conservative NOAEL toxicity reference values (CTRVs) that were obtained from the literature or were calculated using measured site specific bio-concentration factors (BFCs) as described previously.

The evaluation of risk was based on a calculated hazard quotient, or index, derived by dividing the media specific maximum selenium or uranium concentration by the appropriate CTRV. Hazard quotients that exceeded 1.0 were judged to need further evaluation using less conservative assumptions. Terrestrial and aquatic exposure pathways leading to calculated HQs < 1.0 were judge to present acceptable levels of risk to exposed receptor because of the large level of conservatism inherent in this level of assessment.

The results of the Tier 1 screening-level risk analysis (presented in Table 4.7) show that for about half of the exposure scenarios, HQ's exceeded 1 as indicated by the gray shading in Table 4.7 and as summarized below. Of the HQs greater than 1.0, most exceeded 20 for exposure scenarios involving selenium and were generally less than 20 for exposure scenarios for uranium (Table 4.7). Exposure pathways with HQs exceeding 1.0 included several aquatic and terrestrial pathways for selenium, but only aquatic pathways for uranium.

Aquatic and terrestrial exposure pathways for the conservative screening level assessment that resulted in HQs >1.5 were as follows:

Selenium- Aquatic	Water-Aquatic life Benthic Inverts Tissue Copepod-tissue Frog -tissue Benthic Invertebrates-Avifauna Benthic Invertebrates-Waterfowl Water-Cattle
Selenium- Terrestrial	Soil-Grass Grass -Rodents Rodent-Red-tailed Hawk
Uranium- Aquatic	Water-Aquatic life Water-Copepods Benthic Invertebrates-Tissue Sediment-Benthic Invertebrates Sediment--Cattails Benthic Invertebrates-Waterfowl Copepod-Tissue
Uranium- Terrestrial	Terrestrial Invertebrates-Frog

Based on the relative magnitude of the HQs resulting from this screening level assessment (Table 4.7), selenium appears to contribute relatively more to risk than uranium. Although the results of this conservative screening level assessment identified about half of the exposure pathways with HQs <1 for selenium and uranium, those pathways were included in the less conservative baseline assessment described below.

Table 4.7 Maximum selenium and uranium concentrations screened against conservative NOAEL CTRVs.

Exposure Pathway	Max Conc.[2]	CTRV	HQ[3]	CTRV Reference
		Aquatic- Selenium		
Water-Aquatic life	0.113	0.005	**23**	WDEQ, 2005
Water-Cattails	0.113	0.1	1.1	Suter, 1996
Water-Algae	0.113	0.1	1.1	Suter, 1996
Benthic Inverts-Tissue	287	7.9	**36**	WDEQ, 2005
Benthic Inverts-Tissue	287	2.4	**120**	0.005 x 482[1]
Water-Copepod	0.005	0.092	0.05	Suter, 1996
Copepod-tissue	73	1.2	**61**	0.005 x 235[3]
Water-Birds&Mammals	0.113	0.5	0.23	Llobet et al, 1991
Benthic Invertebrates-Shorebirds	287	7.9	**36**	WDEQ, 2005
Benthic Invertebrates-Waterfowl	287	10	**29**	O'Toole and Raisbeck (1997)
Water-Deer	0.113	0.86	0.13	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
		Terrestrial- Selenium		
Soil-Invertebrates	3.6	70	0.05	Efroymson et al. 1997a (revision)
Astragalus-Tissue	4400	14920	0.41	Knott and McCay (1959), highly tolerant
Soil-Grass	3.6	1	**3.6**	Efroymson et al. 1997a
Grass -Rodents	9.7	5	**1.9**	Davis et al. (1978)
Meadow Vole-Red-tailed Hawk	48	4.6	**10**	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
Grass-Pronghorn	9.7	15	0.65	Raisbeck et al. (1996)
		Aquatic- Uranium		
Water-Aquatic life	3.25	1.4	**2.3**	WDEQ (2005)
Sediment-Benthics	233	17	**14**	Environment Canada (2000)
Sediment-Cattails	233	15	**16**	Mahon and Mathewes (1983)
Algae-tissue	325	224	1.5	3.25 x 69[1]
Benthic Inverts-Tissue	1170	172	**6.8**	3.25 x 53[1]
Water-Copepods	3.25	1.4	**2.3**	WDEQ (2005)
Copepod-Tissue	1170	579	**2.0**	3.25 x 178[1]
Water-Birds&Mammals	3.25	13	0.25	Llobet et al. (1991)
Benthic Invertebrates-Shorebirds	1170	1600	0.73	Haseltine and Sileo (1983)
Benthic Invertebrates-Waterfowl	1170	25	**49**	Haseltine and Sileo (1983)
Water-Deer	3.25	7.0	0.46	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
		Terrestrial- Uranium		
Soil-Invertebrates	27.6	70	0.39	Efroymson, Will, Suter II, 1997 (revision)
Grass-invertebrates	18.5	100	0.19	Sheppard and Evenden 1992
Astragalus-Tissue	6.08	12	0.5	Dreesen et al. (1982)
Soil-Grass	27.6	88	0.31	Dreesen and Marple (1979)
Grass-Tissue	18.5	36	0.5	Dreesen et al. (1982)
Grass-Rodents	18.5	478	0.04	NAS, 1980
Meadow Vole-Red-tailed hawk	4.3	165	0.03	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
Grass-Deer	18.5	15	1.2	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996

[1] TRVs derived from safe level in source (water or soil) x Pit Lake BCF for receptor (Table 4.2).

[2] Note: All biological values are in mg/kg dry weight while units for water are mg/l.

[3] Only HQs > 1.5 are bolded.

4.3.3 Results of Tier 2 Baseline Risk Analysis

The baseline risk analysis was conducted to further evaluate the screening level exposure scenarios that yielded HQs>1 (Table 4.8). However, as mentioned, all of the exposure scenarios evaluated in the screening level analysis with HQs <1, were also included in the baseline assessment. Less conservative assumptions were used for the baseline assessment including use of the 95UCL concentrations to estimate exposures (instead of maximums) and less conservative BTRVs to include both literature derived NOAEL and LOAEL concentrations. However, in some cases safe tissue concentrations were calculated using BCFs as described previously.

The results of the baseline assessment resulted in HQs <1.5 for all exposure scenarios, except five, suggesting that risks to the various aquatic and terrestrial receptors were below levels that would produce population level effects (Table 4.8). For the aquatic scenarios, only uranium in benthic invertebrate tissue, resulted in an HQ of 1.6 and only selenium in benthic invertebrate (shorebirds-waterfowl pathway) resulted in an HQ of 7.8 (based on calculations using the site specific BCF) (Table 4.1). Risks to terrestrial receptors would appear to be minimal as all exposure scenarios for selenium and uranium resulted in HQs < 1.0, except for selenium in the grass-rodent pathway (HQ of 1.9) and the meadow vole-red-tailed hawk pathway (HQ of 1.7), using literature derived BTRVs.

Conclusions that can be drawn from the conservative screening level and follow-on baseline assessment are as follows:

1. Maximum concentrations of selenium and uranium in Pit Lake samples when compared to highly conservative TRVs, resulted in HQs exceeding 1.0 in about half of the exposure scenarios primarily for aquatic receptors.
2. Nearly all 95th UCL selenium and uranium concentrations when compared to less conservative NOAEL and LOAEL TRVs, resulted in HQs that were <1.0.
3. HQs exceeding 1.5 after the less conservative TRV screen were observed for selenium for the following exposure pathways:
    - benthic invertebrates-shorebirds (HQ = 7.8)
    - benthic invertebrates-waterfowl (HQ = 7.8)
    - grass-rodent (HQ = 1.9)
    - meadow vole-red-tailed hawk (HQ = 1.7)
4. HQs exceeding 1.0 after the less conservative TRV screen were observed for uranium for the following exposure pathways:
    - benthic invertebrate tissue (HQ = 1.6)

Table 4.8 **Baseline risk assessment comparing the 95UCL selenium and uranium concentrations against less conservative NOAEL and LOAEL BTRVs.**

1

PATHWAY	95UCLConcent.[2]	BTRV	HQ[3]	BTRV Reference
		Aquatic- Selenium		
Water-Aquatic life	0.11	0.15	0.73	Foe and Knight (1986), Dunber et al. 1983
Water- Cattails	0.11	0.7	0.16	Mahon and Mathewes (1983), (Nuphar)
Water-Algae	0.11	0.7	0.16	Mahon and Mathewes (1983), (Nuphar)
Water- Benthic Inverts	0.11	0.15	0.73	Foe and Knight (1986)
Copepods-Tissue	41	35	1.2	0.15 x 235[1]
Benthic Invertebrates-Shorebirds	78	10	**7.8**	O'Toole and Raisbeck (1997)
Benthic Invertebrates-Waterfowl	78	10	**7.8**	O'Toole and Raisbeck (1997)
Water-Deer	0.11	1.4	0.08	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
		Terrestrial- Selenium		
Soil-Invertebrates	2.04	70	0.03	R. A. Efroymson, M. E. Will, G. W. Suter II, 1997 revision
Astragalus-Tissue	6324	14920	0.42	Knott and McCay (1959), highly tolerant
Grass-Tissue	14	30	0.47	Davis et al. (1978)
Grass- Rodents	9.7	5	**1.9**	Davis et al. (1978), NAS (1980)
Meadow Vole-Red-tailed Hawk	27	15.5	**1.7**	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
Grass- Pronghorn	9.7	15	0.65	Raisbeck et al. (1996)
		Aquatic- Uranium		
Water-Aquatic life	3.1	3.2	1.0	WDEQ, 2005 @ 200 mg/l hardness
Benthic Invertebrates (tissue)	271	169	**1.6**	3.2 x 53[1]
Water-Cattail	3.1	15	0.21	Mahon and Mathewes (1983)
Cattail- Tissue	50	45	1.1	3.2 x 14[1]
Water-Algae	3.1	15	0.21	Mahon and Mathewes (1983)
Algae-Tissue	325	221	1.5	3.2 x 69[1]
Copepods-Tissue	236	570	0.41	3.2 x 178[1]
Water-Birds&Mammals	3.1	13	0.24	Llobet et al. (1991)
Benthic Invertebrates-Shorebirds	271	1600	0.17	Haseltine and Sileo (1983)
Benthic Invertebrates-Waterfowl	271	1600	0.17	Haseltine and Sileo 1983
Water-Deer	3.1	14	0.23	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
		Terrestrial- Uranium		
Soil-Invertebrates	2	100	0.15	Sheppard and Evenden (1992)
Astragalus-Tissue	7.8	12	0.65	Dreesen and Marple (1979)
Grass-Tissue	18.5	5000	0.22	Meyer and McLendon (1997)
Grass-Rodents	1.6	118	0.06	NAS (1980)
Meadow Vole-Red-tailed Hawk	1.7	165	0.01	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996
Grass-Deer	18.5	29.6	0.63	Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996

[1] **Based on BCFs in Table 4.1.**

[2] Note: All biological values are in m/kg dry weight while units for water are mg/l.

[3] Only HQs > 1.5 are bolded.

5.0 RISK CHARACTERIZATION

This section evaluates the ecological significance of selenium and uranium on Pit Lake aquatic and terrestrial biota and presents uncertainties, conclusions and recommendations within the following subsections. Section 5.1, Characterization for Assessment Endpoints, integrates exposure and effects data for estimating risks to assessment endpoints. Section 5.2, Ecological Factors affecting Selenium and Uranium Transport to Biota, integrates ecological information on Pit Lake habitat and biological productivity with the chemical assessment to evaluate overall significance of risks to Pit Lake biota Section 5.3, Uncertainties, discusses sources of uncertainty, including contributions from sampling, analytical, site model, and TRV derivation. Section 5.4, Conclusions, summarizes results of the evaluation.

5.1 Characterization for Assessment Endpoints

Based on the conservative screening analysis, about half of the exposure scenarios for selenium and uranium exceeded applicable TRVs. However, the less conservative baseline analysis showed that the 95UCL concentrations of selenium and uranium in Pit Lake biota were generally below NOAEL or LOAEL concentrations. After the baseline assessment, four selenium exposure pathways yielded HQs >1.5, benthic invertebrates-shorebirds (HQ = 7.8), benthic invertebrates-waterfowl (HQ = 7.8), grass-rodent (HQ = 1.9), and meadow vole-red-tailed hawk (HQ = 1.7) and one uranium exposure pathway yielded an HQ > 1.5 in benthic invertebrate tissue (HQ = 1.6). All of the remaining aquatic and terrestrial exposure pathways for the baseline assessment had HQs less than 1.5.

5.1.1 Aquatic Ecosystems Assessment Endpoints

Assessment endpoints for aquatic biota were to ensure that selenium and uranium concentrations did not limit viable populations of benthic invertebrates, copepods, and aquatic plants. Exposure pathways included direct contact with sediment and water and tissue concentration derived from the literature or as calculated using BCFs. Risks based exclusively on conservative screening-level TRVs and chronic exposures to maximum concentrations of metals in surface water and sediments or to levels in tissues yielded HQs in the 10-20 range for both selenium and uranium suggesting that under these conservative assumptions, some level of potential risk to aquatic biota would exist if aquatic biota were exposed to these upper range concentrations of these chemicals. Under less conservative assumptions of exposure and NOAEL and LOAEL TRVs, only one exposure scenario resulted in HQs >1.5. For uranium, benthic invertebrate tissue concentrations had an HQ of 1.6 and for selenium, there were no exposure pathways with HQs > 1.5. The conclusion drawn about this assessment endpoint was that current exposures to aquatic organism from selenium and uranium in the Pit Lake were slightly above acceptance criteria for one exposure pathway for uranium and none for uranium. Therefore, for almost all exposure scenarios for benthic invertebrates, copepods, or aquatic plants, measured concentrations in source media were below levels that would negatively impact aquatic biota.

5.1.2 Waterfowl and Bird Life Assessment Endpoint

Assessment endpoints for waterfowl and bird life, taken as shorebirds feeding on benthic invertebrates, were to ensure that selenium and uranium concentrations did not limit viable populations of waterfowl or shorebirds. Risks based exclusively on conservative chronic screening-level TRVs and maximum concentrations of selenium in benthic invertebrates yielded HQs in the 30-35 range suggesting that some level of potential risk to aquatic biota from selenium would exist if waterfowl and shorebirds were chronically exposed to these upper range concentrations of these chemicals. The HQ for uranium for the benthic invertebrate-waterfowl pathway was about 50 but was less than 1.0 for the benthic invertebrate-shorebird pathway. Results of the baseline assessment suggested that under the less conservative assumptions of exposure and NOAEL and LOAEL TRVs for selenium, chronic exposures to waterfowl and shorebirds from a diet of benthic invertebrates still resulted in HQs >1.5. Under these less conservative conditions, uranium exposures to waterfowl and shorebirds through a benthic invertebrate diet, were within the acceptance criteria of HQ< 1.0. The conclusion drawn about the waterfowl and shorebird assessment endpoint was that chronic exposures to selenium through a benthic invertebrate diet pathway were above the acceptance criteria. In contrast, chronic uranium exposures to birds through a benthic invertebrate diet were well below the acceptance criteria. When evaluated against the assumptions of chronic consumption of Pit Lake benthic invertebrates and year round occupancy, risks to waterfowl and shorebirds to both selenium and uranium, is judged to be insignificant.

5.1.3 Terrestrial Herbivore Assessment Endpoint

The assessment endpoint for herbivores, taken as meadow voles, mule deer or pronghorn was to ensure that chronic selenium and uranium exposures through grass and drinking water were protective of those herbivores. Results of the conservative screening analysis indicated the drinking water exposure pathway for deer or pronghorn was not significant as HQs were less than 1.0. The dietary pathway, which assumed chronic ingestion of shoreline grass, resulted in very slight exceedences of TRVs for meadow voles (HQ =1.9) for selenium and no exceedences for uranium. Results of the baseline assessment only identified the grass to meadow vole pathway as still slightly exceeding the hazard quotient acceptance criteria. The conclusion drawn about the herbivore assessment endpoint was that chronic exposures of meadow voles, deer or pronghorn to selenium and uranium in drinking water and a grass diet was of little significance to the maintenance of viable populations of these organisms. When evaluated against the assumptions of chronic consumption of Pit Lake grass and water and year round occupancy, risks to herbivores as represented by deer, pronghorn and meadow voles, to both selenium and uranium, is judged to be insignificant.

