TETRA TECH

July 15, 2009

Anna Krzyszowska-Waitkus
Wyoming Department of Environmental Quality
122 W 25th Street
Cheyenne, Wyoming 82002

RE: ExxonMobil Highland Reclamation Project

Dear Dr. Krzyszowska-Waitkus:

Attached are our responses to the WDEQ comments from September 16, 2008, for the three reports concerning the Highland Pit Lake. These were transmitted electronically to you on July 14, 2009. Please let Mahesh or me know if you have any additional questions or concerns.

Sincerely,

Tetra Tech, Inc.

Kristen Burt for

Rebecca Bilodeau
encl (3)

cc: Steve Ingle, WDEQ
Rob Boner
Bruce Wielinga, AMEC
Mahesh Vidyasagar, ExxonMobil
NRC Doc Control Desk
Tom McLaughlin, NRC

NMSS01

NMSS

Response to Comments from WDEQ for Sep 16, 2008 comments for the Long Term Geochemical Evolution of the Highland Pit Lake, Long Term Pit Lake and Groundwater Hydrology at the Highland Mine Site, and Final Highland Pit Lake Ecological Risk Assessment Reports.

I. Long Term Geochemical Evolution of the Highland Pit Lake

Specific questions:

Question I.1. Figure 3.6 Highland Mine Site and Monitoring Well Locations is missing. Please provide this Figure.

Response:

The figure is attached to these responses.

Question I.2. Section 4.3 Long-term estimates of selenium. It is stated that the concentration of Selenium is predicted to increase from its current level of 0.09 mg/L to 0.14 mg/L after 1000 years. Does this mean that the concentration of Se will increase 35% in Pit Lake water after 1000 years? According to Table 3.10, the concentration of selenium in the Pit Lake at all depths was 0.1224 mg/L (2003 measurements). Please explain the use of 0.09 mg/L as the current level of Se concentration.

Response:
The concentration of selenium is predicted to increase in the pit lake by about 56% over 1,000 years as a result of evapoconcentration. While the concentration of selenium in the influent ground water is low, pure water is removed by evaporation and therefore selenium in the pit lake will become slightly more concentrated with time. In the near term the concentrations of selenium are predicted to decline from historic highs of approximately 0.30 mg/L in 1986, to a low of about 0.084 mg/L from years 2030 and 2050. After 2050 the concentration is predicted to slowly increase due to evapoconcentration to 0.14 mg/L, or to a concentration equivalent to that recorded in 1995, and much lower than historical levels. It is expected that these small changes in the concentration of selenium in the pit lake will be negligible relative to any biological impacts.

We are not certain at this time where the concentration of 0.1224 mg/L provided in Table 3.10 was derived from and may represent a typographical error. Review of the historical dataset shows the averaged concentration of dissolved and total selenium in the pit lake in 2003 was 0.111 mg/L and 0.090 mg/L, respectively. Thus, the 0.09 value used for the "current level" could have been derived from the averaged total selenium concentration. The fact that the apparent dissolved concentration in 2003 was higher than the total selenium concentration suggests that there was analytical error.

Question I.3. Section 6.0 Summary and conclusions. The predicted concentration of Selenium was not listed. Please add this information.

Response:
The predicted concentration of selenium is 0.14 mg/l, and is included on page 46. This will be included in the conclusions section of any revised version of the report, if issued.

Question I.4. Using average of three samples for the baseline surface water quality is not sufficient. The slow increase of the concentration of various elements over the time makes it important to use data from more collection sites to estimate the baseline. Please consider using more data to describe the current level specially selenium concentration.

Response:
We would agree that an average of three samples is unlikely to support the establishment of a baseline, if just three samples were used. However, the pit lake has been samples for numerous years and the data is very consistent with an average selenium concentration for data collected from 2000 through 2008 of 0.10 mg/L and a standard deviation of about 0.014 mg/L.

Question I.5. The results of the final report titled Final Highland Pit Lake Ecological Risk Assessment by ARCADIS showed that the median Se concentration in water samples collected in 2004/2005 was 0.11 mg/L as compared to 0.09 mg/L collected in 2003. This would be an increase of 18% over the period of one year. The model study indicates the increase of 36% in the Se concentration over 1000 years (from0.09 mg/L to 0.14 mg/L). Please validate the model if the calculation of the Selenium concentration increase over a period of one year was correct.

Response:
Review of data collected and reported in the annual reports provides an average concentration of selenium in the pit lake in 2003 of 0.112 mg/L and for the years 2004 through 2005 the average concentration was 0.095. Data collected to support the ecological risk assessment appears to vary slightly from the data gathered during routine sampling events. This could result from use of different analytical laboratories for the analysis or the inherent difficulty analyzing for selenium. The reported selenium concentrations assuming ± 20% in analytical precision around 0.095 mg/L would provide a range from 0.076 mg/L to 0.114 mg/L.

