FINAL COMPLETION REVIEW REPORT

For the Hecla Mining Company Durita Facility Montrose County, Colorado

Colorado Radioactive Materials License No. 317-02

March 2, 2016

Prepared by the Colorado Department of Public Health and Environment

Radiation Program

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Colorado Radiation Control Program Draft Completion Review Report (CRR) for the Durita Site

Date: March 2, 2016

Licensee: Hecla Mining Company

Radioactive Materials License No.: CO-317-02

Facility Name: Durita Site

Location: Montrose County, Colorado

Licensed area being terminated: Approximately 160 acres

Manager: Edgar F. Ethington

Technical Reviewers: Dr. Shiya Wang (Environmental Protection Specialist), Lee Pivonka (geologist), and Jennifer Opila (Program Manager)

I Summary

This completion review report (CRR) documents the Colorado Department of Public Health and Environment Hazardous Materials and Waste Management Division (CDPHE-HMWMD) staff conclusions that the licensee has completed remedial actions at the Hecla Mining Company's Durita site in accordance with approved plans. Section A of the summary section of this report contains the staff's bases for its conclusion that all applicable standards and requirements have been met.

The Hecla Mining Company's Durita site is a heap leach tailings facility site that has been decommissioned and reclaimed under Colorado Department of Public Health and Environment Hazardous Materials and Waste Management Division (CDPHE-HMWMD) Agreement State authority, derived from Title II of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). UMTRCA requires that prior to termination of the license, the U.S. Nuclear Regulatory Commission (NRC) shall make a determination that the licensee has complied with all applicable standards and requirements. Under the Agreement State program, the State of Colorado is responsible for approval of

remediation plans for the Durita site and for inspections to ensure that the actual remedial actions have been completed pursuant to the approved plans.

This report documents CDPHE-HMWMD's bases for its conclusion that decommissioning and reclamation have been acceptably completed at the Durita site. Staff reviewed remedial actions at the Hecla site to ensure they were constructed in accordance with approved plans and specifications. Licensed professional engineers prepared these design plans and specifications. Areas of review included as-built drawings, construction operations, laboratory testing and field-testing, and quality assurance audits. In addition, the review was based on state staff observations of the remedial actions and reviews of records and testing during on-site inspections.

Documents reviewed in preparing this CRR are referenced at the end of this report and are available for review at the Colorado Department of Public Health and Environment Hazardous Materials and Waste Management Division's record center. The NRC STP Procedure SA-900 entitled, "Termination of Uranium Milling Licenses in Agreement States," was used as guidance to prepare this report. The applicable standard for uranium mill reclamation is Part 18 of the Colorado Rules and Regulations Pertaining to Radiation (6 CCR 1007-1-18), titled Licensing Requirements for Uranium and Thorium Processing. This state regulation is consistent with and compatible with NRC regulations, as required by the state's agreement with the NRC.

All applicable standards and requirements, with appropriate references to related sections of this CRR, are identified in Table l of this summary. Section A summarizes how each criterion has been met. CDPHE-HMWMD (the department) has performed a complete review of the Durita site for compliance with all applicable standards and requirements. The department's review of licensee submittals was conducted using guidance documents NRC NUREG-1620, NUREG/CR-5849, NUREG-1506, and NUREG /CR-3199, NUREG/CR-4192, NUREG/CR-3747, NUREG/CR-4323 and other appropriate documents.

The purpose of this report is to provide the state of Colorado's current evaluation of the completed uranium mill tailings repositories and final site drainage control at the Durita heap leach site. The Durita site is owned by the Hecla Mining Company (Hecla) and has been operated under Colorado Specific Radioactive Materials License Number 317-02. Site cleanup and construction of final waste repositories on-site have been completed in accordance with the Reclamation Plan submitted by Hecla in 1991 (AK Geoconsult, 1991). The elements of the reclamation plan have been evaluated based upon scientific and engineering principles. The construction and underlying design also have been evaluated against the requirements of Appendix A of Part 18 of the Colorado Rules and Regulations Pertaining to Radiation Control, 6 CCR 1007-1 (the regulations). This evaluation can be found in Part I of this completion review report. The state's finding regarding conformance with the radiation regulations is presented in the Licensing Statement for the Radioactive Materials License 317-02 prepared in 1993 and also in 1999. Review of construction verification reports together with field visits during construction and reclamation indicate that the tailings repositories and runoff control structures have been constructed in accordance with the state-approved reclamation plan.

Table 1

Applicable Standards/Requirements		Section A Page	CRR Section
Colorado Rules and Regulations Pertaining to Radiation Control, Part 18, Appendix A	Criterion 1 1A. Tailings siting 1B. Site features 1C. Tailings isolation 1D. No active maintenance	 5 6 8 8	 3.2 3.2 3.5, 3.6, &3.7
	Criterion 2 Non-proliferation	 9	 3.5
	Criterion 3 Above or below grade.	 9	 3.4
	Criterion 4 4A. Erosion potential 4B. Wind protection 4C. Flatness of slopes 4D. Rock & vegetative cover 4E. Seismic design 4F. Sediment deposition	 9 10 10 10 10 11	 6.3 3.5 3.5, 3.10 3.5, 3.10 3.11 6.6
	Criterion 5 5A. Primary groundwater protection 5B. Secondary groundwater protection. 5C. Maximum values for groundwater protection 5D. Corrective action program 5E. Groundwater protection programs. 5F. Seepage issues 5G. Tailings disposal 5H. Stockpiling	 11 13 15 15 15 16 16 18	7.0 7.0 7.5 3.5 3.5
	Criterion 6 Disposal of by-product material	19	 3.5, 3.6, & 3.7
	Criterion 6A Final radon barrier 6A (1) Timeliness of cover 6A (2) Construction extensions 6A (3) Acceptance of NORM materials	19	3.10, 5.5 3.5
	Criterion 7 Groundwater detection monitoring	19	7.0
	Criterion 8 Airborne effluent releases	20	 3.1.3
	Criterion 9 Ownership & long-term surveillance	20	 9.0
	Criterion 10 Secondary groundwater protection standards	21	 6.0
Compliance with license conditions		21	Section 8.0