5.1.3 Terrestrial Carnivore Assessment Endpoint

The assessment endpoint for carnivores, taken as red-tailed hawk, was to ensure that chronic exposures to selenium and uranium through a dietary pathway were protective of these species. The red-tailed hawk was assumed to consume only meadow voles and consumption of this diet was assumed to be chronic and to consist entirely of voles. Results of the conservative screening analysis indicated that a meadow vole diet containing selenium resulted in exposures above (HQ = 10) the acceptance criteria of HQ = 1.0 while those for uranium were well below HQs of 1.0. Results of the less conservative baseline assessment still resulted in a meadow-vole to red-tailed hawk HQ of 1.7 for selenium, while uranium levels in the diet remained below acceptance criteria. The conclusion drawn about this carnivore assessment endpoint was that chronic exposures to a meadow vole diet resulted in exposures to red-tailed hawks that were very slightly above acceptance criteria only for selenium. When evaluated against the assumptions of chronic consumption of Pit Lake meadow voles and year round occupancy, risks from both selenium and uranium to predators, as represented by red-tailed hawks, is judged to be insignificant.

Ecological Factors Affecting the Significance of Selenium and Uranium Exposures to Biota

In assessing ecological risk, chemical concentration data, relevant TRVs, and the resulting HQs must be evaluated in light of available habitat and food sources that serve in hosting and sustaining resident and migratory wildlife. For aquatic species such as benthic invertebrates, amphibians, and copepods, the habitat, including food sources, must be sufficient to maintain these populations indefinitely. For visiting wildlife including waterfowl and other birds, and large mammals including mule deer, sufficient habitat and food sources must exist to support the activities of migrant species. This means that the level of risk to these migrant species will also depend on the abundance of food and nesting habitat.

Highland Pit Lake provides little habitat and primary and secondary biological productivity to maintain a significant permanent aquatic plant and animal community or to host migrant species that frequent the lake primarily during summer months. This is primarily due to the general configuration of the lake which has very steep banks with a very small shallow water zone conducive to establishment of an aquatic biological community. As mentioned in Sections 2.0 and 3.0, littoral zone habitat that supports vegetation and benthic invertebrate communities comprises less than 2 acres (0.9 ha) of the 130 acre lake surface area. The rooted macrophyte, cattail, occupies about 1 acre in this 2 acres of the littoral zone or about 0.08% of the total lake area.

The benthic invertebrate community is almost exclusively confined to a small area (about 2 acres) of the littoral zone supporting cattails. Standing crop biomass estimates made periodically throughout the 10 month study period averaged only about 40 kg of benthic invertebrates for the entire littoral zone. This amount of benthic invertebrate biomass as a food source would sustain a very low number of any organism that required a benthic invertebrate food base.

For example, if waterfowl would use the lake as a food source, a 2 pound (900g) duck would consume about 5% of its body weight a day or 45 grams of food per day. Over the course of a year, that would amount to 16.4kg consumed /year-duck. If the benthic invertebrate population could sustain a 30% predation rate, about 12 kg (40 kg x 0.3) would be available for duck consumption per year. Obviously the low benthic invertebrate standing crop of 40 kg would be inadequate to support even one resident waterfowl relying on benthic invertebrates as a food source. A similar calculation could be made for other species that require zooplankton or benthic invertebrates as a food source resulting in a similar conclusion.

The copepod biomass in the limnetic zone of the lake averaged 422 kg for measurements made on five different occasions during the study period. Copepods serve primarily as a food source for fish. However, fish do not occur in the Pit Lake. However, if a similar calculation is done to that for benthic invertebrates, the results show that the standing crop of copepods, assuming a 30% predation rate, would support 15 fish weighing 1 lb (or 15 waterfowl of the same weight). The low benthic invertebrate and copepod productivity likely explains why none of the 45,000 fish stocked in the lake survived. The existing food base was not sufficient to maintain the introduced fish.

The lack of littoral zone habitat, including the small area of rooted macrophytes and the low food availability helps explain why our observations (made on 25 visits to the lake) to observe waterfowl and other bird species, almost never showed the lake to be used by birds as a food source. On one occasion, an Eared Grebe was observed to be feeding in the littoral zone near the cattail beds but this occurred only once and was never observed on subsequent visits.

During the course of this study, only four bird species attempted to nest at the lake. These included one pair of Canada Goose, one of Blue-winged Teal, one Red-winged Blackbird and dozens of cliff swallows which nested on the cliffs surrounding the south end of the Pit Lake. The Canada goose and blackbird nests were predated soon after they were established and were not re-established. The Blue-winged Teal produced two young that were alive two weeks after hatching. The Cliff Swallows appeared to be successful in raising young at the Pit Lake although the mud nests were not monitored closely due to difficulty in accessing the nest sites and the decision not to collect birds as a part of this risk assessment study.

Although the results of the risk analysis showed that chemical concentrations in aquatic and terrestrial biota were of low risk when screened against NOAEL and LOAEL TRVs, the organisms current living in the lake have developed in the presence of the selenium and uranium that is present in the water and sediments. Obviously, no benthic or planktonic fauna or flora existed in the lake as it began to fill. Consequently, the aquatic organisms that currently live in the lake are tolerant of the chemical conditions in the lake.

All of these factors suggest that:

1) current concentrations of selenium and uranium in surface water, sediment, soils and aquatic and terrestrial biota associated with the lake have not been detrimental to those populations based on their existence at the lake and on the results of the risk assessment,
2) the lack of habitat and associated biological productivity currently provide a very small potential for transfer of Pit Lake selenium and uranium to migrant species including waterfowl, shore birds, and mammals such as deer and small mammals, and
3) biological conditions in the lake may decline over time as the lake levels rise to equilibrium level. This is owing to the fact that the rising lake levels will reduce littoral zone habitat conducive to enhance plant and animal productivity and to nesting habitat for birds.

5.3 Uncertainties

Uncertainty in the risk estimation and characterization can result from a number of sources. In the exposure and risk calculations, the primary sources of uncertainty can be divided into two categories: (1) the applicability and relevance of the overall exposure and risk procedures used for the Pit Lake assessment and (2) the accuracy of the input variables (USEPA, 1997).

Exposure and risk procedures include the Conceptual Pit Lake Model (CSM), the assumptions used to estimate exposure, and the selection and use of the lower and upper limit NOAEL TRVs to estimate risk. The CSM was developed to represent the Pit Lake-specific environmental conditions and Wyoming DEQ regulatory framework which focuses primarily on water quality issues.

Selenium and uranium concentration data used in the exposure estimates were based on field data from the Pit Lake. Those data were intended to represent the important aquatic and terrestrial components and pathways for selenium and uranium. Although extensive sampling of certain physical and biological components was conducted, uncertainty remains with regard to the accuracy with which the data represent true concentration distributions. This is particularly true for sediments and biological components where spatial distribution and selenium and uranium concentrations can vary appreciably. In the case of the Pit Lake, the coefficient of variation (i.e. (SD/mean) x 100) for selenium and uranium in biota was typically 100-200% of the mean. To counter this uncertainty, highly conservative assumptions (i.e. maximum and 95th UCL exposure point concentrations) were used to estimate exposure point concentrations, consistent with USEPA guidance. In reality, average concentrations of selenium and uranium in Pit Lake samples better reflects exposures to current aquatic and terrestrial biota.

Therefore, while there could be significant uncertainty about the true accuracy of exposure calculations and applicability of TRVs, the conservative nature of assumptions helps ensure that the bias of the risk calculations is protective of receptor organisms. For example, the highly conservative assumptions associated with the initial screening-level analysis are not meant to accurately estimate risk, but to maximize confidence that decisions made on the basis of the screen are protective. The follow-up Tier 2 risk analysis, using less conservative assumptions about exposure concentrations and TRVs better reflects conditions at the Pit Lake but still provides a conservative estimate of risks due to the use of the 95 UCLs for exposure concentrations and upper limit NOAEL TRVs obtained either from the literature or as calculated using site specific data.

In general, risk assessments draw from information gained from laboratory and other carefully controlled experimental exposures. This information is then used to extrapolate conditions likely to exist in the natural environment. The laboratory information often does not provide complete linkages for these extrapolations. Consequently, assessment factors are often used to compensate for the many uncertainties inherent in the extrapolation from laboratory effects data to effects in natural ecosystems (Warren-Hicks and Moore 1998). According to Calabrese and Baldwin (1993), uncertainties arise when extrapolations are made from the following:

1. Acute to chronic endpoints;
2. One life stage to an entire life cycle;
3. Individual effects to effects at the population level or higher;
4. One species to many species;
5. Laboratory to field conditions;
6. One to all exposure routes;
7. Direct to indirect effects;
8. One ecosystem to all ecosystems; and/or
9. One location or time to others.

The net effect of these uncertainties may result in either an overestimate or underestimate of effects potentials, depending on site-specific conditions, the types of receptors included in the evaluation, and the chemicals under study. Because of the very limited potential for transfer of significant amounts of selenium and uranium to aquatic and terrestrial biota and to the fact that birds and many mammals observed in the lake environs are migratory, it is likely certain that the risks to biota under the exposures scenarios examined is greatly overestimated.

5.4 Conclusions

During planning of the Highland Pit Lake assessment, the potential for unacceptable risks from selenium and uranium to aquatic and nearby terrestrial biota were of primary interest. A tiered approach was used to assess risks from selenium and uranium to Pit Lake biota via several exposure pathways. The first tier compared measured concentrations of selenium and uranium in Pit Lake samples with corresponding samples from the Box Creek control site. Results showed that concentrations of these elements in Pit Lake samples exceeded those in background samples.

The second tier evaluation was done by comparing maximum measured concentrations with highly conservative, lower limit TRVs that were highly protective of the more sensitive individuals of a species group such as benthic invertebrates. Results of this screen, using calculated Hazard Quotients, showed that most concentrations in Pit Lake samples exceeded the conservative TRVs yielding HQs that exceeded 1.0.

The use of the less conservative 95UCl exposure concentration upper limit TRVs were protective of individuals or populations of a species. Results of this less conservative analysis showed that risks, as defined by HQs, were for the most part below levels considered hazardous to the biota under study.

The conclusion resulting from the chemical assessment alone was that risks to most receptors were below accepted safe level criteria. The few pathways that resulted in HQs exceeding 1.0 after the final TRV screening were either not complete (i.e. benthics to avifauna), were not observed during frequent visits to the site, or were less than full time exposures, as is assumed in the published TRVs.

A large number of waterfowl and other wildlife species use the Pit Lake during spring and fall migration and as summer range. Nesting birds during the summer of 2005 were very limited and consisted mostly of cliff swallows that nest on the vertical cliffs surrounding most of the lake. While the conservative, exposure-based risk estimates indicate potential risk to aquatic and terrestrial biota including exposure scenarios involving birds and mammals, less conservative assumptions demonstrated that risks were within limits represented by upper limit NOAEL TRVs.

Based on this site specific risk assessment, we would conclude that the Pit Lake does not pose an unacceptable risk to aquatic and nearby terrestrial biota as inferred from measured selenium and uranium concentrations in those biota and comparisons of those concentrations to upper limit NOAEL toxicity reference values. Likewise, migrant species either use the lake for resting (i.e. waterfowl) and as a drinking water and loafing area for terrestrial wildlife such as mule deer and to a lesser degree, pronghorn. Waterfowl and large herbivores only use the lake environs for at most a 6 month period during the year.

Finally, the lack of suitable and abundant habitat and food sources greatly limit the potential of the Pit Lake as a source of selenium and uranium to migrant species. Resident populations of aquatic species have developed under existing and prior chemical conditions at the lake, including selenium and uranium in surface water and sediments. Therefore, these species have tolerated chronic exposures to Pit Lake selenium and uranium. Based on projected final lake levels (Figure 3.3), and the configuration of the landscape to be covered by the water, the amount of habitat and risks to aquatic biota is expected to remain with limits of current standards for selenium and uranium.

Conclusion can be summarized as follows:

1. Measurements of selenium and uranium in selected aquatic and terrestrial media were made over a 10 month period beginning September 2004 through July 2005,
2. Concentrations in Pit Lake samples exceeded Box Creek samples by at least an order of magnitude,
3. In some cases. HQs for a conservative screening of measured concentrations against low TRVs exceeded 1.0 suggesting the need for further analysis,
4. HQs for a more realistic screening of measured concentrations against high but still protective TRVs generally were less or slightly above 1.0, implying a low level risks to biota, and
5. Integrating habitat and biomass estimates into the interpretation of the chemical data, including food availability and frequency of use of the lake by migratory species, leads to the conclusion that risks to resident and migratory biota at Highland Pit Lake are very low.

6.0 REFERENCES

Allaway, W. H. and J. F. Hodgson. 1964. Symposium on nutrition, forage and pastures: Selenium in forages as related to the geographic distribution of muscular dystrophy in livestock. J. Animal Sci. 23:271-277.

Anspaugh, L. R., Phelps, P. L., Holleday, G., Hamhy, K. 0., 1971, in.: Proc. Symp. Health Physics Aspects of Nuclear Facility Siting, Idaho Falls, 3-6 November, 1970, Vol. *2,* p. 428 (Idaho Falls: Eastern Idaho Chapter, Health Physics Society).

Arnold, R.L., O.E. Olson, and C.W. Carlson. 1973. Dietary selenium and arsenic additions and their effects on tissue and egg selenium. Poultry Science 52:847-854.

Beath, O. A. 1962. The story of selenium in Wyoming. University of Wyoming, Laramie.

Bennett, B. G. 1983. Exposure of man to environmental selenium - an exposure commitment assessment. Sci. Total Environ. 31: 117-127.

Berg, L.R. and R.D. Martinson, 1972. Effect of diet composition on the toxicity of zinc for the chick. Poult. Sci., 51: 1690-1694.

Berlin, M. and B. Rudell. 1979. Uranium. pp 647-658 In: Friberg, L, G. F. Nordberg, and V. B Vouk (eds) Handbook on the Toxicology of Metals. Elsevier/North Holland Biomedical Press.

Berman, E., 1980, Selenium, in Berman, E., editor, Toxic metals and their analysis: Heyden, London, p. 183-190.

Bowen, H. J. M. 1979. Environmental Chemistry of the Elements. Academic Press, London.

Calabrese, E.J., and L.A. Baldwin, 1993. Performing Ecological Risk Assessments. Lewis Publishers. Chelsea, Michigan. 215 pages.

Cannon, H.L. 1952. The effect of uranium-vanadium deposits on the vegetation of the Colorado Plateau. Am. J. Sci. 250, pp. 735–770.

Cannon, H.L., 1960. Botanical prospecting for ore deposits. Science, 132: 591--598.

Clulow, F. V., Lim, T. P., Davr, N. K. & Avadhanula, R. (1992). Ra-226 levels and concentration ratios between water, vegetation, and tissues of ruffed grouse *(Bonasa umbellus)* from a watershed with uranium tailings near Elliot Lake, Canada. *Environ. Pollut.,* 77, 39-50.

Connor, J. J., and H.T. Shacklette. 1975, Background geochemistry of some rocks, soils, plants, and vegetables in the conterminous United States, with sections on Field studies by R. J. Ebens, J. A. Erdman, A. T. Miesch, R. R. Tidball, and H. A. Tourtelot: US. Geological Survey Professional Paper 574-F, 168 p.