The averaged concentration data for selenium shows a decreasing trend from 2000 to 2007, from 0.115 mg/L to 0.090 mg/L. A short term trend of decreasing selenium concentrations is predicted by the model (Figure 4-4). The decreasing trend is due to the influx of ground water with very low selenium concentrations into the lake exceeding the rate of evaporation while filling. Once the lake reaches steady state and loss through evaporation equals water influx, selenium concentrations are predicted to gradually increase due to evapoconcentration. The modeled increase in selenium in the pit lake water column is conservative in that no selenium removal from the water column via volatilization and/or sedimentation is included in the model.

Question 1.6. It is stated on Page 44, that "*Dissolved uranium and radium are not expected to be strongly affected by mineral precipitation, adsorption, or sedimentation*

processes within the Pit Lake that would remove these constituents form solution." Selenium and uranium sedimentation is the important process as it can be seen from the results of the Final Highland Pit Lake Ecological Risk Assessment by ARCADIS. The concentration of Se in the Pit Lake sediments varied form 1.7-84 mg/L 9median 15 mg/L) and Ur range was detected between 17 and 273 mg/L (median 153 mg/L). Therefore, the assumption that the removal of selenium, radium and uranium from the water column of Pit Lake by sedimentation is not an important process is incorrect. How will such an assumption affect model results?

Response:
Review of previous studies (SMI, 1998) that attempted to estimate removal of Ra, Se, and U from Highland Pit Lake provided inconsistent and inconclusive results on the importance of adsorption and sedimentation processes for removal of these constituents. The elevated concentration of constituents (U and Se) in the sediments could result from deposition of solids from pit walls, erosion and/or dust to the pit or from removal of constituents from the water column via sedimentation. The current data set does not allow for a clear differentiation of these processes.

Thus, to maintain conservatism in the model predictions, sedimentation as a mechanism to remove these constituents from the water column was not incorporated into the current model. While this process for removing U and Se was not included in the modeling, it is true that the concentrations of selenium and uranium measured in the lake sediments are high and thus could indicate that sedimentation is an important process. High U and Se levels in the sediment could also be a result of high U and Se in the material that is eroding into the pit and not be related to precipitation of Se and U. However, this mechanism is not well understood in this system and additional data is needed to accurately predict the long-term affects of this process on constituent concentrations in the water column. <u>If sedimentation is a significant mechanism</u> for removing these constituents from the water column then the <u>model will over predict</u> the final concentrations of these constituents in the lake.

Shepherd Miller, Inc. (1998) Hydrologic and Chemical Evolution of Highland Pit Lake, Converse, County, Wyoming. November 12.

<u>II. Long Term Pit Lake and Groundwater Hydrology at the Highland Mine Site</u>

<u>Specific questions:</u>

<u>Question II.1</u>. "Pages 3 and 4 of Appendix A do not shoe the vertical permeability test results. The results appear on the table as ######, please correct the table to show the vertical permeability results."

Response: *The corrected table is attached.*

<u>III. Final Highland Pit Lake Ecological Risk Assessment</u>

Specific Questions

Question III.1. "It is stated on Page 1-1 that WDEQ water quality standards for selenium and uranium are 0.005ppm and <1.4 ppm respectively. Please provide the reference and correct values of the WDEQ water quality standards for selenium and uranium."

Response: *The WDEQ water quality standards, as of April 25, 2007, are:*

Selenium	*Chronic criteria = 0.005 ppm*
	Acute criteria = 0.02 ppm
Uranium	*No Current standard, 1.4 is an outdated standard*

From: *WDEQ Water Quality Rules and Regulations Chapter 1, filed with Wyoming Secretary of Sate, April 25th, 2007.*

General Comments/Questions

1. "The selenium concentration in water of Pit Lake is at a higher level than the WDEQ water standards. According to the results of the "Long Term Geochemical Evolution of the Highland Pit Lake by Terra Tech" [sic], the concentration of selenium and uranium will slowly increase with time. The goal of the report Final Highland Pit Lake Ecological Risk Assessment by ARCADIS was achieved and the model provided the risk assessment analysis for 2004/2005 data. However, it is unknown if wildlife will be protected from the slowly rising concentration of Se and Uranium in the future. Please provide such analysis and evaluation"

Response:

The results from the Tier I and Tier II analyses in conjunction with the Interpretation of the results in the context of the Pit Lake physical conditions provide the evaluation of the current and future predicted concentrations with regard to potential risks. The minimal increase in selenium is essentially the same value as was used in the risk assessment. Please see responses to Question I.2 and General Questions 2, 3, and 4 for additional information. The WYDEQ does not have an aquatic life criterion (standard) for uranium.