1.0 Section A – Compliance with Appendix A of Part 18 of the Colorado Rules and Regulations Pertaining to Radiation Control

Part 18, Appendix A, of the Colorado Rules and Regulations Pertaining to Radiation Control (6CCR 1007-1) establishes criteria relating to the disposition of radioactive tailings or wastes.

1.1 Criterion 1:

Criterion 1 A: The broad objective in siting and design decisions is the permanent isolation of radioactive materials so that disturbance and dispersion of these materials by natural forces are minimized and the closed site requires no ongoing maintenance.

The siting of all the repositories, including alternative sites, was thoroughly evaluated during the license renewal process in the early 1990s. The Durita site is located Section 34 of Township 46 North and Range 16 West, New Mexico Meridian, on gently north sloping terrain in the Coke Oven Syncline at the southeast end of the Paradox Valley, in western Montrose County, approximately 100 miles south of Grand Junction and 2.5 miles southwest of the town of Naturita. The climate is semiarid. The Paradox Valley is a collapsed salt diapir and a closed geologic and topographic basin. The Durita site sits at an elevation of approximately 5,600 feet with the surrounding edges of the Paradox Valley at 7,000 feet. Cretaceous age marine Mancos Shale underlies the site. Most of the site is blanketed with alluvium (stream-derived soils) and colluvium (slope wash-derived soils) composed of sandy clay, which is up to 20 feet thick. This soil contains variable amounts of rock fragments, primarily sandstone. Near the east-central portion of the site, an erosion-resistant remnant of the Mancos Shale forms a hill some 100 feet higher than the local terrain called Mancos Hill (Photograph 1).

Two drainages to Dry Creek cross the site and another one cuts across the northwest corner. These drainages encompass approximately 800 acres of watershed that originate in the southwest margin of the valley. The channels from these watersheds

will occasionally carry large amounts of runoff in response to infrequent, intense thunderstorms. At the site, the channels are narrow, 5 feet to 10 feet wide, up to 14 feet deep, and exist within 100- to 300-foot-wide floodplains.

The site is located toward the center of the valley, away from geologic hazards such as rock falls, landslides or snow slides. Overall, the site is isolated such that disturbance from natural forces is minimal.

Photograph 1: View of the Durita site looking southwest. Mancos Hill is visible in the middle distance. The disposal cell is between the viewer and Mancos Hill. Leach pads LT-201 and LT-202 are to the right of Mancos Hill and leach pad LT203 is to the left and behind Mancos Hill.

Criterion 1 B: The site selection process must optimize the following features to the maximum extent possible:

- Remoteness from populated areas;

- Hydrologic and other natural conditions as they contribute to continued immobilization and isolation of contaminants from groundwater sources;
- Potential for minimizing erosion, disturbance and dispersion by natural forces over the long term.

The Durita site was found to be favorable among potential alternative sites for final disposal of uranium mill tailings for several reasons, including:

- The regional geology is well known.
- The site is located in a stable geologic area.
- The site is located in a structural basin.
- The site contains geologic media favorable for radioactive waste disposal because the material will inhibit the migration of radioactive materials.
- No major resource deposits exist at the site.

There is no evidence of impacts of the facility on groundwater and surface water use. The groundwater is isolated from surface releases by low hydraulic conductivity, chemical impediments to the transport of chemicals of concern, and in the instance of the lower saturated interval by hydraulic potential. Surface water is ephemeral. There are no major population centers located near the Durita site. The population of Naturita, the closest town located about two and one-half miles northeast of the site, is approximately 534 people as of 2012. The nearest residence is at the Coke Oven Ranch, located about one-half mile north of the site.

Removal of these materials to another site would have increased human exposures to radioactive and non-radioactive materials without an overall improvement to long-term control or reductions to long-term impacts.

The regional groundwater resources for western Colorado have been described by Pearl 1974[1]. Generally, groundwater is found in alluvial deposits adjacent to perennial streams. Groundwater is also present locally throughout the western slope in several

[1] Pearl, R. H., 1974, *Geology of Ground Water Resources in Colorado*, Colorado Geological Survey, Denver, Colorado.

of the formations that underlie the site, including the Mancos Shale, Dakota Sandstone, Burro Canyon Formation and Morrison Formation. The nearest groundwater user is the Coke Oven Ranch located approximately one-half mile north of the Durita site. The well at the ranch is reported to be developed in the Dakota Formation. This well is not hydraulically connected to the uppermost water-bearing zone beneath the site.

Monitoring wells drilled beneath the Durita site indicate that there are two rock units that appear to be hydraulically connected and constitute a single water-bearing stratum. Under most of the site, the uppermost water-bearing unit is a sandstone-claystone that appears to be at least 10 feet thick. The top of this unit was encountered from 20 feet to 55 feet below the ground surface. Along the north side of the site in the vicinity of monitor wells MW-11 and MW-12, the uppermost water-bearing unit is a 1-foot thick sandstone. This unit is also present in the other upgradient wells, but is dry. The repositories are separated from this water-bearing stratum by very dense and indurated Mancos Shale, which is effectively impermeable to water flow. The calcareous shale will also react chemically with any acidic leachate release.