Cumbie, P. M. and S. L. Van Horn. 1978. Selenium accumulation associated with fish mortality and reproductive failure. Proc. Annu. Conf. Southeast Assoc. Fish Wildl. Agencies 32: 612-624.

Davis, R. D., P. H. T. Beckett and E. Wollan. 1978. Critical levels of twenty potentially toxic elements in young spring barley. Plant Soil 49: 395-408.

Dickson, J.D. 1969. Notes on Hair and Nail Loss After Ingesting Sapucaia Nuts (Lecythis elliptica). Econ. Bot., 23,133-134

Dreesen, D. R. and M. L. Marple. 1979. Uptake of trace elements and radionuclides from uranium mill tailings by four-wing saltbush (Atriplex canescens) and alkali sacaton (Sporobolus airoides).

Pages 127 - 143 *in* Symposium on Uranium Mill Tailings Management, Fort Collins, Colorado. Civil Engineering Department, Colorado State University, Fort Collins.

Dreesen, D. R., J. M. Williams, et al. 1982. Mobility and bioavailability of uranium mill tailings contaminants. Environ. Sci. Tech. 16: 702-709.

Dunbar, A. M., J. M. Lazorchak, and W. T. Waller. 1983. Acute and chronic toxicity of sodium selenate to Daphnia magna Straus. Environ. Toxicol. Chem. 2: 239-244.

Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten. 1997a. Toxicological Benchmarks for Screening Contaminants of Concern for Effects on Terrestrial Plants. ES/ER/TM-85/R3, Oak Ridge National Laboratory, Environmental Sciences Division.

Environment Canada. 2000. Priority Substances List Assessment Report B Releases of Radionuclides from Nuclear Facilities (Impact on Non-Human Biota). Draft. Health Canada. Canadian Environmental Protection Act, 1999. July.

Fergusson, J. E. 1990. The Heavy Elements: Chemistry, Environmental Impact and Health Effects. Pergamon Press, Oxford, U.K.

Ferretti, R.J. and S. Schwartz. 1951. Natl. Nucl. Energy, Ser.. Div. IV, 23, Toxicology of Uranium, 274.

Foe, C. and A. W. Knight. 1986. Selenium bioaccumulation, regulation, and toxicity in the green algae, Selenastrum capricornutum, and dietary toxicity of the contaminated alga to Daphna magna. Pages 77-88 *in* Selenium in the Environment, Proceedings. California Agricultural Technology Institute. Publication No. CAT1/860201. Fresno, CA.

Forstner and Wittmann (1981). Metal pollution in the aquatic environment. Springer-Verlag, Berlin. 486p.

Free, E. E. 1917. Symptoms of poisoning by certain elements in Pelargonium and other plants. Johns Hopkins Univ. Circ. 293: 195-198.

Fresquez, P.R., D.R. Armstrong, and J.G. Salazar. 1994. "Radionuclide Concentrations in Game and Nongame Fish Upstream and Downstream of Los Alamos National Laboratory: 1981 to 1993," Los Alamos National Laboratory report LA-12818-MS.

Gissel-Nielsen, G. 1975. Selenium concentration in Danish forage crops. *Acta Agriculturae Scandinavica* 25:216–220.

Hadjimarkos, D. M. 1970. Effect of selenium in the hamster. Pages 215-218 *in* C. F. Mills (ed.), Trace Element Metabolism in Animals. E. & S. Livingstone, Edinburgh.

Halverson AW, IS Palmer, and PL Guss. 1966. Toxicity of selenium to post-weanling rats. Toxicol Appl. Pharmacol 9:477-484.

Hapke, H. J. 1991. Effects of metals on domestic animals. Pages 531-546 *in* E. Merian (ed.), Metals and Their Compounds in the Environment. VCH, NewYork, NY.

Haseltine, S. D. and L. Sileo. 1983. Response of American black ducks to dietary uranium: A proposed substitute for lead shot. J. Wildl. Mgmt. 47: 1124-1129.

Heinz, G. H. and D.J. Hoffman. 1987. Reproduction in mallards fed selenium. Environmental Toxicology and Chemistry 6: 423-433.

Heinz, G. H., D.J. Hoffman, and L. G. Gold. 1989. Impaired reproduction of mallards fed an organic form of selenium. Journal of Wildlife Management 532: 418-428.

Hutchinson, T. C.: 1973. Comparative studies of the toxicity of heavy metals to phytoplankton and their synergistic interactions. Wat. Pollut. Res. Can. 8: 68-90

Hyne, R. V., Padovan, A., Parry, D.L., and S.M. Renaud. 1993. Increased fecundity of the Cladoceran Moinodaphnia macleayi on a diet supplemented with a green alga and its use in uranium toxicity tests. Aust. J. Mar. Freshwater Res. 44(389-99).

IRIS. 1999. Integrated Risk Information System. On-line service (www.epa.gov/iris/). U.S. Environmental Protection Agency, Washington, DC.

Iyengar et al. (1978) Determination of certain selected bulk and trace elements in the bovine liver matrix using neutron activation analysis. Physics in Medicine and Biology 23: 66

Kabata-Pendias, A. and H. Pendias. 1992. Trace Elements in Soils and Plants. CRC Press, Inc. Florida.

Kloke, A., D. R. Sauerbeck, and H. Vetter. 1984. The contamination of plants and soils with heavy metals and the transport of metals in terrestrial food chains. Page 113 *in* J. O. Nriagu (ed.) Changing Metal Cycles and Human Health. Springer-Verlag, Berlin.

Knott, S. G. and C. W. R. McCay. 1959. Two naturally occurring outbreaks of selenosis in Queensland. Aust. Vet. J. 35: 161-165.

Kumar and Prakash (1971). Studies on sulphur selenium antagonism in blue-green algae. I. Sulphur nutrition. Arch. Mikrobiol. 77: 196-202

Langden R.E. and A.L. Kidwell. 1973. "Geology and Geochemistry of the Highland Uranium Deposit, Converse County, Wyoming." *Earth Science Bulletin*, Vol. 6:41-48.

Laul, J.C., W.C. Weimer, and L.A. Rancitelli. 1977. Biogeochemical Distribution of Rare Earths and Other Trace Elements in Plants and Soil. BNWL-SA-6078. Battelle Pacific Northwest Laboratory.

Lindberg, P. 1968. Selenium determination in plant and animal material, and in water: A methodological study. Acta Vet. Scand., Suppl. 23, 48 pp.

Llobet, J. M., J. J. Sirvent, A. Ortega, and J. L. Domingo. 1991. Influence of chronic exposure to uranium on male reproduction in mice. Fund. Appl. Toxicol. 16: 821-829.

Mahon, D. C. and R. W. Mathewes. 1983. Uptake of naturally occurring radioisotopes by vegetation in a region of high radioactivity. Can. J. Soil Sci. 63: 281-290.

Maier, K.J. and A. W. Knight. 1994. Ecotoxicology of selenium in freshwater systems. Rev. Environ. Contam. Toxicol. 134, 31–48.

Maynard, E.A. and H.C. Hodge. 1949. Studies of the toxicity of various uranium compounds when fed to experimental animals. Pages 309-376 *in* C. Voegtlin and H.C. Hodge (eds.) The Pharmacology and Toxicology of Uranium Compounds. McGraw Hill, New York, NY.

Menzie, C.A., D.E. Burmaster, J.S., Freshman, and C.A. Callahan, 1992. Assessment of methods for estimating ecological risk in the terrestrial component: A case study at the Baird and McGuire Superfund Site in Holbrook, Massachusetts. Environ. Toxicol. Chem. 11: 245-260.

Meyer, M. C. and T. McLendon. 1997. Phytotoxicity of depleted uranium on three grasses characteristic of different successional stages. J. Environ. Qual. 26: 748-752.

MFG, Incorporated (MFG). 2003. Final Draft Long-Term Geochemical Evolution of the Highland Reservoir, Converse County, Wyoming, February.

MFG, Incorporated (MFG). 2004. Final Draft Long-Term Pit Lake and Groundwater Hydrology at the Highland Mine Site, Converse County, Wyoming. February.

Moede AR, Greene RW, Spencer DF (1980) Effects of selenium on the growth and phosphorus uptake of *Seenedesmus dimorphus* and *Anabaena cylindriea.* Environ Exp Bot 20:207-212

Moxon, A. L. and D. C. Mahan. 1981. Toxic dietary selenium levels for weanling swine. Pages 471-474 *in* J. M. Gawthorne, J. McC. Howell, and C. L. White (eds.), Trace Element Metabolism in Man and Animals, Procceedings of the Fourth International Symposium, Perth, Western Australia. Springer-Verlag, New York, NY.

Moxon, A.L. and W. Poley. 1938. The relation of selenium content of grains in the ration to the selenium content of poultry carcass and eggs. Poultry Sci., 17: 77-80.

Munsell, H. E., G. M. Devaney, and M. H. Kennedy. 1936. Toxicity of food containing selenium as shown by its effect on the rat. U. S. Dept. Agric. Tech. Bull. 534.

National Academy of Sciences (NAS). 1976. Medical and Biological Effects of Environmental Pollutants - Selenium. National Academy of Sciences, Washington, D.C.

National Academy of Sciences (NAS). 1980. Recommended Dietary Allowances, pp. 162-164. National Academy of Sciences, Washington, D.C.

National Academy of Sciences (NAS). 1983. Drinking water and health, Vol. 5. National Academy of Science Press, Washington, D.C.

Olson, O. E. 1986. Selenium Toxicity in Animals with Emphasis on Man. J. Am. Coll. Toxicol. 5: 45-70.

O'Toole, D., and M.F. Raisbeck. 1997. Experimentally induced selenosis of adult mallard ducks: clinical signs, lesions, and toxicology. Vet. Pathol. 34: 330-340.

Pierce, A. W. and G. B. Jones. 1968. Aust. J. Exp. Agric. Anim. Husb. 8: 277.

Poston, T. M., Hanf, R. W., and Simmons, M. A. 1984. Toxicity of uranium to *Daphnia magna.* Water, Air and Soil Pollution 22: 289-298.

Raisbeck, M. F., D. O'Toole, R.A. Schamber, E.L. Belden, and L.J. Robinson. 1996. Toxicologic evaluation of a high selenium hay diet in captive pronghorn antelope (*Antilocapra americana*). J. Wildl. Dis. 32: 9-16.

Robinson G. A., Wasnidge D. C. and Floto F. (1984) A comparison of the distributions of the actinides uranium and thorium with the lanthanide gadolinium in the tissues and eggs of Japanese quail. Concentrations of uranium in feeds and foods. *Poultry Sci. 63, 883-891.*

Rosenfeld, I. and O. A. Beath. 1954. Effects of selenium on reproduction in rats. Proceedings: Society of Experimental Biology and Medicine.

Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996. Toxicological Benchmarks for Wildlife. Oak Ridge, TN, ORNL.

Sample, B.E., G.W. Suter, II, M.B. Shaeffer, D.S. Jones, and R.A. Efroymson. 1997. Ecotoxicological Profiles for Selected Metals and Other Inorganic chemicals. Oak Ridge National Laboratory, Oak Ridge TN.

Schroeder & Mitchener, 1971. Toxic effects of trace elements on the reproduction of mice and rats. *Archives of Environmental Health*, 23:102-106.

Scott, M. L. and J. N. Thompson. 1971. Selenium content of feedstuffs and effects of dietary selenium levels upon tissue selenium in chicks and poults. Poult. Sci. 50: 1742-1748.

Sheard, J.W. (1986) Distribution of uranium series radionuclides in upland upland vegetation of northern Saskatchewan. I &II. Canadian Journal of Botany, 64, 2446–2463.

Sheppard, M. I. and D. H. Thibault. 1984. Natural uranium concentrations of native plants over a low-grade ore body. J. Bot. 62: 1069-1075.

Sheppard, S. C. and W. G. Evenden. 1992. Bioavailability indices for uranium: Effect of concentration in eleven soils. Arch. Environ. Contam. Toxicol. 23: 117-124.

Shrift, A. 1954. Sulfur-selenium antagonism. I. Antimetabolite action of selenate on the growth of *Chlorella vulgaris.* Amer. J. Bot. 41:223-230.

Sielicki and Burnham (1973) The effect of selenite on the physiological and morphological properties of blue-green alga *Phormidium luridum* var. *olivacea.* Journal of Phycology 9: 509-514.

Sors, T.G., D.R. Ellis, N.N. Gun, B. Lahner, L. Sangman, T. Leustek, I.J. Pickering, and D.E. Salt. Analysis of sulfur and selenium assimilation in *Astragalus* plants with varying capacities to accumulate selenium. The Plant Journal 42 (6): 785.

Stephens, D.W., B. Waddell, L.A. Peltz, and J.B. Miller. 1992. Detailed study of selenium and selected elements in water, bottom sediment, and biota associated with irrigation drainage in the Middle Green River basin, Utah, 1988-90. U.S. Geological Survey-Water Resources Investigations Report 92-4084. 164pp.

Stewart, R. D. H., Griffiths, N. M., Thomson, C. D. & Robinson, M. F. (1978). Quantitative selenium metabolism in normal New Zealand women. British Journal of Nutrition 40, 45-54

Stoklasa J. and J. Penkava. 1928. Biology of uranium. Biochem. Z. 194: 15-77.

Suter, G. W. 1996. Toxicological benchmarks for screening contaminants of potential concern for effects on freshwater biota. Environmental Toxicology and Chemistry 15: 1232-1241.

Suter, G.W. II. 1993. Ecological Risk Assessment. Lewis Publishers, Boca Raton, FL.

Swanson, S. M. 1985. Food-chain transfer of U-series radionuclides in a Northern Saskatchewan aquatic system. Health Phys. 49: 747-770.

Underwood, E. J. 1977. Trace Elements in Human and Animal Nutrition, 4th Ed. Academic Press, New York, NY.

USEPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. EPA 540-R-97-006.

USEPA. 1998. Guidelines for Ecological Risk Assessment. Final. Risk Assessment Forum. EPA/630/R-95/002F.

USEPA. 2000. Ecological Soil Screening Level Guidance – Draft. USEPA, Office of Emergency and Remedial Response, Washington, D.C.

USEPA. 2004. Draft Selenium Aquatic Life Water Quality Criterion. Office of Water. EPA-822-D-04-001. December 17, 2004.

Van Derveer, W.D. and S.P. Canton. 1997. Selenium sediment toxicity thresholds and derivation of water quality criteria for freshwater biota of western streams. Environ. Toxicol. Chem. 16(6):1260-1268.

Venugopal, B. and T. P. Luckey. 1975. Toxicology of non-radioactive heavy metals and their salts. Pages 4-73 *in* F. Coulston and F. Korte (eds.), Environmental Quality and Safety, Suppl. Vol. I, Heavy Metal Toxicity, Safety, and Hormology. Academic Press, New York, NY.

Vocke, R.W., K.L. Sears, J.J. O'Toole, and R.B. Wildman. 1980. Growth responses of selected freshwater algae to trace elements and scrubber ash slurry generated by coal-fired power plants. Water Res. 14: 141-150.

Wahlgren, M.A., J.J. Alberts, D.M. Nelson, and K.A. Orlandini. 1976. Study of the behavior of transuranics and possible chemical homologues in Lake Michigan water and biota. In: IAEA. Transuranic nuclides in the environment, IAEA, Vienna, pp. 9-24.

Wahlstrom, R. C. and O. E. Olson. 1959. The effect of selenium on reproduction in swine. Journal of Animal Science 18: 141-145.

Warren-Hicks, W.J. and D.R.J. Moore, 1998. Uncertainty in Ecological Risk Assessment. SETAC Press. 314 pages.

Water Waste and Land (WWL). 1989. *Supporting Information to License Amendment Response Highland Reclamation Project, Glenrock, Wyoming.* Report prepared for Exxon Coal and Minerals Company by Water, Waste and Land, Inc. Fort Collins, Colorado.