2. "It was stated in the Summary of the "Final Highland Pit Lake Ecological Risk Assessment by ARCADIS" that "...it is unknown if concentrations of selenium and uranium in the Pit Lake may be slowing or preventing succession based on the establishment of a water column prey base (e.g. plankton and water column invertebrates, which could in turn support the establishment of a fish community..." It would be valuable to provide more detailed results of the water column toxicity test species as mentioned on page 5-13 while referring to two independent studies. Please provide the references to these two independent studies. To obtain the best result, it

would be necessary to analyze the water column invertebrate toxicity test species using water from Pit Lake. Please consider such studies.

Response:

The correct citation reads as follows (pgs. 5-14 and 5-15):

"The primary question and uncertainty relates to the questions of whether concentrations of selenium and uranium in the Pit Lake may be slowing or preventing succession based on the establishment of a water column prey base (e.g. plankton and water column invertebrates, which could in turn support the establishment of a fish community..."

The water column toxicity tests mentioned on page 5-13 in the conclusion sections were also summarized in section 5.4.2.4:

"...the Tier 2 HQs for aquatic invertebrates for selenium are 22 and 5.4 based on the WDEQ chronic and acute water quality criteria respectively. When available studies specifically for aquatic invertebrates were considered, two studies demonstrated NOAEL [NO ADVERSE EFFECTS LEVEL] values for daphnia magna of 0.15 mg/l[6]. Because the lake selenium EPC of 0.11 mg/l is below this value, it is possible that lake selenium concentrations are not adversely affecting aquatic invertebrates. Because it is not known which TRVs best represent toxicity at the Pit Lake, the assessment used the more broadly applicable and conservative values as the primary line of evidence in this ERA. However, it is possible based on alternative TRVs that current concentrations of selenium and uranium in the Pit Lake and biota are within acceptable levels."

The footnote "6" stated that "The additional toxicity data that were reviewed and considered in the ERA are summarized in Appendices B-E." These two studies specifically referred to are the following:

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.

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.

The paragraph quoted above is indicating that the risk assessment was extremely conservative, using the WDEQ criteria to develop the hazard quotient for selenium. Literature studies, 2 of which are cited above, have demonstrated that values greater than the final predicted Pit Lake selenium concentration are still protective of aquatic

organisms. Additionally, the organisms current living in the lake have developed in the presence of the selenium that is present in the water and sediments. 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:

a. Current concentrations of selenium 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,

b. The lack of habitat and associated biological productivity currently provide a very small potential for transfer of pit lake selenium to migrant species including waterfowl, shore birds, and mammals such as deer and small mammals,

c. Biological conditions in the lake will not change appreciably as the lake levels rise to equilibrium level. This is owing to the fact that the rising lake levels will not increase littoral zone habitat conducive to enhance plant and animal productivity and to nesting habitat for birds.

The text quoted in the WDEQ question is providing insight to some of the uncertainties of the Risk Assessment. Uncertainty analysis is part of the Ecological Risk Assessment process. This uncertainty is very minimal compared with the results of the risk analysis, and the ecological setting of the Pit Lake. Therefore, we do not think it is necessary to conduct toxicity tests on the Pit Lake water at this time.

3. "Results of the "Final Pit Lake Ecological Risk Assessment by ARCADIS" are not very conclusive. The lack of significant aquatic communities might be due to the high concentration of Ur and Se that will rise over years (according to "Long Term Geochemical Evolution of the Highland Pit Lake by Terra Tech" [sic]) or might be due to the young ecosystem formed in 1984. However, according to the report results, due to lack of productivity in Pit Lake, particularly for plankton, invertebrates, and fish there is a limited impact on the upper trophic-level receptors (birds and mammals). Please elaborate."

Response:

As described in section 5.3.1, the result of the Tier I and Tier II analysis indicates a low potential risk to ecological receptors from selenium concentrations. The third element of the analysis is the interpretation of the risk in the context of the site specific ecological factors. To sustain a complex ecosystem with multiple trophic levels, there must be sufficient habitat and food sources to maintain species populations. The steep banks of the majority of the Pit Lake prevent shallow water zones, with the exception 0.9 ha of littoral zone. This is conducive to very limited habitat for an aquatic biological community. In turn, with a very limited biomass of benthic invertebrates (~ 40 kg, as estimated in the study), there is very limited food for an organism that would feed upon those species. As described in the study, the amount of biomass (food) supported by the benthic invertebrates is not enough for

one (1) typical duck in the course of a year, and the copepods present would support approximately 15 total fish. Clearly, the lack of habitat / food demonstrates that the Pit Lake is not able to support upper trophic levels. The limited habitat (i.e. no shallow water zones) is preventing the development of aquatic species populations, not the concentration of selenium. In fact, this lack of habitat is common in Pit Lakes. The US Fish and Wildlife Service indicated, in a 2004 letter from Mr. Brian Kelly to Mr. Lowell Spackman, WDEQ that:

"Wildlife use and the risk presented by inorganic contaminants in pit lakes is unknown. Riparian and aquatic communities **may** become established in some pit lakes; however, the nature of these communities is unknown. Pit lakes are typically deep with steep sides, thereby limiting riparian and shallow lentic habitat." (emphasis added)

Mr. Kelly continues to describe situations where exposure to upper trophic level receptors "may occur" through consumption of food or submerged vegetation from the pit lake. Mr. Kelly also suggests that the unknown risk from constituents at the lake could be determined through monitoring and assessment of the site, specifically for "occurrence or absence of submerged aquatic vegetation and aquatic invertebrates in the pit lake which could serve as dietary pathways". Clearly, as Mr. Kelly indicated, there are situations at other sites where significant risks exist. Indeed, the purpose of conducting the Ecological Risk Assessment was to determine the ecological conditions at the lake, and if potential risks to ecological receptors exist. The field component of the study spanned 2004 and 2005, documented the conditions at the lake and the wildlife in the vicinity. Beyond the field component, the study investigated the risk not just to direct water consumption by aquatic and other organisms, but to the bioaccumulation through dietary pathways. The study answered the "unknowns" at the site posited by Mr. Kelly, and concluded that the level of risk to ecological receptors is very low. The results from the investigation were very clear, there is no habitat, and no potential habitat due to steep side slopes and very deep water, to support a complex ecosystem.

4. "The results of the "Long Term Geochemical Evolution of the Highland Pit Lake by Terra Tech" [sic] indicated the slow increase of the selenium and uranium concentration from already high level [sic] of these contaminants. The current concentration of Se in water (median of 0.11 ppm) in the Pit Lake was 5.5 times higher than acute concentration for aquatic life and 22 times higher than the chronic value for aquatic life (WDEQ, Chapter 1). Please provide possible options on how to clean the water of the Highland Pit Lake to acceptable levels based upon the current references."

Response:

The standard does not apply to the Highland Pit Lake for the following 2 reasons:

a) the Aquatic life standards do not apply to Class 4 waters, which WDEQ defines as:

"Class 4 waters are waters, other than those designated as Class 1, where it has been determined that aquatic life uses are not attainable pursuant to the provisions of Section 33 of these regulations." And "Class 4C waters are isolated waters that have been determined to lack the potential to normally support and sustain aquatic life..."

The Highland Pit Lake is isolated, is not a tributary to any other water body, and lacks the potential to normally support and sustain aquatic life. It has physical conditions that are inconsistent with effective habitat.

b) As WDEQ is aware, the Pit Lake is impacted by 11e.(2) byproduct material, and the Nuclear Regulatory Agency has concurred. ExxonMobil is currently involved in discussions with the NRC to finalize the Long Term Surveillance Boundary around the Pit Lake, with the understanding the Federal (NRC) jurisdiction applies to the Pit Lake and surrounding area. Reclamation and closure of the Pit Lake would therefore be governed by 10 CFR 40, not WDEQ regulations.

5. "What's the reclamation land use of the lake? If it is livestock or fishing- there is a need to change it."

Response:

The Permit for the Pit Lake area states that the final land use of the site would be consistent with the original land use, which was livestock grazing. It was plausible that the lake might become a recreational/fishing area if acceptable to the state. However, in light of the impact of the 11e.(2) byproduct material, the current and future land use of the lake are not determined at this time.