Detection monitoring was conducted on the site from 1976 until early 1998 and showed no impacts to the groundwater. The potential for erosion and dispersion of contaminated materials is minimized through the cover design employed for the disposal repositories. Wind and water erosion are minimized by the application of a rock cover across the side-slopes of the repositories. The location of the closure cell down gradient from the Mancos Hill protects it from flooding.

The site and design features assure that the tailings and associated waste will be isolated from populated areas and groundwater. Erosion and other dispersive forces were minimized.

Criterion 1C: In the selection of disposal sites, primary emphasis must be given to isolation of tailings or wastes, a matter having long-term impacts, as opposed to consideration only of short-term convenience or benefits, such as minimization of transportation or land acquisition costs.

The Durita site was selected as the primary site for long-term isolation of tailings due to its remote location, geologic stability and demonstrated ability to isolate wastes over the long term.

Criterion 1D: Tailings should be disposed of in a manner that no active maintenance is required to preserve conditions of the site.

The Durita site and cover design have been thoroughly evaluated for long-term containment of the waste under the existing license. The cover and repository configurations are designed to meet the requirements of the Colorado Rules and Regulations Pertaining to Radiation Control, policies of the department and regulatory guidance of the U.S. Nuclear Regulatory Commission. The side slopes of the repositories are covered by rock on gentle slopes, and vegetative top cover occurs on the very gently sloping tops of the leach tank repositories. Rock covers the top and sides of the closure cell. These regulations and policies are designed to assure that no active maintenance is required. This site is geologically stable and will be adequate for the long-term containment of radioactive waste.

As discussed in the CRR Sections 3.8 and 6.4, CDPHE staff considers that the riprap layers will require little active maintenance over and beyond the 1,000-year design life, for the following reasons: (1) the riprap has been designed to protect the tailings from rainfall and flooding, which have very low probabilities of occurrence over a 1,000-year period, resulting in no damage to the layers from these events; (2) the rock of the riprap layers is designed to be durable and is not expected to deteriorate significantly over the 1,000-year design life; and (3) during construction, the rock

layers have been placed in accordance with appropriate engineering and testing practices, minimizing the potential for damage, dispersion and segregation of rock.

1.2 Criterion 2

To avoid proliferation of small waste disposal sites and thereby reduce perpetual surveillance obligations, byproduct material shall be disposed of at existing large mill tailings disposal sites.

The evaporation pond residues have been combined into one cell (the closure cell), and the mill residues were placed in the existing heap leach cells and closure cell to avoid the proliferation of small waste sites. The disposal of all these materials at one location reduced reclamation costs and long-term maintenance costs.

1.3 Criterion 3

The “prime option” for disposal of tailings is placement below grade.

The pre-existing condition and nature of the tailings disposal sites at Durita made below-grade disposal of the tailings an impractical option. Below-grade disposal would bring the wastes closer to groundwater and reduce the isolating features of the site geology. This location and its designed liners, covers and diversion channels are adequate to resist the long-term forces of erosion.

1.4 Criterion 4

Design criteria for a repository include minimization of upstream catchment areas, good wind protection and flat covers to minimize erosion constructed of vegetation or durable rock. A rock cover should be designed to withstand the probable maximum precipitation (PMP) event and areas of concentrated runoff need to be riprapped. The repository should not be sited near a capable fault and should be designed to withstand the maximum credible earthquake (MCE).

- The watershed area upstream of the Durita site is 800 acres. The repositories are located on upland slopes, away from the drainage channels, and three of the cells are protected by small hills. Ephemeral channels that exist adjacent to the disposal cells were realigned, re-graded, and armored to protect the disposal cells from the PMP event. Protection against floodplain scour adjacent to the existing ephemeral channels is provided by the use of rock-fill trenches from channel bed elevation to the calculated vertical scour depth. A riprap blanket not less than 18 inches was constructed to protect floodplain banks from lateral erosion under conditions up to the probable maximum flood (PMF) discharge. A surface water diversion channel was completed along the south side of the closure cell to minimize the upstream watershed area.
- The Durita site is located within the topographic bowl called the Coke Oven Syncline. Uplands on three sides of the site provide good wind protection.
- The sides of the leach tanks have 5H: 1V slopes and utilize a rock cover designed to withstand the PMP event. The tops of the leach tanks are gently sloping. Surface water diversions and erosion protection are designed to assure stability of the repository during maximum probable precipitation and/or flooding. The closure cell was designed with a 2.5-foot thick radon cover, 5H: IV slopes and a rock cover over the entire cell. The rock cover is designed to withstand the PMP event.
- A temporary cover of 2.5 feet was placed over the tailings leach tanks when active operations ceased. An additional 2.8 feet to 5 feet of soil cover was placed on the leach tanks to reduce the radon emanations to less than 20 pCi/m^2s. The tops of the leach tanks were vegetated.
- The Durita site is located within the Colorado Plateau Seismotectonic Province as described by Kirkham and Rogers[2] (1981). They have estimated an MCE of 5.5 to 6.5, for the province, making it one of the more stable provinces in Colorado. Recent faulting is rare in this province except for faults related to the Uncompahgre Plateau or collapse of the salt anticlines, according to F.M.