Wentsel, R.S., LaPoint, T.W., Simini, M., Checkai, R.T., Ludwig, D., and Brewer, L., 1996. Tri-Service Procedural Guidelines for Ecological Risk Assessments. U.S. Army Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Maryland.

Wester, P. O., D. Brune and G. Nordberg. 1981. Arsenic and selenium in lung, liver and kidney tissue from dead smelter workers. Br. J. Ind. Med. 38:179.

Wiemeyer, S. N. and D. J. Hoffman. 1996. Reproduction in Eastern Screech-Owls Fed Selenium. J. Wildl. Manage. 602: 332-341.

Wyoming Department of Environmental Quality (WDEQ). 2005. Wyoming Water Quality Rules and Regulations, Chapter 8, Quality Standards for Wyoming Groundwaters.

Zafrir H, Waisel Y, Agami M, Kronfeld J, Mazor E. 1992. Uranium in plants of southern Sinai. *Journal of Arid Environment* 22: 363–368.

Zayed, A., S. Gowthaman, and N. Terry. 1998. Phytoaccumulation of trace elements by wetland plants: 1. Duckweed. J. Environ. Qual. 27: 715-721.

Zook, E. G., F. E. Greene, and E. R. Morris. 1970. Nutrient composition of selected wheat products. VI. Distribution of manganese, copper, nickel, zinc, magnesium, lead, tin, cadmium, chromium, and selenium, as determined by atomic absorption spectroscopy and colorimetry. Cereal Chem. 47: 720-731.

Appendix A

Summary Statistics for Selenium and Uranium Concentrations in Aquatic Biota from Highland Pit Lake and Box Creek

Species		Se mg/kg-DRY					U mg/kg-DRY				
		Pit Lake				Box Creek	Pit Lake				Box Creek
		9/04	10/04	2/05	6/05		9/04	10/04	2/05	6/05	
Leopard Frog	Min	95				0.3	9				0.08
	Max	136				3.7	15				0.32
	Mean	119			50	1.9	13			8	0.21
	STDEV	20				1.57	3				0.12
	95UCL	142				3.66	17				0.34
	n	4 (0)			1(0)	4(0)	4 (0)			1(0)	4(0)
Copepods	Min	39	25	8	31		516	613	225	505	
	Max	39	25	14	73		516	613	411	1170	
	Mean	39	25	11	47		516	613	346	945	
	STDEV			2	23				88	381	
	95UCL			13	70				434	1327	
	n	1 (0)	1(0)	5(0)	3(0)		1 (0)	1(0)	5(0)	3(0)	
Gastropod (snail)	Min	43	27	9	15		128	83	56	56	
	Max	45	36	9	15		206	91	56	56	
	Mean	44	32	9	15	0.45	167	87	56	56	0.28
	STDEV	1	6				55	6			
	95UCL	1	42				254	96			
	n	2 (0)	2(0)	1(0)	1(0)	1 (0)	2 (0)	2(0)	1(0)	1(0)	1(0)
Odonata	Min	130	0	0	130		64	0	0	1	
	Max	130	0	0	287		64	0	0	30	
	Mean	130			211	0.93	64			14	0.14
	STDEV				75					12	
	95UCL				286					26	
	n	1 (0)			5(0)	1(0)	1 (0)			5(0)	1(0)
Waterboatman	Min	13	27	6	23		3.70	83	4	4	
	Max	21	36	7	38		7.17	94	5	8	
	Mean	17	32	6	27	0.91	5.44	88	4.33	6.46	0.14
	STDEV	5	6	0	8		2.45	7.35	0.77	1.51	
	95UCL	26	42	7	35		9.32	100	5.32	8.15	
	n	2 (0)	2(0)	3(0)	4(0)	1(0)	2 (0)	2(0)	3(0)	4(0)	1(0)
Spiders					110					16	
	n				1(0)					1(0)	
Amphipods-BR	Min			46					22		
	Max			54					29		
	Mean			50					26		
	STDEV			5					5		
	95UCL			9					7		
	n			2(0)					2(0)		
Beetles-BR				50					16		
	n			1(0)					1(0)		
Fly Larvae-2	Min				6					3	
	Max				12					3	
	Mean				10					3	
	STDEV				4					1	
	95UCL				5					1	
	n				3(0)					3(0)	
Caddisfly				53		0.87			301		0.37
	n			1(0)		1(0)			1(0)		1(0)

APPENDIX B

A Literature Review on the Toxicity of Selenium

Toxicity to Birds

Black-crowned night herons were fed diets containing Se as selenomethionine at concentrations of 0 and 10 mg/kg for 13 days prior to egg laying (Smith et al. 1988). Hatching success, organ weights, hemoglobin concentration, hematocrit and eggshell thickness did not differ between controls and experimental birds. Developmental malformations commonly associated with Se exposure were not observed in heron embryos or hatchlings. An ingestion rate of 0.161 kg/day (Kushlan 1978) and body weight of 0.883 kg (Dunning 1993) were used to convert the exposure concentrations to units of mg/kgBW/day. A NOAEL of 1.8 mg/kgBW/day and an estimated LOAEL of 18.0 mg/kgBW/day were calculated based on the results of this experiment.

A feeding study with mallard ducks was conducted to identify diagnostic criteria for Se toxicosis in birds (Albers et al. 1996). One-year old male mallards were fed diets containing 0, 10, 20, 40 or 80 mg/kg Se as seleno-DL-methionine for 16 weeks. All ducks receiving diets containing 80 mg/kg died; 15 % of the birds fed 40 mg/kg Se died. Food consumption and body weight were significantly decreased in birds that received the 40 mg/kg Se diet; muscular atrophy, delayed molt, sloughed or broken claws and loss of feathers from the head and neck were also observed in this group. Testis weights were significantly decreased in the males which received the 20 mg/kg diet. Proposed diagnostic criteria for non-fatal chronic selenosis were low body weight due mostly to loss of breast muscle mass, poor plumage, delayed molt, a liver Se concentration that exceeds 66 mg/kg dry weight, reduced hatching success or an increased number of musculoskeletal abnormalities in embryos, or eggs that have a concentration of Se exceeding 10 mg/kg dry weight. An ingestion rate of 0.139 kg/day and adult body weight of 1.25 kg (Piccirillo and Quesenberry 1980) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 2.2 mg/kgBW/day (20 mg/kg; effects on testis) and a NOAEL of 1.1 mg/kgBW/day (10 mg/kg) were calculated based on the results of this experiment.

American kestrels were fed diets containing Se (as selenomethionine) at concentrations of 0, 6 or 12 mg/kg (dry weight) for 11 weeks (Santolo et al. 1999). No differences in egg production, hatchability, or incidence of embryonic malformations were observed in any treatment group. Fertility was significantly lower in birds fed diets containing 12 mg/kg Se as compared to control birds. To convert the dietary concentration from dry to wet weight, a percent moisture content of 32 % (mean water content for small mammals; Sample and Suter, 1994) was assumed, resulting in dietary exposure concentrations of 4.08 and 8.16 mg/kg. An ingestion rate of 0.0307 kg/day (Barrett and Mackey 1975) and body weight of 0.111 kg (Dunning 1993) were used to convert the exposure concentrations to units of mg/kgBW/day. A

LOAEL of 2.26 mg/kgBW/day and a NOAEL of 1.13 mg/kgBW/day were calculated based on the results of this experiment.

Wiemeyer and Hoffman (1996) evaluated dietary toxicity of Se (as selenomethionine) to Eastern screech owls. Owls were fed diets containing 0, 4.4 or 13.2 mg/kg Se (wet weight). Laboratory analysis of the diets confirmed the following exposure concentrations: not detected (ND) to 0.13 mg/kg for the control group, and 3.53 and 12 mg/kg for the two exposure groups. Adult body weight, number of eggs laid per pair, number of eggs hatched per pair, and number of nestlings surviving to five days were significantly lower for birds which received the highest dose. Control and low dosage birds did not differ in adult body weight, food consumption, or reproductive parameters. An ingestion rate of 0.025 kg/day (Pattee et al. 1988) and adult body weight of 0.185 kg (Dunning 1993) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 1.62 mg/kgBW/day and a NOAEL of 0.48 mg/kgBW/day were derived based on the results of this study.

Mallard ducks were fed diets containing Se as selenomethionine at concentrations of 0 and 10 mg/kg for 41 days prior to egg laying (Heinz and Hoffman, 1987). Birds exposed to dietary Se produced fewer young and had a higher incidence of abnormal embyros than controls. An ingestion rate of 0.139 kg/day and body weight of 1.25 kg (Piccirillo and Quesenberry 1980) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 1.11 mg/kgBW/day and an estimated NOAEL of 0.11 mg/kgBW/day were calculated based on the results of this experiment.

Heinz et al. (1989) evaluated dietary toxicity of organic Se as selenomethionine to mallard ducks. Ducks were exposed to diets containing 0, 1, 2, 4, 8 or 16 mg/kg Se diet (wet weight) for 100 days. Reduced duckling survival was observed in groups fed diets containing 8 mg/kg Se. Diets containing 8 and 16 mg/kg Se caused malformations in 6.8 and 67.9 %, respectively, of unhatched eggs compared with 0.6 % for controls. An ingestion rate of 0.10 kg/day and body weight of 1.0 kg (cited by authors) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 0.8 mg/kgBW/day and a NOAEL of 0.4 mg/kgBW/day were calculated. Based on the ecological significance of the endpoint (survival) and because the LOAEL is the lowest cited adverse effect level for birds, the TRV values from this study will be used to evaluate the risk posed by Se to avian receptors.

Albers, P.H., D.E. Green and C.J. Sanderson. 1996. Diagnostic criteria for selenium toxicosis in aquatic birds: Dietary exposure, tissue concentrations and macroscopic effects. J. Wildl. Diseases. 32(3):468-485.

Barrett, G.W. and C.V. Mackey. 1975. Prey selection and caloric ingestion rate of captive American kestrels. Wilson Bull. 87(4):514-519.

Dunning, J.B. Jr. 1993. *CRC Handbook of Avian Body Masses*. CRC Press, Boca Raton, FL.

Heinz, G.H., D.J. Hoffman, A.J. Krynitsky and D.M.G. Weller. 1987. Reproduction in mallards fed selenium. Environ. Toxicol. Chem. 6:423-433.

Heinz, G.H., D.J. Hoffman and L.G. Gold. 1989. Impaired reproduction of mallards fed an organic form of selenium. J. Wildl. Manage. 53:418-428.

Kushlan, J.A. 1978. "Feeding ecology of wading birds." In: Wading Birds. Sprunt, A., J.C. Ogden and S. Winckler (eds.). National Audubon Society Research Report No. 7. p. 249-297.

Pattee, O.H., S.N. Wiemeyer and D.M. Swineford. 1988. Effects of dietary fluoride on reproduction in Eastern screech-owls. Arch. Environ. Contam. Toxicol. 17:213-218.

Piccirillo, V.J. and R.P. Quesenberry. 1980. Reproductive capacities of control mallard ducks (*Anas platyrhynchos*) during a one-generation reproduction study. J. Environ. Path. Toxicol. 4:133-139.

Sample, B.E. and G.W. Suter II. 1994. Estimating exposure of terrestrial wildlife to contaminants. ES/ER/TM-125. Oak Ridge National Laboratory, Oak Ridge, TN.

Santolo, G.M., J.T. Yamamoto, J.M. Pisenti and B.W. Wilson. 1999. Selenium accumulation and effects on reproduction in captive American kestrels fed selenomethionine. J. Wildl. Manage. 63(2):502-511.

Smith, G.J., G.H. Heinz, D.J. Hoffman, J.W. Spann and A.J. Krynitsky. 1988. Reproduction in black-crowned night herons fed selenium. Lake and Reservoir Management. 4(2):175-180.

Wiemeyer, S.N. and D.J. Hoffman. 1996. Reproduction in Eastern screech owls fed selenium. J. Wildl. Manage. 60(2): 332-341.

Toxicity to Mammals

Male house rats (*Rattus rattus*) were fed diets containing Se (as sodium selenite) at concentrations of 0, 2 and 4 mg/kg for 5 weeks (Kaur and Parshad 1994). Ingestion of a diet containing Se at 4 mg/kg caused a significant decrease in sperm concentration, motility, the percentage of live spermatozoa, and testicular and cauda epididymal weight. A dose-dependant effect of Se on sperm morphology was observed; sperm from rats fed 2 mg/kg and 4 mg/kg dietary Se had three and 20 times more abnormalities than sperm from control rats, respectively. An ingestion rate of 0.016 kg/day (U.S. EPA 1988; value cited for 150 g Fischer 344 rats) and body weights of 0.14 and 0.15 kg (cited by authors for rats from the 4 and 2 mg/kg groups, respectively) were used to convert the exposure units to mg/kgBW/day. A LOAEL of 0.46 mg/kgBW/day and a NOAEL of 0.21 mg/kgBW/day were calculated based on the results of this experiment.

Rosenfeld and Beath (1954) evaluated toxicity of Se in drinking water to rats. Rats were exposed to potassium selenate at concentrations of 1.5, 2.5 and 7.5 mg/L for one year. No adverse effects on reproduction were observed among rats exposed to 1.5 m/L Se, but the number of second generation young was reduced by 50 % in the group exposed to 2.5 mg/L. An ingestion rate of 0.046 L/day and body weight of 0.35 kg (U.S. EPA 1988) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 0.33 mg/kgBW/day and a NOAEL of 0.20 mg/kgBW/day were calculated based on the results of this experiment.

Long-Evans rats were given drinking water containing Se (either as sodium selenite or sodium selenate) at concentrations of 0 or 2 Φg/ml for 180 days (Schroeder 1967). Mice (Charles River CD strain) were given selenite in drinking water at a concentration of 0 or 2 Φg/ml for 360 days. Increased mortality was observed in rats given selenite in drinking water (58 and 30 % after two months for males and females, respectively). Livers of rats that died were grossly abnormal, with fatty infiltration and degeneration, and cellular atrophy. No adverse effects were observed in mice. A water ingestion rate of 0.053 L/day and body weight of 0.43 kg (U.S. EPA 1988) were used to convert the exposure concentrations to units of mg/kgBW/day. Based on the mortality observed in rats, a LOAEL of 0.25 mg/kgBW/day and an estimated NOAEL of 0.025 mg/kgBW/day were calculated based on the results of this experiment. Based on the ecological significance of the endpoint (survival) and because the LOAEL is the lowest cited adverse effect level for mammals, the TRV values from this study will be used to evaluate the risk posed by Se to mammalian receptors.

Kaur, R. and V.R. Parshad. 1994. Effects of dietary selenium on differentiation, morphology and functions of spermatozoa of the house rat, Rattus rattus. Mutat. Res. 309(1):29-35.

Rosenfeld, I. And O.A. Beath. 1954. Effect of selenium on reproduction in rats. Proc. Soc. Exp. Biol. Med. 87:295-297.

Schroeder, H.A. 1967. Effects of selenate, selenite and tellurite on the growth and early survival of mice and rats. J. Nutr. 92:334-338.

U.S. EPA. 1988. Recommendations for and documentation of biological values for use in risk assessment. EPA/600/6-87/008.

APPENDIX C

A Literature Review on the Toxicity of Uranium

Toxicity to Birds

Kupsh et al. (1991) evaluated renal damage in Japanese quail exposed to uranyl nitrate. Uranyl nitrate solution at concentrations of 0.15 or 50 micromoles per kilogram (ΦMol/kg) BW as uranium (U) was administered intravenously. Eighteen hours later, the quail were sacrificed and the kidneys were examined. Severe damage was observed in the quail exposed to a U concentration of 50 ΦMol/kg body weight, particularly in the distal tubules. Glomerular damage was marked in quail kidneys, with atrophy, necrosis, and proteinuria. Due to the exposure route, this study was not used to derive a TRV for U to birds. Only studies that evaluated oral exposure to U were used to derive a TRV for this risk assessment, which is evaluating dietary exposure to contaminants of concern.