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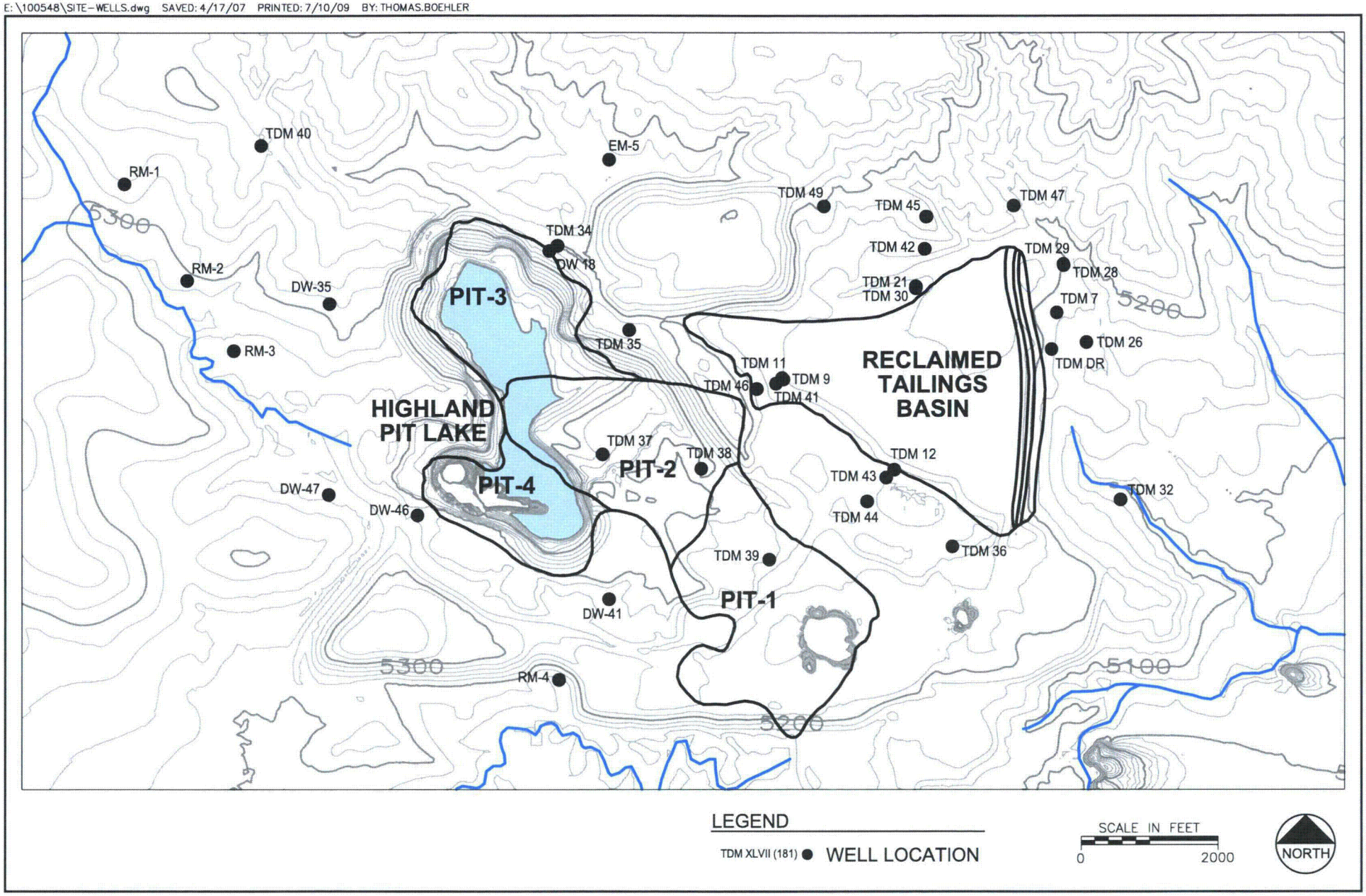

Project No. 180549

April 2007

FIGURE 3-6
HIGHLAND MINE SITE AND MONITORING WELL LOCATIONS

APPENDIX A
HYDROLOGIC TESTS CONDUCTED NEAR HIGHLAND MINE SITE

Location	Hydrologic Unit	Hydrologic Sub-Unit	Test Type	Interval (ft bgs)	Reported Horizontal		Reported Vertical		Reported Storage		Reference	Comments
TDM VIII	TDSS		Core Analysis	112.9-113.2	372	m/d	3,117	md			Exxon, 1983ba	gas flood
TDM XII	TDSS		Core Analysis	127.4-127.8	2,804	m/d	2,992	md			Exxon, 1983b	gas flood
TDM XX	TDSS		Core Analysis	122.7-123.1	6,390	m/d	5,522	md			Exxon, 1983b	gas flood
TDM XXI	TDSS		Drawdown		1,190	m/d					Exxon, 1983b	12 gpm, >1000 min
TDM XII	TDSS		Drawdown		2,220	m/d					Exxon, 1983b	12 gpm, >1000 min
TDM VIII	TDSS		Drawdown		7,930	m/d			4.80E-04	--	Exxon, 1983b	8 gpm, >1000 min
TDM VIII	TDSS		Recovery		7,420	m/d					Exxon, 1983b	8 gpm, >1000 min
2700-0505	OSS		Core Analysis	384-411	1,672	m/d	3,450	m/d			Exxon, 1983b	gas flood
0865-0875	OSS		Core Analysis	353-361	1,036	m/d					Exxon, 1983b	gas flood
0819-4950	OSS		Core Analysis	695-764	2,236	m/d					Exxon, 1983b	gas flood
2700-2310	OSS		Core Analysis	650-704	3,079	m/d					Exxon, 1983b	gas flood
4260-0940	OSS		Core Analysis	627-659	3,235	m/d					Exxon, 1983b	gas flood
4260-0940	OSS		Core Analysis	745-795	3,103	m/d					Exxon, 1983b	gas flood
2650-0320	OSS		Core Analysis	367-400	2,288	m/d	1,687	m/d			Exxon, 1983b	gas flood
0600-0810	OSS		Core Analysis	633-667	834	m/d	626	m/d			Exxon, 1983b	gas flood
TDM XX	OSS		Drawdown		2,060	m/d					Exxon, 1983b	9.6 gpm, >1000 min, upper and middle OSS
TDM VI-1	OSS		Drawdown		6,260	m/d			1.90E-04	--	Exxon, 1983b	12 gpm, >1000 min, middle OSS
1	TDSH		Core Analysis	60.5	3.6	m/d					Exxon, 1983b	gas flood
1	TDSH		Core Analysis	75.5	1	m/d					Exxon, 1983b	water flood
1	TDSH		Core Analysis	80.5	9.3	m/d					Exxon, 1983b	water flood
1	TDSH		Core Analysis	85.5	0.1	m/d					Exxon, 1983b	water flood
4	TDSH		Core Analysis	35.5	0.15	m/d					Exxon, 1983b	water flood
4	TDSH		Core Analysis	40.5	0.03	m/d					Exxon, 1983b	water flood