[2] Kirkham, R. M., and Rogers, W. P., 1981, *Earthquake Potential in Colorado, A preliminary Evaluation, Bulletin 43*, Colorado Geological Survey, Department of Natural Resources, State of Colorado, Denver, Colorado.

Fox & Associates (1982). According to the F.M. Fox report (1982), evidence indicates that the collapse of salt structures was active in the last 500,000 years and may be active at present. However, the faults associated with collapse are gravity faults that are generally slow moving with a low potential for generating even moderate earthquakes. There is no evidence for recent movement along faults in the immediate vicinity of the site. The site does not appear to be located adjacent to a capable fault. There is no evidence either at the surface or in the holes drilled for monitor wells to indicate faulting or even abrupt structural changes under the site. The MCE for a 1,000-year event would generate a peak acceleration of 0.12g. Stability analyses indicate that the repositories have significant safety factors for static and pseudostatic conditions. All design analyses indicate that the covers will withstand wind and water erosion for more than 1,000 years. Based upon the existing information, the site will provide permanent isolation of the tailings.

- The Durita site has no open impoundments and so the expectation that the impoundment design should promote sediment deposition is moot. However, the Durita site does promote deposition of water-deposited sediment from highlands to the south and of wind-deposited sediments as evidenced by the current distribution of surface deposits.

1.5 Criterion 5

Criterion 5 of the Colorado Rules and Regulations Pertaining to Radiation Control sets forth groundwater protection standards. Criterion 5A-5D and Criterion 10 incorporate the basic groundwater standards imposed by the Environmental Protection Agency in 40 CFR Part 192, Subparts D and E (48 FR45926: October 7, 1983) which apply during operations and prior to the end of closure.

<u>Criterion 5A (1):</u> The primary groundwater protection standard is a design standard for surface impoundments used to manage byproduct material. Unless exempted under paragraph 5A(3) of this criterion, surface impoundments shall have a liner that is

designed, constructed and installed to prevent any migration of wastes out of the impoundment to the adjacent subsurface soil, groundwater or surface water at any time during the active life (including the closure period) of the impoundment. The liner must be constructed of materials that may allow wastes to migrate into the liner (but not into the adjacent subsurface soil, groundwater or surface water) during the active life of the facility, provided that impoundment closure includes removal or decontamination of all waste residues, contaminated containment system components (liners, etc.), contaminated subsoils, and structures and equipment contaminated with waste and leachate. For impoundments that will be closed with the liner material left in place, the liner must be constructed of materials that can prevent wastes from migrating into the liner during the active life of the facility.

The leach areas and evaporation ponds were constructed with appropriate liners. The closure cell was constructed with an appropriate liner and was seated in the upper portion of the Mancos Shale.

Criterion 5A (2): The liner shall be:

(a) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients, physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation and the stress of daily operation;
(b) Placed on a foundation of base capable of providing support to the liner and resistant to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression or uplift; and
(c) Installed to cover all surrounding earth likely to be in contact with the wastes or leachate.

The evaporation ponds, leach tank cells and the closure cell were constructed with compacted clay liners on top of scarified Mancos Shale and were installed to cover all surrounding earth likely to be in contact with the waste.

Criterion 5A (3): Hydrogeologic Setting

The applicant or licensee will be exempted from the requirements of paragraph 5A (1) of this criterion if the department finds, based on a demonstration by the applicant or licensee, that alternate design and operation practices, including the closure plan, together with site characteristics will prevent the migration of any hazardous constituents into groundwater or surface water at a future time.

The licensee did not request exemption from the requirements of paragraph 5A (l). However, the closure of the site will protect the groundwater because the waste in the evaporation ponds were treated and stabilized. It was then transferred into the closure cell in order to minimize on-site disposal locations. The leach tanks were stabilized and dewatered. The closure cell and leach tank areas were constructed to promote runoff. The compacted clay cover will reduce infiltration. Precipitation in the area is 12 inches per year, while the evaporation rate is 49 inches per year; therefore infiltration is limited. The HELP (version 3.3) model was used to evaluate infiltration. The 1997 calculations for percolation/infiltration in the closure cell was determined to be 0.00043 inches per year and for the leach tanks was determined to be 0.00103 inches/year. These calculations compare closely to those done in 1993.

The compacted on-site clay used in constructing the leach tanks and disposal cell liners has a measured permeability from 9.2×10^{-7} to 1×10^{-8} cm/sec (Coe & Van Loo, 1976). Hydraulic conductivity tests on soils conducted with 5 percent sulfuric acid had values of 8.2 and 2.5×10^{-8} cm/second.

The site is underlain by low-hydraulic conductivity shales having high carbonate content capable of neutralizing any potential acidic leachate. The soils have a moderate field capacity. Permeability generally decreases with depth in the Mancos Shale. The radionuclides and heavy metals contained in the neutralized raffinate will precipitate, be chemically reduced, and/or be absorbed onto the clays and iron oxides in the Mancos Shale.

The vertical hydraulic potential of groundwater found at the Mancos Shale – Dakota Sandstone contact is upwards. Any liquids moving down from the surface will be blocked from entering the groundwater aquifer by the energy potential of the confined aquifer.

The treatment of the waste, the design and construction of the closure cells and the hydrogeologic/geologic and chemical conditions at the site inhibits the migration of any raffinate produced to groundwater or surface water.

Criterion 5B (1): The department shall identify hazardous constituents, establish concentration limits, set the compliance points and may adjust the point of compliance if needed in accord with developed data and site information as to the flow of groundwater contaminants, when the detection monitoring established under Criterion 7 indicates leakage of hazardous constituents from the disposal area.