Three-week old Leghorn chicks were injected with 0 or 250 mg uranyl nitrate/kg BW (Mollenhauer et al. 1986). Dosages were administered subcutaneously at the base of the neck. Degenerative changes were observed in kidneys of U-treated birds, and were present in the proximal and distal tubules and collecting ducts. Kidneys of chickens, like those of mammals, were confirmed as a site of U storage. Due to the exposure route, this study was not used to derive a TRV for U to birds.

One-day old Leghorn cockerels (Hy-Line, W-36) were administered doses of uranyl nitrate by subcutaneous injection at concentrations of untreated controls, saline controls, 70, 100, 130, 160, 190, 220, 250, 280, 310, 340, 370, 400, 430, or 460 mg UN/kg BW (Harvey et al. 1986). Mortality was monitored for seven days and an LD_{50} value was calculated. The lowest dose that resulted in mortality was 160 mg/kg BW. The 7-day LD_{50} for uranyl nitrate was 235 mg/kg BW. Microscopic examination revealed mild focal proximal convulated tubular degeneration in kidneys within 12 hours of injection. At 48 hours, renal lesions included moderate to severe nephrosis, cellular and protein casts, and some regeneration. By 96 hours, no major lesions in kidneys were observed. Severe hepatic necrosis was present in liver sections. Due to the exposure route, this study was not used to derive a TRV for U to birds.

Japanese quail were given intravenous injections of UCl_3 or $OU(NO_3)$ at a concentration of 1.5 Φmol/100g to evaluate distribution in tissues and eggs (Robinson et al. 1984). Whole body losses 18 hours following injection were 24% for females and 72% for males. Cumulative deposition in yolks of eggs laid over 8 days following injection were 1.9% for U(III) and 1.7% for U(VI). Marked deposition of U was observed in leg bones of female quail [12.5% for U(III) and 14.1% for U(VI)]. Tissue distribution was the only effect measured in this experiment. Due to the exposure route, this study was not used to derive a TRV for U to birds.

American black ducks were fed diets containing powdered U at concentrations of 0, 25, 100, 400 or 1,600 mg/kg for 6 weeks (Haseltine and Sileo 1983). One male in the 100 mg/kg treatment group died during the experiment, but pathological kidney changes associated with U toxicity in mammals were not observed; the authors did not attribute the death to U exposure. Treatment-related weight loss was not observed at any exposure concentration. No significant gross or microscopic lesions were observed in birds exposed at any concentration. Examination of the kidneys did not reveal any lesions in the distal third of the proximal convoluted tubule, which is characteristic of U exposure in mammals. A body weight of 1.25 kg (Dunning 1993) and an ingestion rate of 0.125 kg/day (Heinz *et al.* 1989) were used to convert the exposure concentrations to units of mg/kgBW/day. A NOAEL of 160 mg/kgBW/day and an estimated LOAEL of 1600 mg/kgBW/day will be used to evaluate the toxicity of U to avian receptors.

Dunning, J. B., Jr. (1993). CRC Handbook of Avian Body Masses. Boca Raton, FL, CRC Press.

Haseltine, S. D. and L. Sileo (1983). "Response of American black ducks to dietary uranium: a proposed substitute for lead shot." J. Wildl Manage. **47**: 1124-1129.

Harvey, R. B., L. F. Kubena, S. L. Lovering, Mollenhauer, H.H. and T. D. Phillips (1986). "Acute toxicity of uranyl nitrate to growing chicks: A pathophysiologic study." Bull. Environ. Contam. Toxicol. **37**: 907-915.

Heinz, G. H., D. J. Hoffman and L. G. Gold (1989). "Impaired reproduction of mallards fed an organic form of selenium." J. Wildl. Manage. **53**: 418-428.

Kupsh, C.C., R.J. Julian, V.E.O. Valli and G.A. Robinson. 1991. Renal damage induced by uranyl nitrate and estradiol-17beta in Japanese quail and Wistar rats. Avian Pathology. 20(1):25-34.

Mollenhauer, H. H., R. B. Harvey, L. F. Kubena, R. E. Droleskey and R. Davis (1986). "Distribution and form of uranium-containing deposits in chickens treated with uranyl nitrate." Veterinary Pathology **23**: 706-711.

Robinson, G. A., D. C. Wasnidge and F. Floto (1984). "A comparison of the distributions of the actinides uranium and thorium and the lanthanide gadolinium in the tissues and eggs of Japanese quail: Concentrations of uranium in feeds and foods." Poultry Science **63**: 883-891.

Toxicity to Mammals

Acute toxicity of U to male Sprague-Dawley rats and male Swiss mice was evaluated by (Domingo *et al.* 1987). Single doses of uranyl acetate were administered by subcutaneous injection or orally via gavage. Oral and subcutaneous exposure concentrations for rats were 0, 20, 40, 80, 160, 320, 640 or 1,280 mg/kg and 0, 1.25, 2.5, 5, 10, 20, or 40 mg/kg. Exposure concentrations for mice were 0, 44, 80, 144, 259, 466, or 839 mg/kg and 0, 10, 15, 22.5, 33 or 50 mg/kg. For animals whose exposure was via gavage, LD_{50}

concentrations were 204 and 242 mg/kg for rats and mice, respectively. The LD_{50} values for subcutaneous exposure were much lower, 8.3 mg/kg for rats and 20.4 mg/kg for mice.

Sprague-Dawley rats were given uranyl nitrate hexahydrate in drinking water at concentrations of 0, 0.96, 4.8, 24, 120 or 600 mg/L for 91 days (Gilman *et al.* 1998a). At the end of the study, animals were euthanized and hematological, biochemical and histopathological analyses were conducted. No significant differences in weight gain, food consumption, or water intake were observed at any exposure concentration. Significant histopathological changes were observed in the kidney and liver. Incidence and severity of renal lesions were significantly different from control animals at all U exposure concentrations. A LOAEL of 0.06 and 0.09 mg/kgBW/day for male and female rats, respectively, (units reported by authors) and estimated NOAEL of 0.006 and 0.009 mg/kgBW/day were identified from this study. The biological significance of kidney lesions is not known; therefore, this study was not used to select a TRV for this risk assessment.

New Zealand white rabbits were given uranyl nitrate hexahydrate in drinking water for 91 days (Gilman *et al.* 1998b). Males were exposed at concentrations of 0, 0.96, 4.8, 24, 120 or 600 mg/L, while exposure concentrations for females were 0, 4.8, 24 or 600 mg/L. At the end of the study, animals were euthanized and hematological, biochemical and histopathological analyses were conducted. No significant differences in weight gain, food consumption, or water intake were observed for either sex at any exposure concentration. Significant dose-related histopathological changes were observed in the kidney and thyroid glands, and to a lesser extent in the liver. Incidence and severity of renal lesions were significantly different from control animals at all U exposure concentrations. A LOAEL of 0.05 mg/kgBW/day (units reported by authors) and an estimated NOAEL of 0.005 mg/kgBW/day were identified from this study. The biological significance of kidney lesions is not known; therefore, this study was not used to select a TRV for this risk assessment.

Sprague-Dawley rats were exposed to uranyl acetate dihydrate in drinking water at concentrations of 0, 2, 4, 8 and 16 mg/kgBW/day for 4 weeks (Ortega *et al.* 1989). No significant differences in weight gain, food or water consumption were observed at any exposure concentration. Histopathological lesions in kidneys, liver and spleen were observed in rats exposed at a concentration of 16 mg/kgBW/day. A LOAEL of 16 mg/kgBW/day and a NOAEL of 8 mg/kgBW/day were identified from this experiment. The biological significance of kidney lesions is not known; therefore, this study was not used to select a TRV for this risk assessment.

Reproductive toxicity of uranyl acetate to male Swiss mice was evaluated by (Llobet *et al.* 1991). Mice were exposed to U in drinking water at concentrations of 0, 10, 20, 40 or 80 mg/kgBW/day for 64 days. At the end of the treatment period, each mouse was mated with two untreated females for four days. There was a significant decrease in pregnancy rate for all females mated to U exposed mice. Number of implantations, resorptions and dead fetuses did not differ in females that became pregnant. Adult body weights were significantly lower than controls for the 80 mg/kgBW/day exposure group. Testicular function and spermatogenesis were not significantly different from controls for any exposure group. Based on the decreased pregnancy rate, a LOAEL of 10 mg/kgBW/day and an estimated NOAEL of 1.0 mg/kgBW/day were identified from this experiment.

Swiss mice were administered uranyl acetate dihydrate at concentrations of 0, 5, 10, and 25 mg/kgBW/day (Paternian *et al.* 1989). Male mice were exposed for 60 days prior to mating, and female mice were exposed for 14 days prior to mating. Treatment of the females continued throughout mating, gestation, and nursing of the litters. Oral doses were given intragastrically. No adverse effects on fertility were observed at any exposure concentration. Numbers of late resorptions and dead fetuses were significantly increased for the 25 mg/kg/day exposure group. There was a significant increase in the number of dead young per litter for both the 10 and 25 mg/kg/day exposure groups. Growth of the offspring was significantly lower in all U-treated groups, and a significant dose-response relationship was observed. Based on the reduced growth, a LOAEL of 5 mg/kgBW/day and an estimated NOAEL of 0.5 mg/kgBW/day were identified.

To evaluate developmental toxicity of U, pregnant Swiss mice were given by gavage daily doses of 0, 5, 10, 25 and 50 mg/kgBW/day of uranyl acetate dihydrate on gestational days 6 to 15 (Domingo *et al.* 1989). Maternal toxicity was observed. Maternal weight gain was significantly lower in the 10, 25 and 50 mg/kg exposure groups, and food consumption was significantly lower in all U-exposed mice. Relative liver weights were significantly higher in all exposed females. There were no treatment-related effects on number of implantations, incidence of post-implantation loss, number of live fetuses per litter, or fetal sex ratio. Body weights of live fetuses were significantly reduced in all U-treated groups, and a significant dose-response relationship was observed. Uranium treatment resulted in a significantly increased incidence of external malformations (cleft palate, short or curled tails, hematoma) at all exposure concentrations. An increased incidence of poorly ossified or unossified skeletal elements was observed in mouse fetuses at exposure concentrations of 25 and 50 mg/kgBW/day. Based on the reduced fetal weight and increased incidence of external malformations, a LOAEL of 5 mg/kgBW/day and a estimated NOAEL of 0.5 mg/kgBW/day were identified from this experiment, and will be used to evaluated risk to mammals from exposure to U.

Domingo, J. L., J. M. Llobet, J. M. Tomas and J. Corbella (1987). "Acute toxicity of uranium in rats and mice." Bull. Environ. Contam. Toxicol. **39**: 168-174.

Domingo, J. L., J. L. Paternian, J. M. Llobet and J. Corbella (1989). "The developmental toxicity of uranium in mice." Toxicology **55**: 143-152.

Gilman, A., A. Gilman, D. C. Villeneuve, V. E. Secours, A. P. Yagaminas, B. L. Tracey, J. M. Quinn, V. E. Valli, R. J. Willes and M. A. Moss (1998a). "Uranyl nitrate: 28-day and 91-day toxicity studies in the Sprague-Dawley rat." Toxicol. Sci. **41**(1): 117-128.

Gilman, A., D. C. Villeneuve, V. E. Secours, A. P. Yagaminas, B. L. Tracey, J. M. Quinn, V. E. Valli and M. A. Moss (1998b). "Uranyl nitrate: 91-day toxicity studies in the New Zealand white rabbit." Toxicol. Sci. **41**(1): 129-137.

Llobet, J. M., J. J. Sirvent and A. Ortega (1991). "Influence of chronic exposure to uranium on male reproduction in mice." Fundam. Appl. Toxicol. **16**: 821-829.

Ortega, A., J. L. Domingo and J. M. Llobet (1989). "Evaluation of the oral toxicity of uranium in a 4-week drinking water study in rats." Bull. Environ. Contam. Toxicol. **42**: 935-941.

Paternian, J. L., J. L. Domingo, A. Ortega and J. M. Llobet (1989). "The effects of uranium on reproduction, gestation, and postnatal survival in mice." Ecotoxicol. Environ. Safety **17**: 291-296.

APPENDIX D

Literature Review of Toxicity Data to Develop Selenium Toxicity Reference Values

Selenium

Species		Se (ppm)	Effect	Reference
MAMMALS-DIETARY				
General		0.1	Safe limit	Kabata-Pendias and Kabata (1992)
Swine		0.13	NOAEL	Lindberg (1968)
General		2	Safe limit	Hapke (1991)
Swine		2.5	NOAEL	Moxon and Mahan (1981)
Rat		3.75	Increased reproduction	Halverson (1966)- DW=WW/0.2
General		4.5	Critical conc.	NAS (1980), Underwood (1977)
General		5	Upper critical conc.	Davis et al. (1978)
General		5	Safe limit	NAS (1980)
Pronghorn antelope		15	NOAEL	Raisbeck et al. (1996)
Cattle		4	LOAEL	Underwood (1977)
General		4	Toxic	Hapke (1991)
Cattle		5	Toxic	NAS (1976),Underwood (1977), Cumbie and Van Horn (1978)
Dogs		5	Chronic poisoning	Munsell et al. (1936)
Swine		5	Weight loss	Moxon and Mahan (1981)
Rat		5	Toxic	NAS (1976)
General		5	Prevented normal growth	Rosenfeld and Beath (1964)
Dogs		7.2	Toxic	Olson (1986)
Sheep		8	Weight loss	Pierce and Jones (1968)
General		9	Lethal to juveniles	Rosenfeld and Beath (1964)
Swine		10	Reduced reproduction	Wahlstrom and Olson (1959)
Swine		10	Selenosis	Rosenfeld and Beath (1954)
Sheep		10	Toxic	Hapke (1991)
General		10	Decreased adult food intake	Rosenfeld and Beath (1964)
General		10	Decreased reproduction	Wahlstrom and Olson (1959)
Sheep		16	Some mortality	Pierce and Jones (1968)
Dogs		20	Lethal	Munsell et al. (1936)
Swine		20	Toxic/lethal	Moxon and Mahan (1981)
Human		3300	Hair loss, nail splitting	Dickson (1969)
MAMMALS-IN TISSUE				
Human	Lung	0.21	NOAEL	Berman (1980)
	Heart	0.27	NOAEL	Bowen (1979)
	Liver	0.39	NOAEL	Berman (1980)
	Muscle	0.4	NOAEL	Berman (1980)
	Body	0.53	NOAEL	Fergusson (1990), DW=WW/0.35
	Kidney	0.63	NOAEL	Berman (1980)
	Body	0.83	NOAEL	Kieffer (1979), DW=WW/0.35
	Lung	1	NOAEL	Anspaugh et al. (1971), DW=WW/0.2
	Liver	1.45	NOAEL	Wester et al. (1981), DW=WW/0.2
	Muscle	2	NOAEL	Anspaugh et al. (1971), DW=WW/0.2
	Kidney	3.95	NOAEL	Wester et al. (1981), DW=WW/0.2
	Body	12.9	NOAEL	Stewart et al. (1978), DW=WW/0.35