APPENDIX A
HYDROLOGIC TESTS CONDUCTED NEAR HIGHLAND MINE SITE

Location	Hydrologic Unit	Hydrologic Sub-Unit	Test Type	Interval (ft bgs)	Reported Horizontal		Reported Vertical		Reported Storage		Reference	Comments
RM-1	TDSS		Drawdown		0.1	ft/day					Hydro-Engineering, 1985	1.5 gpm, 25 min
RM-2	TDSS		Drawdown		0.89	ft/day					Hydro-Engineering, 1985	1.1 gpm, 35 min
RM-2	TDSS		Recovery		5.8	ft/day					Hydro-Engineering, 1985	1.1 gpm, 35 min
RM-3	TDSS		Drawdown		8	ft/day					Hydro-Engineering, 1985	1.1 gpm, 35 min
RM-3	TDSS		Drawdown		22	ft/day					Hydro-Engineering, 1985	1.9 gpm, 20 min
RM-4	TDSS		Drawdown		23	ft/day					Hydro-Engineering, 1985	2.7 gpm, 35 min
TDM IX	TDSS		Recovery		0.13	ft/day					Hydro-Engineering, 1985	7.7 gpm,
TDM IX	TDSS		Drawdown		0.23	ft/day					Hydro-Engineering, 1985	2.6 gpm, >100 min
TDM XXXI	??		Recovery		2.1	ft/day					Hydro-Engineering, 1985	0.4 gpm, 21 min
TDM XXXII	OSS		Recovery		0.25	ft/day					Hydro-Engineering, 1985	0.8 gpm, >40 min
TDM XXXVI	OSS		Drawdown		0.059	ft/day					Hydro-Engineering, 1985	1.2 gpm, 8 min
TDM XXXVI	OSS		Recovery		0.1	ft/day					Hydro-Engineering, 1985	1.2 gpm, 8 min
TDM XXXVI	OSS		Drawdown		0.063	ft/day					Hydro-Engineering, 1985	0.7 gpm, >20 min
TDM XXXIII	??		Constant Head		4	ft/day					Hydro-Engineering, 1985	3-4 gpm, >60 min

APPENDIX A
HYDROLOGIC TESTS CONDUCTED NEAR HIGHLAND MINE SITE

Location	Hydrologic Unit	Hydrologic Sub-Unit	Test Type	Interval (ft bgs)	Reported Horizontal		Reported Vertical		Reported Storage		Reference	Comments
TDM XXXIV	OSS		Constant Head		0.018	ft/day					Hydro-Engineering, 1985	
TDM XXXV	TDSS		Constant Head		0.0024	ft/day					Hydro-Engineering, 1985	
PRI A field	OSS	20SS	Drawdown		49.1	gpd/ft 2			7.68E-05	--	Everest, 1987	48-hr test in 20SS, average of 16 observation wells, b = 15 ft
PRI A field	OSH	15SH	Drawdown				5.10E-09	cm/s			Everest, 1987	
PRI A field	OSH	15SH	Core Analysis				1.10E-08	cm/s			Everest, 1987	
PRI A field	OSH	15SH	Core Analysis				1.60E-08	cm/s			Everest, 1987	
PRI A field	OSH	35SH	Core Analysis				2.30E-10	cm/s			Everest, 1987	
PRI A field	OSH	35SH	Core Analysis				1.70E-09	cm/s			Everest, 1987	
PRI B field	OSS	30SS	Drawdown		68.2	gpd/ft 2					Everest, 1988a	24-hr test in 30SS, average of 8 observation well, b=15 ft
PRI C field	OSS	50SS	Drawdown		4.1	ft/day			5.00E-05	--	Everest, 1988b	72-hr test in 50SS, average of 27 observation wells, b=29 ft
PRI C field	OSH	45SH	Drawdown				1.30E-08	cm/s			Everest, 1988b	
PRI C field	OSH	55SH	Drawdown				1.10E-08	cm/s			Everest, 1988b	
PRI C field	OSH	45SH	Core Analysis				9.30E-11	cm/s			Everest, 1988b	
PRI C field	OSH	55SH	Core Analysis				1.50E-10	cm/s			Everest, 1988b	
PRI D field	OSS	40SS	Drawdown/ Recovery		3.7	ft/day			3.50E-05	--	PRI, 1990	tests in 40SS, average of 19 observation wells, b=40 ft
PRI D ext field	OSS	40SS??	Drawdown/ Recovery		1.81	ft/day			3.94E-05	--	PRI, 2000	average of 18 observation wells
PRI D field	OSH	45SH	Drawdown				3.95E-09	cm/s			PRI, 1990	average of 2 wells
PRI D field	OSH	35SH	Drawdown				1.01E-07	cm/s			PRI, 1990	average of 2 wells
PRI E field	OSS	50SS	Drawdown/ Recovery		7.2	ft/day			3.00E-05	--	PRI, 1991	average of 3 tests, 61 observation wells, b=35 ft
PRI E field	OSH	55SH	Drawdown				3.39E-08	cm/s			PRI, 1991	average of 2 observation wells, same as THSH??