License amendment 10, dated May 15, 1997, established background and point-of-compliance wells. Concentration limits were established after representative samples of waste and background water quality parameters were evaluated. Based upon analysis of data collected from 1991 to 1997, it was determined that no releases of hazardous constituents had been detected by the groundwater monitoring system.

Criterion 5B (2): Describes the three tests to determine if a constituent is hazardous.

Selenium, arsenic and uranium were selected as indicators for the determination of impoundment leakage because they were present in the feed tails and in the disposed byproducts. These metals are listed in Criterion 10, and are the most mobile of expected hazardous constituents. The constituents were detected in the uppermost aquifer. The constituents meet the three tests described in paragraph 5B (2) and are considered to be hazardous.

Criterion 5B (3): Even when constituents meet all three tests in Paragraph 5B (2) of this criterion, the department may exclude a detected constituent from the set of hazardous constituents on a site-specific basis if it finds that the constituent is not capable of posing a substantial present or potential hazard to human health or the environment. The hazardous constituents were not excluded from the detection monitoring or compliance monitoring programs.

The only potential well user is at the Coke Oven Ranch, which obtains its groundwater from the Dakota Sandstone on the north side of the syncline. Subsurface water in the Dakota Sandstone follows geologic structure and topography, and flows from north to south on the north side of the syncline towards the Sand Creek drainage. The water tapped by the Coke Oven Ranch well is not in the flow path from the Durita site and therefore does not pose a threat to human health or the environment.

Criterion 5B (4): In making any determinations under paragraphs 5B (3) and 5B (6) of this criterion about the use of groundwater in the area around the facility, the department will consider any identification of underground sources of drinking water and exempted aquifers by the Colorado Water Quality Control Commission or any other agency having jurisdiction.

The Mancos Shale has not been generally identified as an underground source of drinking water nor is it an exempted aquifer. If potable water is obtained from this formation it can be used, but no wells near the site obtain water from the Mancos Shale. A determination under paragraphs 5B (3) and 5B (6) on the use of groundwater was not made, because monitoring indicates that there is no impact or release from the facility.

Criterion 5B (5): Concentrations at the Point of Compliance
Groundwater in the compliance wells was compared against groundwater in the background wells. The historical groundwater data were analyzed for descriptive and comparative statistics. The descriptive statistics characterized the number of

measurements/analysis, frequency of detection range, average concentration and variability of each parameter for each well. A comparative statistical analysis was performed for the relevant indicator parameters: arsenic, selenium and uranium. The comparative statistical analysis consisted of a test of proportions procedure. Although a statistically significant difference was noted for arsenic between upgradient well MW-14 and downgradient well MW-12, the difference resulted from a greater number of detections in the upgradient well than the downgradient well. Therefore, the difference in the occurrence in arsenic between these two wells is not related to a release from the site. Based on the comparative statistical analysis, no evidence of a release related to the site was observed in groundwater. (1995 Annual Groundwater Report)

Criterion 5B (6): Alternate Concentration Limits
This criterion is not applicable because there is no evidence of a release to groundwater.

Criterion 5C: Maximum Values for Groundwater Protection
Arsenic, barium, lead and selenium were present in the groundwater during the detection monitoring program, as well as radium-226 and gross alpha particle activity. All of the detected concentrations were below drinking water standards and the maximum values for groundwater protection described in Criterion 5C. The department set standards that are consistent with paragraph (5) of Criterion 5. Uranium levels are higher in the background well than in the downgradient or crossgradient wells. The groundwater monitoring program results support the conclusion that the activities at the Hecla- Durita site have not adversely impacted the underlying groundwater. The 1996 annual report includes temporal graphs for arsenic, selenium and uranium for the period from 1991 thru 1996. These three constituents were determined to be relevant indicator parameters because they were found in the byproduct materials placed in the disposal areas. A lack of detections above the analytical detection limit for arsenic and selenium prevent meaningful trend analysis.

The temporal graphs for uranium concentrations indicate higher values were observed for five of the seven wells (MW-9, MW-10, MW-12, MW-13, and MW-14) during 1991, the first year of monitoring. Lower levels were observed for each of the five wells during the next five years. The average uranium concentrations in all downgradient wells were less than the values observed in upgradient well MW-14. This information indicates that the downgradient wells have not been impacted by seepage from the wastes.

Criterion 5D: Corrective Action Program
A corrective action program was not implemented at this site because the groundwater protection standards established under paragraph 5B (1) were not exceeded.

Criterion 5E: In developing and conducting groundwater protection programs, applicants and licensees shall also consider the following:

(1) Installation of bottom liners,
(2) Mill process designs to reduce the net input of liquid to the tailings impoundment,
(3) Dewatering of tailings and
(4) Neutralization to promote immobilization of hazardous constituents.

Because there is no evidence of groundwater contamination from the site, development of a groundwater protection program was not needed. Nevertheless, prior to site closure, liners were already in place or were constructed; liquids were removed from the leach tank areas via *in-situ* drainage systems; liquids in the evaporation ponds were solidified and neutralized; and relatively impermeable clay caps covered these areas in order to limit infiltration. These activities will help protect the groundwater by limiting infiltration. The annual average yearly precipitation is less than 12 inches, while the evaporation rate is 49 inches per year. The HELP (version 3.3) Model was used to evaluate infiltration. The 1997 calculations

for percolation/infiltration in the closure cell was determined to be 0.0011 inches per year and for the leach tanks was determined to be 0.0019 inches/year. These calculations compare closely to those done in 1993.