Selenium, Continued

Species	Se (ppm)	Effect	Reference
MAMMALS-IN TISSUE			
Swine			
Muscle	0.52	NOAEL	Lindberg (1968)
Heart	1.05	NOAEL	Lindberg (1968)
Lung	1.13	NOAEL	Lindberg (1968)
Spleen	1.26	NOAEL	Lindberg (1968)
Pancreas	1.42	NOAEL	Lindberg (1968)
Liver	1.82	NOAEL	Lindberg (1968)
Kidney	11.47	NOAEL	Lindberg (1968)
MAMMALS-DIETARY WATER			
Human	0.05	Safe drinking water	EPA MCL
Hamster	3	NOAEL	Hadjimarkos (1970)
Monkey	1	Lesions	Bowen (1972)
Rats	2	Tumor production	Schroeder and Mitchner (1971a)
Rats	3	Toxic	Hadjimarkos (1970)
Hamster	9	LOAEL	Beath (1962)
AVIFUANA-DIETARY			
Chicken- juvenile	2	NOAEL	Arnold et al. (1973)
Mallard- juvenile	10	NOAEL	O'Toole and Raisbeck (1997)
Chicken- juvenile	3	Min. toxic level	Munsell et al. (1936)
Chicken- juvenile	5	Reduced hatching	Moxon and Poley (1938)
Chicken- juvenile	8	Reduced hatching	Arnold et al. (1973)
Chicken- juvenile	10	0% hatching	Moxon and Polley (1938)
Chicken- juvenile	10	20% growth red.	Berg and Martinson (1972)
Mallard- juvenile	25	Lesions, weight loss	O'Toole and Raisbeck (1997)
AVIFAUNA-IN TISSUE			
Coot-liver	8.5	NOAEL	Stephen et al. (1992)
INVERTEBRATES DIETARY AQUATIC			
Daphnia magna	295	NOAEL	Foe and Knight (1986)
INVERTEBRATES-WATER AQUATIC			
Daphnia magna	0.15	NOAEL	Foe and Knight (1986)
Crabs	1	LC50-96 hr	Forstner and Wittmann (1981)
Daphnia magna	1.99	Toxic	Dunbar et al. (1983)

Selenium, Continued

Species	Se (ppm)	Effect	Reference
PLANTS / GRASS-TISSUE			
General	0.032	NOAEL	Fergusson (1990)
General	0.033	NOAEL	Kabata-Pendias and Pendias(1992)
Wheat	0.7	NOAEL	Zook et al. (1970)
Wheat	0.7	NOAEL	Lindberg (1968)
Wheat	0.8	NOAEL	Scott and Thompson (1971)
General	1	NOAEL	Bennet (1983)
Wheat	2.2	NOAEL	Fergusson (1990)
Barley	30	Upper critical concentration	Davis et al. (1978)
PLANTS / FORB TISSUE			
General	0.1	NOAEL	Hapke (1991)
Alfalfa	0.1	NOAEL	Kabata-Pendias and Pendias(1992)
Clover	0.1	NOAEL	Kabata-Pendias and Pendias(1992)
Brassica oleracea	0.13	NOAEL	Bowen (1974)
Kale	0.13	NOAEL	Fergusson (1990)
Cabbage	0.15	NOAEL	Fergusson (1990)
Clover	0.32	NOAEL	Allaway and Hodgson (1964), Gissel-Nielsen (1975)
General	1	NOAEL	Kabata-Pendias and Pendias(1992)
General	2	NOAEL	Fergusson (1990)
Neptunia amplexicaulis	4000	NOAEL	Knott and McCay (1959), highly tolerant
Astragals racemosus	14920	NOAEL	Knott and McCay (1959), highly tolerant
General	5	Toxic	Fergusson (1990)
General	15	Growth reduction	Kloke et al. (1984)
General	18	Toxic	Kabata-Pendias and Pendias(1992)
PLANTS / WOODY-TISSUE			
Angiosperms	0.03	NOAEL	Conner and Shacklette (1975)
Gymnosperms	0.03	NOAEL	Conner and Shacklette (1975)
PLANTS / AQUATIC-WATER			
Algae			
Green	0.01	NOAEL	Bowen (1979)
General	0.05	NOAEL	Foe and Knight (1986)
Chorella spp	0.03	Toxic	Hutchinson (1973)
Selenastrum spp	0.03	Toxic	Foe and Knight (1986)
Selenastrum spp	0.1	Sublethal	Maier and Knight, 1994
Selenastrum spp	0.1	Decreased replication	Foe and Knight(1986)
Scenedesmus spp	0.1	Reduced growth	Moede et al. (1980)
Chorella spp	0.13	Toxic	Shrift (1954)
Selenastrum spp	0.3	Reduced growth	Vocke et al. (1980)
Scenedesmus spp	22.1	Reduced growth	Moede et al. (1980)

Selenium, Continued

Species	Se (ppm)	Effect	Reference
PLANTS / AQUATIC-WATER			
Blue-green			
Anabaena spp	0.025	Toxic	Kumar and Prakash (1971)
Phormidium spp	0.56	Toxic	Sielicki and Burnham (1973)
Microcoleus spp	5.2	Toxic	Vocke et al. (1980)
Microcoleus spp	10	Reduced growth	Vocke et al. (1980)
Anabaena spp	20	Toxic	Moede et al. (1980)
Anabaena spp	22	Reduced growth	Moede et al. (1980)
Anacystis spp	39	Toxic	Kumar and Prakash (1971)
Lemna minor	2	LOAEL->10% growth decrease	Zayed et al. (1998)

APPENDIX E

Literature Review of Toxicity Data to Develop Uranium Toxicity Reference Values

Uranium

Species	U(ppm)	Effect	Ref
MAMMALS-DIETARY			
Ruminants	0.4	Max. recommended level	Dreesel and Marple (1979)
Mice	2-237	NOAEL	NAS (1980)
Rats	474	NOAEL	NAS (1980)
Rats	500	Tolerated	Venugopal and Luckey (1975), soluble U salts
Rats	200000	Tolerated	Venugopal and Luckey (1975), insoluble U salts
Rabbit	56	LOAEL- renal damage	IRIS (1999), Maynard and Hodge (1949)
Rats	>500	Growth depression	Venugopal and Luckey (1978), soluble U salts
Rats	1000-4000	Mortality	Venugopal and Luckey (1978), soluble U salts
Rats	2370	Growth depression	NAS (1980)
Mice	2370	Growth depression	NAS (1980)
Mice	4740	Mortality	NAS (1980)
Rats	9480	Mortality	NAS (1980)
MAMMALS-IN-TISSUE			
Elk			
Muscle	0.002-0.005	NOAEL	Fresquez et al. (1994)
Brain	0.0032-0.0045	NOAEL	Fresquez et al. (1994)
Liver	0.006-0.009	NOAEL	Fresquez et al. (1994)
Heart	0.011-0.019	NOAEL	Fresquez et al. (1994)
Kidney	0.022-0.134	NOAEL	Fresquez et al. (1994)
Human			
Liver	0.003	NOAEL	Iyengar et al. (1978)
Kidney	0.017	NOAEL	Iyengar et al. (1978)
Bone	0.12	NOAEL	Bowen (1979)
Muscle	0.36	NOAEL	Bowen (1979)
Rabbit			
Bone	0.05	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
Kidney	0.16-0.42	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
Muscle	0.29	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
Heart	0.455	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
Liver	0.68	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
General- kidney	1	Renal damage	Berlin and Rudell (1979)
MAMMALS-DIETARY WATER			
Human	0.035	Safe limit	NAS (1983)
Mice	26-235	Decreased pregnancy rate	Llobet et al. (1991), non-dose dependent
Mice	235	Decreased body weight	Llobet et al. (1991)
AVIFAUNA-DIETARY			
Am. black duck	25-1600	NOAEL	Haseltine and Sileo (1983)
AVIFAUNA-IN TISSUE			
Japanese quail	0.08	NOAEL	Robinson et al. (1984), DW=WW/0.35
Ruffed grouse			
Liver	0.2	NOAEL	Clulow et al. (1992)
Muscle	0.2	NOAEL	Clulow et al. (1992)
Bone	0.4	NOAEL	Clulow et al. (1992)

Uranium, Continued

Species	**U(ppm)**	**Effect**	**Ref**
INVERTEBRATES-SOIL TERRESTRIAL			
Lumbricus terrestris	3-100	NOAEL	Sheppard and Evenden (1992)
Lumbricus terrestris	1000	Decreased longevity	Sheppard and Evenden (1992)
INVERTEBRATES-TISSUE TERRESTRIAL			
Blackflies	2.85	NOAEL	Swanson (1985), DW=WW/0.2
Dragonflies	4.75	NOAEL	Swanson (1985), DW=WW/0.2
Caddisflies	22	NOAEL	Swanson (1985), DW=WW/0.2
INVERTEBRATES-WATER AQUATIC			
Cladoceran- *Moinodaphnia macleayi*	0.01	NOAEL	Hyne et al. (1993)
Cladoceran- *Moinodaphnia macleayi*	0.025	Decreased survival	Hyne et al. (1993)
Daphnia magna	0.52	Decreased reproduction	Poston et al. (1984)
Daphnia magna	1.44	No reproduction	Poston et al. (1984)
Daphnia magna	5.3	LC50-48hr, 67ppm CaCO3	Poston et al. (1984)
Daphnia magna	44.6	LC50-48hr,126ppm CaCO3	Poston et al. (1984)
Daphnia magna	74.3	LC50-48hr,188ppm CaCO3	Poston et al. (1984)
PLANTS / GRASS-TISSUE			
Corn	0.008	NOAEL	Laul et al. (1977)
Sporobolus airoides	0.05-0.17	NOAEL	Dreesen and Marple (1979)
Calamagrostis rubescens	0.06	NOAEL	Mahon and Mathewes (1983)
General	36	NOAEL	Dreesen et al. (1982)
PLANTS / GRASS-IN SOIL			
Sporobolus airoides	2-176	NOAEL	Dreesen and Marple (1979)
Aristida purpurea	50-5000	NOAEL	Meyer and McLendon (1997)
Buchloe dactyloides	50-5000	NOAEL	Meyer and McLendon (1997)
Schizachyrium scoparium	50-5000	NOAEL	Meyer and McLendon (1997)
Aristida purpurea	25000	Decreased survival, biomass,fecundity	Meyer and McLendon (1997)
Buchloe dactyloides	25000	Decreased survival, biomass, fecundity	Meyer and McLendon (1997)
Schizachyrium scoparium	25000	Decreased survival, biomass, fecundity	Meyer and McLendon (1997)
Species	**U(ppm)**	**Effect**	**Ref**
PLANTS / FORB TISSUE			
Brassica oleracea	0.011	NOAEL	Bowen (1979)
Lupinus articus	0.025	NOAEL	Mahon and Mathewes (1983)
Equisetum	0.03	NOAEL	Wahlgren et al. (1976)
Epilobium angustifolium	0.03	NOAEL	Mahon and Mathewes (1983)
General	0.12	NOAEL	Bowen (1979)
Astragalus spp	0.12	NOAEL	Zafrir et al. (1992), DW=AW/0.1
Cleome droserifolia	0.185	NOAEL	Zafrir et al. (1992), DW=AW/0.1
Aster subspicatus	0.32	NOAEL	Mahon and Mattewes (1983)
Annuals	12	NOAEL	Dreesen et al. (1982)

Uranium, Continued

Species	**U(ppm)**	**Effect**	**Ref**
PLANTS / FORB-IN SOIL			
General	2	Beneficial	Stoklasa and Penkava (1928)
Brassica rapa	50-300	NOAEL	Sheppard and Evenden (1992)
Geranium spp	500	NOAEL	Free (1917)
General	48	LOAEL	Stoklasa and Penkava (1928)
General	476	Thin roots, twisted leaves	Stoklasa and Penkava (1928)
Brassica rapa	1000	Decreased germination	Sheppard and Evenden (1992)
General	10000	Lethal	Stoklasa and Penkava (1928)
PLANTS / WOODY-TISSUE			
General	0.28	NOAEL	Bowen (1979)
Angiosperms	0.022	NOAEL	Cannon (1960)
Acacia raddiana	0.095	NOAEL	Zafrir et al. (1992), DW=AW/0.1
Betula papyrifera- twig	0.19	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Alnus rugosa- twig	0.29	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Betula papyrifera- leaves	0.51	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Alnus rugosa- leaves	0.54	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Gymnosperms			
Juniper- fruit	0.05-0.1	NOAEL	Cannon (1952), DW=AW/0.1
Picea mariana- terminal 15cm	0.13-0.22	NOAEL	Sheard (1986)
Picea spp- twig	0.19-0.28	NOAEL	Dunn (1981)
Pinus banksiana- twig	0.2	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Pinus banksiana- needles	0.24	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Picea mariana- twig	0.28	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Juniper- stems	0.38	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Picea mariana- needles	0.38	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Juniper- needles	0.48	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Pinus banksiana-- terminal 15cm	0.57	NOAEL	Sheard (1986)
Juniper- roots	0.8-2	NOAEL	Cannon (1952), DW=AW/0.1
Shrubs			
Atriplex canescens	0.01-3	NOAEL	Dreesen and Marple (1979)
Saltbrush- stems	0.05	NOAEL	Cannon (1952), DW=AW/0.1
Saltbrush- fruits	0.09	NOAEL	Cannon (1952), DW=AW/0.1
Artemisia judaica	0.1	NOAEL	Zafrir et al. (1992), DW=AW/0.1
Alnus crispa- terminal 15cm	0.13	NOAEL	Sheard (1986)
Ledum spp- terminal 15cm	0.16-0.19	NOAEL	Sheard (1986)
Saltbrush- leaves	0.19	NOAEL	Cannon (1952), DW=AW/0.1
Ledum spp- stem	0.19	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Ledum spp- leaves	0.34	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Vaccinium myrtilloides	0.51-0.61	NOAEL	Sheard (1986)
Vaccinium vitisidaea	0.22-0.29	NOAEL	Sheard (1986)

Uranium, Continued

Species	U(ppm)	Effect	Ref
PLANTS / WOODY-IN SOIL			
Atriplex canescens	1.5-176	NOAEL	Dreesen and Marple (1979)
PLANTS / AQUATIC-WATER			
Nuphar lutea	0.2-0.34	NOAEL	Mahon and Mathewes (1983)
PLANTS / AQUATIC-WATER			
Nuphar lutea	0.08-0.7	NOAEL	Mahon and Mathewes (1983)
PLANTS / AQUATIC-SEDIMENT			
Nuphar lutea	14-15	NOAEL	Mahon and Mathewes (1983)

APPENDIX F

Summary of Safe Levels of Selenium and Uranium in Wildlife

Safe Dietary Levels

Receptor		Selenium	Uranium
Mammal	Human	2	167
	Cattle	2	0.4
	Elk	2	0.4
	Deer	2	0.4
	Coyote	2	167
	Mt. Lion	2	167
	Porcupine	2	167
	Raccon	2	167
	Hare	2	28
	Rodents	2	478
	Shrew	2	167
Birds	Meadowlark	2	1600
	Blackbird	2	1600
	Dipper	2	1600
	Coot	2	1600
	Mallard	2	1600
	Hawk	2	1600
	Owl	2	1600
Invertebrate	Insect		100
	Aquatic		100

Note: measurement in mg/kg

Safe water levels

Receptor		Selenium	Uranium
Mammal	Human	0.2	25
	Cattle	0.2	25
	Elk	0.2	25
	Deer	0.2	25
	Coyote	0.2	25
	Mt. Lion	0.2	25
	Porcupine	0.2	25
	Raccoon	0.2	25
	Hare	0.2	500
	Rodents	0.2	25
	Shrew	0.2	25
Birds	Meadowlark	0.2	25
	Blackbird	0.2	25
	Dipper	0.2	25
	Coot	0.2	25
	Mallard	0.2	25
	Hawk	0.2	25
	Owl	0.2	25
Invertebrate	Ter. Insect		
	Aquatic	0.0005	0.1

Note: Measurement in mg/l water

Safe Plant Tissue and Growth Media Levels

Receptor		Selenium	Uranium
Plants (Tissue)	Grass	30	36
	Forb	2	12
	Shrub	2	3
	Conifer	2	3
	Deciduous	2	3
	Aquatic	2	>0.7
Plants (Soil)	Grass		5000
	Forb		300
	Shrub		176
	Conifer		176
	Deciduous		176
(Sediment)	Aquatic		15
Plants (Solution)	Grass		
	Forb		
	Shrub		
	Conifer		
	Deciduous		
	Aquatic	0.05	>0.34