APPENDIX A
HYDROLOGIC TESTS CONDUCTED NEAR HIGHLAND MINE SITE

Location	Hydrologic Unit	Hydrologic Sub-Unit	Test Type	Interval (ft bgs)	Reported Horizontal		Reported Vertical		Reported Storage		Reference	Comments
PRI F field	OSS	40SS/50SS	Drawdown		2.2	ft/day			2.04E-04	--	PRI, 1993	average of 94 observation wells
PRI F field	OSH	35SH	Core Analysis				3.70E-09	cm/s			PRI, 1993	
PRI F field	OSH	35SH	Core Analysis				2.80E-09	cm/s			PRI, 1993	
PRI F field	OSH	55SH	Core Analysis				4.20E-07	cm/s			PRI, 1993	
PRI F field	OSH	55SH	Core Analysis				9.20E-07	cm/s			PRI, 1993	
PRI H field	OSS	40SS/50SS	Drawdown/ Recovery		2.19	ft/day			5.33E-05	--	PRI, 1998	average of 2 tests, 63 observation wells
PRI H field	TDSH		Drawdown/ Recovery				9.40E-08	cm/s	2.40E-04	--	PRI, 1998	average of 5 observation wells, test#1
PRI H field	TDSH		Core Analysis				1.70E-08	cm/s			PRI, 1998	
PRI H field	TDSH		Core Analysis				2.60E-08	cm/s			PRI, 1998	
PRI H field	OSH	35SH	Core Analysis				7.20E-09	cm/s			PRI, 1998	
PRI H field	OSH	35SH	Core Analysis				1.20E-08	cm/s			PRI, 1998	
D&M T.W	OSS		Not specified	Not specified	2,500	ft/yr					D&M, 1978b	Pumped at 55 gpm for 2.3 days
D&M 3A	OSS		Not specified	Not specified	4,400	ft/yr			1.20E-05		D&M, 1978	Observation well for D&M T.W.
D&M 5A	OSS		Not specified	Not specified	6,800	ft/yr					D&M, 1978	Observation well for D&M T.W.
Dewater #4	OSS		Not specified	Not specified	366	ft/yr					D&M, 1978	Pumped at 52 gpm for 4.9 days
Dewater #10	OSS		Not specified	Not specified	323	ft/yr					D&M, 1978	Pumped at 47 gpm for 0.19 days
TW #1	OSS		Not specified	Not specified	310	ft/yr					D&M, 1978	Pumped at 9.9 gpm for 0.33 days
TW #2	OSS		Not specified	Not specified	940	ft/yr					D&M, 1978	Pumped at 82 gpm for 0.33 days
1	OSS		Core Analysis	Not specified	1,011	md					D&M, 1978	Core from Highland West
2	OSS		Core Analysis	Not specified	776	md					D&M, 1978	Core from Highland West
3	OSS		Core Analysis	Not specified	1,341	md					D&M, 1978	Core from Highland West
4	OSS		Core Analysis	Not specified	774	md					D&M, 1978	Core from Highland West
5	OSS		Core Analysis	Not specified	707	md					D&M, 1978	Core from Highland West
6	OSS		Core Analysis	Not specified	1,270	md					D&M, 1978	Core from Highland West