The leach tanks were clay lined in order to collect leached uranium. The process plant was designed to capture the liquid solutions from the tanks. Thus, the operation was designed to preclude releases to groundwater. No impacts to groundwater have been observed from the impoundments.

Criterion 5 F: Where groundwater impacts are occurring at an existing site due to seepage, actions must be taken.

The groundwater data shows no evidence of groundwater impacts due to seepage occurring at the site.

Criterion 5G: Information on the tailings disposal system needed to be provided regarding the following:

(1) Chemical, physical and radioactive characteristics of the waste solutions

In 1991, four evaporation ponds were sampled. Chemicals found in the salts were chloride, sulfate, arsenic, barium, calcium, iron, potassium, sodium and lead. Molybdenum was below the detection limit. Radioactive materials found were gross alpha, gross beta, radium-226, thorium-230 and uranium.

To determine what potential contaminants were brought on site, agglomerator samples were analyzed (AK Geoconsult Inc., 1993). The agglomerator was used in the tailings preparation area to mix acid with tailings from the Naturita site prior to placement in the leach tanks. In 1992, seven agglomerator head samples were analyzed for non-radiological elements and three samples were analyzed for radiological elements. The non-radiological elements were arsenic, cadmium, lead, molybdenum and selenium. The radiological elements were thorium-230 and

radium 226. Arsenic, lead and selenium were detected in the feed tails, while cadmium and molybdenum were not. Radium-226 and thorium-230 were also present in the feedstock and were the principal source of radioactive contamination at the Durita site.

Radionuclides commonly found in relatively high concentrations in tailings from acid leach mills are Ra-226, Pb-210, Po-210 Th-230, and uranium. Metals including barium, beryllium, cadmium, chromium, nickel, antimony, lead, mercury, silver, molybdenum and vanadium may be found in elevated concentrations, as may the regulated nonmetals nitrate, cyanide, selenium and arsenic. Some chemicals such as organic tertiary amines mixed with the dilutants kerosene or benzene also may be present, along with sulfates from the addition of sulfuric acid to the process.

A comprehensive groundwater sampling program was done in 1991 after the new wells had been installed. Groundwater samples were analyzed for all of the constituents above except antimony, nitrate and polonium-210. Polonium-210 was analyzed for in 1995 and was not detected. This data was reviewed by CDPHE. Most metals and other inorganic constituents were determined to be below analytical detection levels. Molybdenum in groundwater samples was generally below detection level except at MW-13 (0.08 mg/L). As discussed above, molybdenum was not detected in the feed tails brought on site. Barium concentrations ranged from 0.01 to 0.05 mg/L, well below drinking water limits. The concentrations of radiochemical parameters were all below drinking water standards and showed no significant difference between upgradient and downgradient locations. Uranium activity was highest in the upgradient and crossgradient wells along the eastern side of the site. These concentrations are consistent with those derived from host rock rather than from on-site seepage from the surface (DOE, 2011).

Volatile and semi-volatile organic compounds utilized in the extraction plant were below detection levels in all of the samples. A non-target compound identified as decyl alcohol was found at trace levels in a duplicate sample for MW-8. Decyl alcohol

was not identified in the MW-8 sample or in any of the other groundwater samples. Because the decyl alcohol was only found in a duplicate sample and in no other samples, it was considered to be an anomaly. MW-8 is an upgradient well.

Hecla-Durita's CRML License No. 317-02, Amendment 06, September 30, 1993, License Condition 26.2.2 required that total dissolved solids, chloride, sodium, carbonate and bicarbonate, sulfate, arsenic, molybdenum, selenium, gross alpha, gross beta, radium- 225, thorium-230 and natural uranium be monitored quarterly in the groundwater, as these constituents were detected in the groundwater or were found in the waste products.

The physical properties of the tailings are described as silty or clayey sand with an average in-place density of 79 pounds per cubic foot to 99 pounds per cubic foot and a long-term moisture weight of 16.2 percent. Porosity at in-place density was 0.52.

(2) Characteristics of the underlying soil and geohydrology, particularly how they will control transport of contaminants and solutions.

There are three hydro-stratigraphic zones: A) an upper unconfined water-bearing zone associated with the alluvium, colluvium and weathered Mancos that is sensitive to significant surface infiltration; B) a middle zone of un-weathered Mancos Shale that acts as a hydraulic aquitard or aquiclude; and C) a lower confined water-bearing unit associated with the lower Mancos Shale and the upper Dakota Sandstone.

Depth from the ground surface to the water surface ranges from approximately 15 feet to 35 feet, with the exception at monitoring location MW-14, where it is at approximately 50 feet. In the vicinity of the Durita site, the direction of groundwater flow is generally from south to north/northwest at a gradient of 0.034 feet/foot. The water-bearing units produce very low yields (approximately 1 gallon per minute) and have low hydraulic conductivities (10-5 to 10-8 cm per second). Transmissivity would

also be low. Relatively higher hydraulic conductivities occur in the weathered or fractured zones and decrease with depth.

(3) Location, extent, quality and current uses of any groundwater at and near the site.

On-site wells are used only for monitoring. The nearest drinking water well is at the Coke Oven Ranch, located approximately one-half mile north of the site and away from the north/northeast direction of the shallow groundwater flow from the site. This well is completed in the lower Dakota Sandstone below the Mancos Shale and is not hydraulically connected to the lower Mancos Shale saturated interval at the Durita site.