Note: mg/kg tissue or media

APPENDIX G

Wildlife Field Notes For Visits To Highland Pit Lake

Avian Activity and Abundance, Highland Pit Lake

Species	# of Birds	Activity	Location	Weather
9/13/2004				
Canada geese	4	Fly-by	NW corner of pitlake	Sunny, Windy
Eared grebe	1	Juvenile, floating/feeding	Near cattails	
Eared lark	2	Flying	Near cattails	
Marshhawk	1	Flying	Near cattails	
Yellow-headed blackbird	8	Flying	Near cattails	
Sum		**16**		
9/14/2004				
Blue-winged teal	7	Flying, floating	Throughout pitlake	Sunny, pleasant
Franklin's gull	17	Fly-by	North part of lake	
Golden eagle	2	Yearling+ adult; Hunting, stooping at gulls	North end of pitlake	
Eared grebe	2	Juvenile + adult, floating/feeding	Near cattails	
Eared grebe	3	Flying	Near cattails	
Marshhawk	2	Flying	Near cattails	
Northern harrier	1	Flying	Near cattails	
Yellow-headed blackbird	2	Flying	Near cattails	
Sum		**16**		
9/15/2004				
Blue-winged teal	7	Floating	Throughout pitlake	Sunny, pleasant
Falcon	3	Flying	Throughout pitlake	
Franklin's gull	12	Floating	Throughout pitlake	
Golden eagle	2	Yearling+ adult; Hunting	North end of pitlake	
Eared grebe	2	Juvenile + adult, floating/feeding	Near cattails	
Eared grebe	8	Flying	Near cattails	
Marshhawk	2	Flying	Near cattails	
Northern shoveler	10	Floating	Throughout pitlake	
Sum		**46**		
10/25/2004				
Blue-winged teal	50	Floating	North end of pitlake	Sunny, Windy
Golden eagle	1	Soaring	Over lake	
Horned lark	3	Flying	Near cattails	
Marshhawk	1	Flying	Near cattails	
Sum		**55**		
10/26/2004				
Blue-winged teal	60	Floating	W end of lake	Sunny, Windy
Franklin's gull	6	Flying	Over lake	
Golden eagle	2	Soaring	Near turnoff to pitlake	
Horned grebe	8	Floating/diving	W end of lake	
Horned lark	8	Flying	Near turnoff to pitlake	
Mallard	12	Flying	Over lake	
Marshhawk	1	Soaring	Near turnoff to pitlake	
Sum		**97**		

Avian Activity and Abundance, Highland Pit Lake, Cont'd

Species	# of Birds	Activity	Location	Weather
10/27/2004				
Blue-winged teal	80	Flying over lake	Over lake	Sunny, Windy
Herring gull	1	Swooping down to lake	Lake center	
Horned grebe	15	Floating/diving, W end of lake	W end of lake	
Horned lark	8	Flying near turnoff to pitlake	Near turnoff to pitlake	
Marshhawk	1	Flying	Near cattails	
Sum		**105**		
2/21/2005				
Canada geese	1	Walking	On point bar - N shore	Cloudy, windy
Northern pintail	0	Old bird nest	30 feet from shore above littoral zone in tall grass clump	
Sum		**1**		
2/22/2005				
Canada geese	45	Flying overhead	North end of pitlake	Sunny, windy
Sum		**45**		
2/23/2005				
Golden eagle	1	Flying	Over uplands west of Pit Lake	Cloudy, windy
Sum		**1**		
2/24/2005				
Canada geese	18	10 landing; 8 resting	Northern arm of Pit Lake; West shoreline	Sunny, pleasant
Sum		**18**		
3/23/2005				
Canada geese	14	Lesser Can's N end of lake	North end of pitlake	Partly sunny, calm
Golden eagle	1	Soaring	Boner property - over nests	
Great horned owl	1	Nesting	By gate entrance	
Mallard	7	Floating	SW lake location 3	
Marshhawk	3	2 females - male courting displays, flying	Near boat ramp	
Northern pintail	1	Floating	SW location 3	
Scaup	2	Floating	N end of lake	
Short-eared owl	1	Flying	S of lake near Boner	
Sum		**30**		
3/24/2005				
Canada geese	4	Two separate pairs; look like ready to nest	Near point at lake center	Very windy, snowy
Short-eared owl	2	Flying	S of Pit Lake	
Sum		**6**		
4/6/2005				
Canada geese	6	Floating pairs; males fought	2 on W end of lake; 2 center of lake; 2 near point	Sunny
Great horned owl	1	Sitting on nest	Nest at S tree near entrance	
Horned lark	12	Flying/landing	Along road	
American kestrel	1	Flying	Near trees at entrance	
Mallard	4	2 flying; 2 floating	2 near W end of lake; 2 on lake near W wall	
Marshhawk	1	Flying	Near W end of lake	

Avian Activity and Abundance, Highland Pit Lake, Cont'd

Species	# of Birds	Activity	Location	Weather
Red-tailed hawk	1	Nesting	In trees 200yds N of owl	
Rough legged hawk	1	Soaring	1/2 mile S of lake	
Short-eared owl	1	Flying	W of lake	
Western meadowlark	1	Calling	Near W wetlands	
Sum		**29**		
4/11/2005				
Canada geese	2	1 male floating; female resting on nest	Male near point bar; female on nest at point bar	Very windy
Lesser scaup	2	Floating	In water at Location #3	
Mallard	5	Floating	In water at Location #4	
Sum		**9**		
4/12/2005				
Canada geese	4	2 pairs: 3 floating; 1 sitting on 4 eggs	Near point on Pit Lake; nest on point bar	Sunny, calm
Great horned owl	2	Sitting in nests	Near gate entrance; near S wetlands	
Killdeer	1	Flying/landing	At point bar	
Pintail	15	Floating	On lake at location # 3	
Rough-legged hawk	1	Flying	SE of boat ramp	
Short-eared owl	1	Flying	S of lake near ridge S of road	
Sum		**24**	At point bar	
4/29/2005				
Canada geese	1	Female nesting on 4 eggs	At point bar	Snowing
Sum		**1**		
5/24/2005				
Blue-winged teal	2	1 pair floating	NE end of lake	Sunny, pleasant
Cliff swallow	75	Building many nests; 1 adult dead in nest	On SW end of pitlake	
Great horned owl	3	3 owlets in nest	2 nest near entrance; 1 nest at wetlands	
Horned lark	4	Flying/landing	Along dirt access road	
Killdeer	2	Flying/landing	1 at boat ramp; 1 near goose nest on point	
Lesser scaup	3	1 dead	1 dead near boat ramp on shore; 2 floating NW end of lake	
Mallard	3	Floating/ flew away	Lake center	
Marshhawk	1	Hunting	1/4 mile south of pitlake	
Meadow lark	5	Singing/ calling	Boat ramp; west wetland	
Redtail hawk	1	Resting on nest	On nest near entrance	
Red-winged blackbird	4	Flying/calling	1 pair by boat ramp; 1 pr at west shore of ne section of lake	
Short-eared owl	1	Flying/ landing/ hunting	1/4 mile SE of pitlake	
Spotted sandpiper	3	Walking	NW shore of lake	
Vesper sparrow	2	Sitting/ flying	Surrounding grasslands	
Sum		**109**		

Avian Activity and Abundance, Highland Pit Lake, Cont'd

Species	# of Birds	Activity	Location	Weather
6/2/2005				
Cliff swallow	8	Flying, 3 in nests at SW wall on pitlake	2 near west wetlands, others at SW wall on pitlake	Windy/ cloudy 50s
Great horned owl	4	3 Fledglings out of nest, 1 adult; flying/hunting	Near nest at gate entrance	
Horned lark	12	Flying/landing	Flushed along road	
Marshhawk	3	Pair hunting, possibly nesting as male was aggressive to us; 1 hunting	Pair at west wetland; 1 above boat ramp	
Meadow lark	6	Calling	Near west wetlands	
Prairie falcon	1	Flying	NE end of lake	
Red-tail hawk	2	1 Flying; 1 on nest	Above boat ramp; On nest at gate entrance	
Red-winged blackbird	6	3 pairs calling/ flying, 2 attacked marshhawks	West wetlands	
Sum		**52**		
6/9/2005				
Blue-winged teal	1	Floating	SW end of lake	Rainy, partly cloudy 50s
Cliff swallow	8	Hunting, swooping	5 NW over lake, 3 flying near west wetland	
Great horned owl	4	Fledglings, flying/ resting in tree - great photo of 1	Near Owl nest at near gate	
Horned lark	12	Flushed, found and marked nest location with 3 eggs	Along road, near boat ramp, nest was 20 ft from road, 1/4 mi from gate	
Killdeer	3	Flushed and flying	1 at boat ramp; 1 along road, 1 outside gate	
Mallard	2	males, fly-by over lake	NE end of lake	
Marshhawk	1	Male, soaring became aggressive…nest?	West wetlands	
Meadow lark	6	Flying, sitting	Near boat ramp	
Red-tail hawk	1	Sitting, flew off as we approached	At nest near gate	
Red-winged blackbird	3	Sitting	West wetlands	
Short-eared owl	1	Hunting, flying	West wetlands	
Vesper sparrow	3	Flying/ sitting	Near boat ramp	
		45		
6/17/2005				
Cliff swallow	35	Flying /hunting	SW and NW edge of pitlake	Sunny, windy 80s
Horned lark	12	Flying/ sitting	Along dirt access road	
Killdeer	3	Walking along shore, flying	Near boat ramp, owls' nest	
Marshhawk	2	male flying overhead, female sitting on nest with 4 eggs	West wetlands	
Meadow lark	6	Flying/ sitting	3 at west wetlands, 3 at boat ramp	
Red-tail hawk	2	Male hunting, female on nest	Nest near gate entrance	
Red-winged blackbird	2	Male hunting in mud, female on nest w/ 3 eggs	North of boat ramp	
Vesper sparrow	1	Sitting on fence post	West wetlands	
		63		

Avian Activity and Abundance, Highland Pit Lake, Cont'd

Activity	# of Birds	Activity	Location	Weather
6/22/2005				Sunny, 90s
Blue-winged teal	3	Floating on lake, 1 adult w/ 2 juveniles	NW end of lake	
Cliff swallow	75	Flying, touching water, building nests	West side of lake; a few near boat ramp.	
Horned lark	18	Flying	Along access road	
Killdeer	4	Flying	Near boat ramp; wetlands; rockpile; near owls' nest	
Marshhawk	2	1 pr hunting, resting on nest. Found nest with 3 eggs, 1 cracked	S end of lake	
Marshhawk	2	1 pr hunting, resting on nest. Nest with 4 eggs	West wetlands	
Meadow lark	6	Flying	South of lake; Boat ramp; Wetlands	
Red-tail hawk	2	Pair hunting	West wetlands	
Red-winged blackbird	5	2 pairs, 1 juvenile (brief flights at wetland), flying; nest with 3 eggs	West wetlands; North of boat ramp	
Short-eared owl	1	Sitting on fence post	SE of lake 1/3 mile	
		118		
7/1/2005				Sunny, 90s
Cliff swallow	60	Flying, nest building	West side of lake; a few near boat ramp.	
Horned lark	12	Flying	Along access road	
Marshhawk	3	1 pr hunting, resting on nest. Nest with 2 eggs, and 1 hatchling being fed a fresh kill (bird)	S end of lake	
Marshhawk	3	1 pr hunting, resting on nest. Nest with 2 eggs (1 egg missing), 1 hatchling appears larger than lake juvenile	West wetlands	
Red-tail hawk	2	Pair hunting	West wetlands	
Red-winged blackbird	4	1 pr, male hunting, female on nest, 1 egg missing, 1 baby alive and 1 baby dead	West wetlands; North of boat ramp	
		84		
7/7/2005				Sunny, 90s
Cliff swallow	40	Flying, nest building	West side of lake; a few near boat ramp.	
Horned lark	12	Flying	Along access road	
Marshhawk	0	Nest found intact and empty, no sign of adults	S end of lake	
Marshhawk	3	1 pr hunting, resting on nest. Nest (3 eggs now missing), 1 hatchling appears healthy and growing	West wetlands	
Red-tail hawk	2	Male hunting, female sitting on nest; nest too high to see if there are juveniles	West wetlands	
Red-winged blackbird	4	1 male, 3 female flying Nest intact and empty	West wetlands; North of boat ramp	
		61		

Avian Activity and Abundance, Highland Pit Lake, Cont'd

Species	# off Birds	Activity	Location	Weather
7/14/2005				Sunny, windy
Cliff swallow	20	Flying	West side of lake; a few near boat ramp.	
Horned lark	4	Flying	Along access road	
Marshhawk	2	Female and juvenile on nest	West wetlands	
Meadow lark	2	Singing/ calling	Near boat ramp	
Red-winged blackbird	3	2 male, 1 female, hunting	North of boat ramp	
		31		
8/26/2005				
Eared Grebe	5	Floating on lake	N-NW part of Pit Lake	
Cliff swallow	0	Swallows gone		
		5		

Wildlife Observation Notes for Highland Pit Lake

Date	Species	#	Description	Location	Notes
13-Sep-04	Leopard frogs	20		Cattails	
	Mule deer buck	3		Boat launch	
	Mule deer buck	2		Gate	
	Mule deer doe	2		Gate	
	Mule deer fawn	2		Gate	
	Shrew?	2		Boat launch	
14-Sep-04	Mule deer buck	2	Antlers on both, single spikes and medium velvet.	Boat launch	
	Mule deer buck	3		Rock pile	
	Mule deer buck	3		Gate	
	Mule deer doe	2		Gate	
	Mule deer fawn	2		Gate	
	Mule deer buck	5		T intersection past rock pile	
	Mule deer doe	14		T intersection past rock pile	
	Mule deer fawn	5		T intersection past rock pile	
	Muskrat	0	Scat	Shoreline	
	Canada Goose scat	0	Scat	Shoreline	
	Cottontail	1	Dead	Floating in water SW corner	
	Shrew?	2		Boat launch	
15-Sep-04	Mule deer buck	3		Rock pile	
	Mule deer buck	3		Gate	
	Mule deer doe	2		Gate	
	Mule deer fawn	2		Gate	
	Mule deer buck	1		Traversing the ridge between Hydrolab location #1 and the boat ramp.	
	Mule deer doe	1		Traversing the ridge between Hydrolab location #1 and the boat ramp.	
	Mule deer buck	6		T intersection past rock pile	
	Mule deer doe	8		T intersection past rock pile	
	Mule deer fawn	2		T intersection past rock pile	
	Shrew?	2		Boat launch	

Wildlife Observation Notes for Highland Pit Lake – Cont'd

25-Oct-04	Mule deer buck	1		Rock pile	
	Cottontail	1		Rock pile	
	Mule deer doe	4		NE ridge	
	Mule deer buck	1		E ridge of pitlake	
	Muskrat	1		Cattails	
	Cottontail	10		Rock pile	
26-Oct-04	Mule deer doe	8		Gate	
	Mule deer fawn	2		Gate	
	Mule deer doe	6		East rim of pitlake	
	Mule deer buck	1		East rim of pitlake	
27-Oct-04	Mule deer doe	1		Turnoff to pitlake	
	Mule deer doe	3		Rock pile	
	Mule deer doe	1		Boat launch	
	Mule deer fawn	1		Boat launch	
	Mule deer doe	6		West of boat ramp	
	Mule deer fawn	2		West of boat ramp	
	Mule deer buck	1		West rim of pitlake	
	Mule deer doe	1		West rim of pitlake	
21-Feb-05	Muskrat	1	Dead	Littoral zone shoreline	Ice on a good portion of the Pit Lake
	Cottontail	2		Rock pile	Meadow voles are working 20-30 feet above littoral zone shoreline
	Mule deer buck	1	With 1 antler - looks rather rough	North end on tailings area	
	Mule deer doe	2		300 yards from lake	
	Mule deer fawn	2		300 yards from lake	
22-Feb-05	Mule deer buck	7		Gate	
	Mule deer doe	10		Gate	
	Mule deer fawn	5		Gate	
	Meadow vole	3	Trapped	Boat launch	
24-Feb-05	Mule deer buck	1	With 1 antler - very sick, could not get up	North end of Pitlake	
	Meadow vole	2	Trapped	Location #3	
	Meadow vole	2	Trapped	Location #4	
	Deer mouse	1	Trapped	Location #3	
22-Mar-05	Mule deer buck	1	With 1 antler - Dead	North end of Pitlake	
	Mule deer buck	1		Boat launch	
	Mule deer doe	2		Boat launch	
6-Apr-05	Cottontail	12		Rock pile	

	Cottontail	3		Rock pile	
	Mule deer buck	2		Gate	
	Mule deer doe	5		Gate	
	Mule deer fawn	2		Gate	

Wildlife Observation Notes for Highland Pit Lake – Cont'd

17-Jun-05	Mule deer buck	4		Rock pile	
	Mule deer doe	1		Rock pile	
	Mule deer doe	2		Wetlands	
22-Jun-05	Mule deer buck	6		Rock pile	
	Mule deer doe	8		Rock pile	
	Mule deer fawn	4		Rock pile	
	Pronghorn	7		Boat launch	
	Cottontail	25		Rock pile	
	Cottontail	5		Boat launch	
1-Jul-05	Mule deer buck	4		Rock pile	
	Mule deer doe	7		Rock pile	
	Cottontail	20		Rock pile	
	Deer mouse	1		In boat	
7-Jul-05	Mule deer buck	4		Rock pile	
	Mule deer doe	5		Rock pile	
	Mule deer fawn	2		Rock pile	
	Cottontail	6		On shore near boat ramp within 1st 100 feet	
14-Jul-05	Mule deer buck	1		Rock pile	
	Mule deer doe	2		Rock pile	
	Cottontail	12		Rock pile	
	Bobcat	1	Ran in front of us, then crossed the fence and into the field adjacent to the highway	Crossing the highway, 5 miles south of Highlands Rd turn off	

APPENDIX H

Analytical Data Validation

MFG, INC.