APPENDIX A
HYDROLOGIC TESTS CONDUCTED NEAR HIGHLAND MINE SITE

Location	Hydrologic Unit	Hydrologic Sub-Unit	Test Type	Interval (ft bgs)	Reported Horizontal		Reported Vertical		Reported Storage		Reference	Comments
Inj.	OSS		Core Analysis	Not specified	1,250	md					D&M, 1978	Core from Highland West
A	OSS		Core Analysis	Not specified	551	md					D&M, 1978	Core from Highland West
B	OSS		Core Analysis	Not specified	1,024	md					D&M, 1978	Core from Highland West
C	OSS		Core Analysis	Not specified	1,234	md					D&M, 1978	Core from Highland West
D	OSS		Core Analysis	Not specified	910	md					D&M, 1978	Core from Highland West
E	OSS		Core Analysis	Not specified	834	md					D&M, 1978	Core from Highland West
F	OSS		Core Analysis	Not specified	1,142	md					D&M, 1978	Core from Highland West
Inj.-1	OSS		Pulse Test	Not specified	1,104	md					D&M, 1978	Highland West Pilot Area
Inj.-2	OSS		Pulse Test	Not specified	1,212	md					D&M, 1978	Highland West Pilot Area
Inj.-3	OSS		Pulse Test	Not specified	910	md					D&M, 1978	Highland West Pilot Area
Inj.-4	OSS		Pulse Test	Not specified	1,326	md					D&M, 1978	Highland West Pilot Area
Inj.-5	OSS		Pulse Test	Not specified	1,645	md					D&M, 1978	Highland West Pilot Area
Inj.-6	OSS		Pulse Test	Not specified	1,265	md					D&M, 1978	Highland West Pilot Area
DM-1	OSS			544-695	580	ft/yr					D&M, 1978	North Morton Ranch Area
DM-4	OSS			523-618	740	ft/yr					D&M, 1978	North Morton Ranch Area
DM-5	OSS			531-605	760	ft/yr					D&M, 1978	North Morton Ranch Area
DM-6	OSS			527-587	490	ft/yr					D&M, 1978	North Morton Ranch Area
DM-8	OSS			527-709	600	ft/yr					D&M, 1978	North Morton Ranch Area
DM-1A	OSS			240-260	2,000	ft/yr					D&M, 1978	North Morton Ranch Area
DM-4A	OSS			190-210	240	ft/yr					D&M, 1978	North Morton Ranch Area
DM-8A	OSS			250-270	190	ft/yr					D&M, 1978	North Morton Ranch Area
DM-1B	OSS			380-400	390	ft/yr					D&M, 1978	North Morton Ranch Area
DM-4B	OSS			400-420	68	ft/yr					D&M, 1978	North Morton Ranch Area
DM-5B	OSS			400-420	15	ft/yr					D&M, 1978	North Morton Ranch Area
DM-6B	OSS			340	93	ft/yr					D&M, 1978	North Morton Ranch Area
DM-SP1	OSS			540-560	1,100	ft/yr					D&M, 1978	North Morton Ranch Area
DM-1P	OSS			560-640	1,100	ft/yr					D&M, 1978	North Morton Ranch Area
DM-2P	OSS			580-680	950	ft/yr					D&M, 1978	North Morton Ranch Area
DM-3P	OSS			580-620	810	ft/yr					D&M, 1978	North Morton Ranch Area

APPENDIX A
HYDROLOGIC TESTS CONDUCTED NEAR HIGHLAND MINE SITE

Location	Hydrologic Unit	Hydrologic Sub-Unit	Test Type	Interval (ft bgs)	Reported Horizontal		Reported Vertical		Reported Storage		Reference	Comments
DM-4P	OSS			520-620	1,100	ft/yr					D&M, 1978	North Morton Ranch Area
DM-5P	OSS			540-600	1,700	ft/yr					D&M, 1978	North Morton Ranch Area
DM-5P2	OSS			540-600	1,700	ft/yr					D&M, 1978	North Morton Ranch Area
DM-6P	OSS			560-600	790	ft/yr					D&M, 1978	North Morton Ranch Area
DM-7P	OSS			580-660	990	ft/yr					D&M, 1978	North Morton Ranch Area
DM-8P	OSS			580-670	950	ft/yr					D&M, 1978	North Morton Ranch Area
DM-9P	OSS			640-720	440	ft/yr					D&M, 1978	North Morton Ranch Area
WELL #2	OSS		Drawdown	115-340	6.80E-04	cm/s			2.50E-04		Golder, 1979	
WELL #1	OSS		Drawdown	100-285	4.00E-04	cm/s					Golder, 1979	

Notes:
cm/sec - centimeters per second
D&M - Dames and Moore
ft bgs - feet below ground surface
ft/d - feet per day
ft/yr - feet per year
gpd/ft^2 - gallons per day per foot squared
gpm- gallons per minute
hr - hour
m/d - meters per day
min - minute
OSH - Ore Body Shale
OSS - Ore Body Sandstone
PRI - Power Resources Incorporation
TDSH - Tailings Dam Shale
TDSS - Tailings Dam Sandstone
[a] - Exxon Production Research Company. 1983. Surface Mine Reclamation Lake Study for Highland Uranium Operations (Updated) (April).
[b] - Dames & Moore. 1978. Identification of Futer Water Problem, Highland Uranium Mine and Mill (March 15).