Criterion 5H: Steps must be taken during the stockpiling of ore to minimize penetration of radionuclides into underlying soils. Suitable methods include lining and/or compaction of ore storage areas.

Tailings processed at the Durita site were not stockpiled, but placed directly into the leach tanks. These leach tanks had engineered liners to minimize penetration of radionuclides into underlying soils. Ore was not processed at Durita.

1.6 Criterion 6

An earthen cover shall be placed over tailings or wastes which provides reasonable assurance of control of radiological hazards for 1,000 years to the extent reasonably achievable, and, in any case, for at least 200 years.

The earth and clay covers designed for the leach tanks are at least 5.28 feet thick on top and 4 feet thick on the sides, with at least 6 inches of rock on the sides of the earthen cover, and additional rock protection in the diversion channels adjacent to the cells. The closure cell cover is at least 8 feet thick and has a 6-inch rock cover

over the sides and top. The covers were designed to reduce radon emanations to less than 20 pCi/m^2 s. The covers were designed to withstand the PMP. All design analyses indicate that the covers will provide adequate radiological protection for more than 1,000 years. Compaction of the materials was monitored and measured during placement of the waste and the soil cover to assure longevity of control. Settlement was also monitored with surveys of settlement monuments placed on the structures. This type of monitoring assures that the cover has not settled at significantly different rates, which could lead to a containment breach. The cover was placed in accordance with approved plans and schedules.

Criterion 6A: The licensee shall complete the final radon barrier as expeditiously as practicable in accordance with a written, department-approved reclamation plan. The department may approve a licensee’s request to extend the time for radon barrier emplacement. The department may authorize by license amendment the acceptance of similar by-product material into the pile or impoundment.

The cover was placed in accordance with approved plans and schedules.

1.7 Criterion 7

The licensee shall establish a detection-monitoring program to detect leakage of hazardous constituents and to demonstrate compliance with established protection standards.

A detection-monitoring program was established for the site in 1976. These wells, monitor wells MW-2 through MW-7, were monitored until 1991. This set of wells monitored the unconfined upper water-bearing zone. In 1991 new wells, monitor wells MW-8 through MW-14, were drilled and completed at the site when a review of the completion records for the 1976 wells indicated that the construction and completion techniques used could allow surface water to enter the wells. Although no conclusive evidence of surface infiltration was found, the possibility could not be ruled out.

Seven new wells were drilled in 1991, including three background wells. This set of wells sampled the lower water-bearing unit.

Evaluation of the data from the 1991 wells performed in late 1997 indicated that the point of compliance wells did not exceed applicable concentrations of background constituents. There is no evidence of groundwater impact due to seepage from the existing cell or leach pads.

1.8 Criterion 8

Milling operations must be conducted so that all airborne effluent releases are reduced to levels as low as is reasonably achievable (ALARA).

Five permanent air-monitoring locations were sampled weekly during process plant operations. One mobile air-monitoring station was also used, often in the yellowcake room. It also was sampled weekly. No air violations were noted in the inspection reports. Outdoor air monitoring results were in the 10-13 to 10-14 micro Curie per cubic centimeter range. Yellowcake room air monitoring results were in the 10-11 to 10-12 micro Curie per cubic centimeter range.

Three high-volume air monitors were used during the remedial construction phase at the site. No air violations are noted in the record.

Point emission sources no longer exist at the Durita site and conventional milling did not occur at this site.

1.9 Criterion 9

The ownership of the tailings and the disposal sites must be transferred to the United States or the State in which such land is located prior to termination of the license.

Current license condition (LC) 13.4 requires that ownership and control of the tailings and/or waste confinement areas shall be such that ownership of the property may be transferred to the federal government under the provisions of the regulations.

In a letter to DOE dated April 12, 1996, Gov. Roy Romer declined the state's option to be custodian of the Durita site and the Umetco site known as Maybell. A letter dated Feb. 27, 2001 from Gary Gamble notified DOE of the planned transfer of the site to the U.S. DOE. On Jan. 18, 2002 Ann Robison of Hecla wrote a letter to DOE regarding transfer of the Durita site to the U.S. Department of Energy (DOE). Pending acceptance of this CRR and an approved long-term surveillance plan, it is anticipated that the Durita site can be transferred to the DOE.

1.10 Criterion 10

Secondary groundwater protections standards required by Criterion 5 are listed for non-radioactive hazardous constituents.

All the applicable hazardous constituents from the Criterion 10 table were monitored and isolated at the Durita site.

1.11 Compliance with License Conditions

The Colorado Department of Public Health and Environment believes that the Hecla Mining Company's Durita site has met all applicable standards and requirements. With a determination by NRC, as required by Section 274c (4) of the Act, that all applicable standards and requirements have been met, the Colorado radioactive material license, 317-02, may be terminated.