DATA EVALUATION SUMMARY

Sample Collection, Transfer and Analysis

Sediment and tissue samples collected from Highland Pit Lake from September 2004 through February 2005 were sent to Energy Laboratories in Casper, Wyoming for analysis. The following table includes a summary of laboratory batch #s, sample dates, number of samples, sample IDs and analyses conducted.

Lab Batch #	Sample Media	Sample Dates	Samples	Sample IDs	Analyses
C04091010	sediment, vegetation, invertebrate, amphibian	/13/04 – 9/14/04	0 -sed 7-veg 6 -inv 4 -amph	LTZ/LF/091304/01/001, LTZ/LF/091304/02/001, LTZ/LF/091304/01/002, LTZ/LF/091304/01/003, LMZ/CO/091304/01/001, LTZ/GP/091304/01/001, LTZ/GP/091304/01/002, LTZ/OD/091304/01/001, LTZ/WB/091304/01/001, LTZ/WB/091304/01/002, LTZ/VEG/091304/01/001, LTZ/VEG/091304/01/002, LTZ/VEG/091304/01/003, LTZ/VEG/091304/01/004, LTZ/VEG/091304/02/004, LTZ/VEG/091304/01/005, LTZ/VEG/091304/01/006, LMZ/SED/091404/01/001, LMZ/SED/091404/01/002, LMZ/SED/091404/01/003, LTZ/SED/091304/01/001, LTZ/SED/091304/01/002, LTZ/SED/091304/01/003, LTZ/SED/091304/01/004, LTZ/SED/091304/01/005, LTZ/SED/091304/02/005, LTZ/SED/091304/01/006	<u>-Sed:</u> total organic carbon (TOC), total organic matter (TOM), inorganic carbon, total Al, Sb, As, Fe, Hg, Mn, Mo, Se, U, V and Ra-226 <u>-Veg, inv, amph:</u> total Se, U
C04110479	vegetation, invertebrate	0/26/04	-veg, -inv	LTZ/VEG/102604/01/001, LTZ/VEG/102604/01/006, LTZ/VEG/102604/01/003, LTZ/VEG/102604/02/001, LTZ/CO/102604/01/001, LTZ/WB/102604/01/001, LTZ/WB/102604/02/001, LTZ/GP/102604/01/001, LTZ/GP/102604/02/001	total Se, U
C05010790	fish tissue	/18/05	-fish	PL-1 Fatheads, PL-2 Fatheads, PL-3 Fatheads, BC-2 Fatheads, LMW-L Fatheads, LMW-M Fatheads, Rep1-C Fatheads, Rep2-C Fatheads, Rep3-C Fatheads	total Se, U
C05020645	snail, fish tissue	/7/05, 2/14/05	-snail -fish	BC-2-Snails, BC-2- Snail shells, LMW-L-Snails, LMW-L- Snail shells, LMW-M-Snails, LMW-M-Snail shells, Control Snails, Control Snail shells, LMW-L-Fatheads, LMW-M-Fatheads	total Se, U
C05030609	soil, invertebrate	/24/05	6 -soil 3 -inv	M-Soil #1, M-Soil #2, M-Soil #3, M-Soil #4, M-Soil #5, M-Soil #6, Copepod-1, Copepod-2, Copepod-3, Copepod-4, Copepod-5, Water Boatman-1, Water Boatman-2, Water Boatman-3, Fly Larvae-1, Fly Larvae-2, Fly Larvae-3, Snails, Caddis Fly	total Se, U
C05030630	mouse tissue	/24/05	-mouse	M-1 Mouse, M-2 Mouse, M-3 Mouse, M-4 Mouse, 2A-Mouse, 2B-Mouse, 2C-Mouse, 4A-Mouse, 4B-Mouse	total Se, U

--All samples were dried and prepared at the MFG laboratory before shipping to Energy Labs. The case narratives were reviewed with no problems noted for analyses conducted. All samples listed on the COCs were analyzed. All samples were analyzed within the recommended holding time for each method.

--Analyses were run by the following methods: TOC and TOM (ASA29-3), inorganic carbon (USDA23c), total Al, Fe (SW6010B), total Sb, As, Mn, Mo, U, V (SW6020), total Se (SW7742), total Hg (SW7471A) and total Ra-226 (E903.0).

--Proposed detection limits (DL) were met for all analyses with the exception of U, which reported higher reporting limits (0.03 – 0.3 mg/kg) due to sample interference; project proposed DLs for uranium was 0.01mg/kg.

--The following quality control samples were submitted: replicate samples LTZ/SED/091304/02/005, LTZ/VEG/091304/02/004, LTZ/LF/091304/02/001, LTZ/VEG/102604/02/001, LTZ/WB/102604/02/001 and LTZ/GP/102604/02/001.

Accuracy

The accuracy of the data was evaluated based on the extraction efficiency (laboratory control sample (LCS) %recoveries), matrix spike (MS) and matrix spike duplicate (MSD) % recoveries, and method blank results.

--The recoveries for the LCS were within the laboratory control limits for all analyses, when reported.

--MS and MSD recoveries were within laboratory limits for all analyses with the exception of a few. The MS recoveries for Al (C04091010) exceeded lab limits (85-125%) at 79.4% and 79.3%, but were within project limits (75%-125%). The MSD for Se in batch C04091010 exceeded limits at 73.5% recovery; the other MS and two MSDs for the same batch were within limits. For batch C04110479, the U MSD exceeded limits at 61.6% recovery; however the MS was within at 92.5%. In batch C05010790, the Se MSD recovery was outside limits (156%), but the MS was within limits (104%), also the U MSD recovery was outside limits (129%), but the MS was within (124%). Other QC results were acceptable for the same analytes, thus it was not necessary to qualify sample results.

--The analytes of interest should not be detected in any laboratory method blanks greater than the method detection limit (MDL) for the water quality analysis. Method blank results were ND (not detected) for all analytes with the following exceptions: Al (0.0004 mg/kg), Fe (0.01 mg/kg), Mn (0.00004 mg/kg) and V (0.0003 mg/kg) from C04091010, U at 0.01 mg/kg (RL = 0.006 mg/kg) and Se at 0.008 mg/kg (RL = 0.0003 mg/kg) for C05030609, and U (0.04 mg/kg) from C05030630. With the exception of U for C05030630, all amounts detected were well below the project required reporting limits. There was no method blank data available for the following analyses: Se, U and Hg from batch C04091010, and Se from batch C05020645.

Precision

--Laboratory precision was evaluated based on the RPDs of either the analytical duplicates or the MS/MSD. One duplicate for Se in batch C04091010 was right at laboratory and project RPD control limits (<20% RPD) at 20%; the other two duplicates for the same batch were within limits. The U duplicate RPD from batch C04091010 exceeded limits at 24% RPD, and the MS/MSD RPD for Se in batch C05010790 exceeded at 37% RPD. Higher RPDs occur more frequently in solid samples due to sample heterogeneity. The duplicate and MS/MSD RPDs were within lab and project limits for all remaining analyses.

--RPD results from field sample replicates were used to measure within sample variance, and can also be used as an additional measure of laboratory precision. All of the field sample replicates were below the project designated limit of 50% RPD.

Completeness

--Analytical results were reported for all samples submitted for analysis. The analytical results are usable as reported, noting the data quality concerns observed above.

Summary

The analytical results received from Energy Laboratories for samples collected September 2004 through February 2005 were evaluated for data quality. Sample collection and transfer was verified, all samples were analyzed within holding times and according to requested methodologies. Quality control parameters for accuracy and precision were acceptable for all analyses. The results are considered to be usable with no qualifications.

Reviewer: Jill Richards
Date: 4/6/05

DATA EVALUATION SUMMARY

Sample Collection, Transfer and Analysis

Sediment and tissue samples collected from Highland Pit Lake from June 2005 through July 2005 were sent to Energy Laboratories in Casper, Wyoming for analysis. The following table includes a summary of laboratory batch #s, sample dates, number of samples, sample IDs and analyses conducted.

Lab Batch #	Sample Media	Sample Dates	Samples	Sample IDs	Analyses
C05060792	invertebrate	/20/05	-inv	Stone Fly –Boat Ramp, Back Swimmers –Boat Ramp, Dragon Fly – Boat Ramp, Dragon Fly Larva –BR, Amphipods –BR, Water Boatmen -BR	Se, U, moisture
C05060840	invertebrate, amphibian	/20/05- 6/21/05	–inv, -amph	Amphipods –BR, Beetles –BR, Damsel Flies –BR, Water Boatmen – BR, Snails –BR, Back Swimmers –BR, Dragonflies –BR, Leopard Frog -BR	Se, U, moisture
C05060910	vegetation, soil	/22/05	–veg, -soil	Astragalus, Astragalus No. 2, Terrestrial Grass No. 1, Terrestrial Veg No. 2, Terrestrial Veg No. 3, Stonewort No. 2 –BR, Stonewort No. 3 -BR	Se, U, moisture
C05060911	sediment, vegetation	/22/05	–sed, -veg	Sed Littoral 1, Sed Littoral 2, Sed Littoral 3, Sed Limnetic SW, Sed Limnetic NW, Sed Limnetic NE, Stonewort No. 1 Grab	Se, U, moisture
C05060915	invertebrate, water, insect	/21/05- 6/22/05	–inv, –water, -insect	Cope Rep 1, Cope Rep 2, Cope Rep 3, Water SW, Water NE, Water NW, Water Littoral 1, Water Littoral 2, Water Littoral 3, Spiders	Se, U, moisture
C05061005	mouse	/23/05	-mouse	M-1, M-2, M-3, M-4	Se, U, moisture
C05070208	vegetation	/1/05	-veg	CAT 1 Chem, CAT 2 Chem, CAT 3 Chem, CAT 1 Biomass, CAT 2 Biomass, CAT 3 Biomass,	Se, U, moisture, biomass
C05070722	soil, vegetation, invertebrate, amphibian, sediment, water	/18/05	–soil, 0 –veg, 5 –inv, –amph, –sed, -water	Control Soil Rep 1, Control Soil Rep 2, Control Soil Rep 3, Control Soil Rep 4, Control Bullrush Rep 1, Control Bullrush Rep 2, Control Bullrush Rep 3, Control Bullrush Rep 4, Control Cat Rep 1, Control Cat Rep 2, Control Cat Rep 3, Control Cat Rep 4, Control Scirpus Rep 1, Control Scirpus Rep 2, Control Scirpus Rep 3, Control Scirpus Rep 4, Control Pond Weed Rep 1, Control Pond Weed Rep 2, Control Pond Weed Rep 3, Control Pond Weed Rep 4, Control Veg Rep 1, Control Veg Rep 2, Control Veg Rep 3, Control Veg Rep 4, Control Water Boatman, Control Fish, Control Damsel Flies, Control Snail, Control Dragon Fly, Control Leopard Frog Rep 1, Control Leopard Frog Rep 2, Control Leopard Frog Rep 3, Control Leopard Frog Rep 4, Control Sed Rep 1, Control Sed Rep 2, Control Sed Rep 3, Control Sed Rep 4, Control Wetland Water Rep 1, Control Wetland Water Rep 2, Control Wetland Water Rep 3	Se, U, moisture

--Samples preparation was conducted at Energy Labs. The case narratives were reviewed with no problems noted for analyses conducted. All samples listed on the COCs were analyzed. All samples were analyzed within the recommended holding time for each method.

--Analyses were run by the following methods: total Uranium (EPA M6020) and total Selenium (SW7742), for solid samples; U (EPA M200.8) and Se (SM 3114B) for water samples. Results for solid samples were reported on a dry weight basis (mg/kg).

--Proposed detection limits (DL) were met for all analyses with the exception of Uranium, which reported higher reporting limits (0.03 – 0.3 mg/kg) due to sample interference; project proposed DLs for Uranium was 0.01mg/kg.

-No field duplicate or blanks were submitted.

Accuracy

The accuracy of the data was evaluated based on the extraction efficiency (laboratory control sample (LCS) %recoveries), matrix spike (MS) and matrix spike duplicate (MSD) % recoveries, and method blank results.

--The recoveries for the LCS were within the laboratory control limits for all analyses, when reported. LCS recoveries were not available for Uranium or Selenium from C05061005

--MS and MSD recoveries were within laboratory limits for all analyses with the exception of a few. The MS recoveries for analyses which exceeded lab limits due to disproportionate sample/spike concentrations (sample concentration > 4x spike concentration) included Uranium (C05060840, C05060911, C05060915, C05061005 and C05060910) and Selenium (C05060911 and C0506100). Other QC results were acceptable for the same analytes, thus it was not necessary to qualify sample results. Post-digestion spikes, when analyzed, were within limits.

--The analytes of interest should not be detected in any laboratory method blanks greater than the method detection limit (MDL) for the water quality analysis. Method blank results were ND (not detected) for all analytes with the following exceptions: Uranium: 0.005 mg/kg (C05060840), 0.003 mg/kg (C05060915), 0.005 mg/kg (C05061005), 0.1 mg/kg (C05070722) and 0.005 mg/kg (C05060910); reporting limit = 0.003 mg/kg. Selenium: 0.01 mg/kg (C05060840), 0.008 mg/kg (C05060911), 0.01 mg/kg (C05070208) and 0.04 mg/kg (C05060910); reporting limit = 0.003 mg/kg. With the exception of Uranium for C05070722, all amounts detected were well below the project required reporting limits.

Precision

--Laboratory precision was evaluated based on the RPDs of either the analytical duplicates or the MS/MSD. The duplicate and MS/MSD RPDs were within lab and project limits for all analyses.

Completeness

--Analytical results were reported for all samples submitted for analysis. The analytical results are usable as reported, noting the data quality concerns observed above.

Summary

The analytical results received from Energy Laboratories for samples collected June 2005 through July 2005 were evaluated for data quality. Sample collection and transfer was verified, all samples were analyzed within holding times and according to requested methodologies. Quality control parameters for accuracy and precision were acceptable for all analyses. The results are considered to be usable with no qualifications.

Reviewer: Jill Richards
Date: 9/24/05