II Documentation of Bases for Conclusion

2.0 Description of Decommissioning and Reclamation Activities

2.1 Reclamation Plan Framework

Hecla Mining Company submitted a conceptual reclamation plan (AK Geoconsult, 1990) to the Colorado Department of Health in 1990. The reclamation plan together with the quality control procedures and the construction verification program formed the basis for construction activities at the site. The final reclamation plan was submitted in 1991 (AK Geoconsult, 1991), and after several modifications was approved by the CDPHE (1993). The preliminary licensing statement, dated May 1993, provided the analysis of the plan and rationale for approval. A portion of the plan called for further testing of materials to confirm their characteristics, select the proper materials and determine appropriate design considerations. Based upon testing of materials and the collection of additional data, detailed specifications were submitted in 1994 for review and approval. The quality control procedures included a work breakdown structure of the reclamation activities and the documentation needed for each portion of the project. Documentation included daily journals, nonconformance reports, variance reports and project verification reports. The quality control procedures also included a description of the testing methods to be used for each phase of the project. The construction verification program for the Durita site was submitted in March 1995 prior to the first construction season. This document included a description of the activities to be verified, including: soils testing, rock testing, land surveying and field observations. The annual report submitted for each year by Hecla contained the construction verification report for each year’s construction activities. Various contractors performed quality control testing at the site. An independent contractor, Monster Engineering, performed verification of testing and construction. State personnel visited the site on numerous occasions to observe construction and cleanup activities.

2.2 Conceptual Plan

The reclamation plan approved under the radioactive materials license called for construction of permanent disposal structures on the Durita site and placement of radioactive materials (tailings; contaminated soils and construction materials) into these structures. The plan comprised six elements:

- Contamination cleanup,
- Leach tank stabilization,
- Evaporation pond stabilization,
- Surface water diversion,
- Erosion protection and
- Surface restoration.

2.3 Contamination Cleanup

Contamination cleanup consisted of cleanup of solid materials and liquid materials. Solid materials (debris and soils) were derived from the process plant area and surface soils. These materials were contaminated with radioactivity due to transportation and handling of tailings to be processed in the leach tanks. The leach tanks were constructed of large earthen dikes approximately 20 feet wide with an out slope of 2Horizontal: 1Vertical and a 12-inch compacted clay liner. Liquid material cleanup involved solidification of evaporation pond residues and relocation of these residues to a final closure cell. A map of the site is attached as Figure 3.

Equipment and facilities in the process plant and tailings process areas were demolished or salvaged. The salvaged items were decontaminated and removed from the site in accordance with the release criteria from Table I in the U.S. Nuclear Regulatory Agency Regulatory Guidance 1.86 (NRC, 1974). Demolition and other process debris were disposed of by on-site burial in the out slopes of the leach tanks, primarily in the north out slope of Leach Tank 201 and Leach Tank 203. Un-crushable debris with significant void spaces was filled with a sand-cement slurry grout prior to burial.

Non-salvaged equipment and structures, including concrete foundations, pads, support structures, tanks and other materials not decontaminated in accordance with release criteria, were buried on-site, in place, or buried in the toe of Leach Tank 201 or Leach Tank 203. Structural materials left in place were covered with clean soil. Tanks and other materials were crushed or cut where feasible, or filled with sand/concrete slurry when crushing or cutting was not feasible, and placed either in the leach tank (LT) out slope or the toe of the leach tanks for burial. Special placement and compaction methods were used at out slope locations of LT-201 and LT-203 where demolition debris and other disposable material were placed. Debris was distributed as uniformly as possible, placed in lifts, and soil was placed and compacted around the debris by hand-guided tampers.

Materials in the leach tank toes were covered and the outer slopes reconfigured from 2Horizontal: 1Vertical to 5Horizontal: 1Vertical slopes. Covered process areas were graded to provide positive sheet flow drainage, smooth contours and minimum surface grade. Final grades in the process plant and tailings preparation areas were restored to approximately original grades in the area. The other five elements are discussed in the following sections.

III Documentation of Work Meeting Applicable Standards and Requirements

3.0 Geotechnical Stability

3.1 Introduction

The Hecla Mining Company's Durita site is a uranium mill and tailings processing site using tank leach recovery that has been decommissioned and reclaimed under Colorado Department of Public Health -Hazardous Materials and Waste Management Division's (CDPHE-HMWMD) Agreement State authority, derived from Title II of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). UMTRCA requires that prior to license termination, the U.S. Nuclear Regulatory Commission (NRC) shall

make a determination that the licensee has complied with all applicable standards and requirements. Under the Agreement State program, the state of Colorado is responsible for approval of the remediation plans for the Durita site and for site inspections to ensure that the actual remedial actions have been completed pursuant to the approved plans. This report documents CDPHE-HMWMD's basis for its conclusion that decommissioning and reclamation have been acceptably completed at the Durita site.

3.2 Site Description

The site encompasses 160 acres and is located on gently north-sloping terrain at the southeast end of the Paradox Valley in western Montrose County, approximately 100 miles south of Grand Junction and 2.5 miles west of the town of Naturita, Colo. (Figure 1).

The site slopes gently to the north with a geologic remnant of the Mancos Shale Formation sticking up about 100 feet near the north center of the site. The site is nearly 5,600 feet above mean sea level and is in an arid climate with about 12 inches of rain per year. No perennial streams exist on the site, but three small drainages run through the center of the site and along the east side and the northwest corner of the site. Vegetation is sparse, consisting of shrubs, primarily sagebrush, widely spaced trees, grasses and forbs.

3.3 Site History

The original license for the site was issued on Nov. 12, 1976 to Ranchers Exploration and Development Corp. of Albuquerque, New Mexico (Ranchers), for the “storage” of uranium mill tailings. Ranchers was later authorized to transport and process 600,000 tons of uranium mill tailings at the site. A new license was issued by the Colorado Department of Public Health and Environment in 1977 and was amended several

times, and renewed, in full, in 1993. The last full license review and renewal took place on Sept. 4, 2003.

Ranchers Exploration and Development Corporation constructed the facility in 1977 and operated it as a secondary-extraction tank leach facility that recovered uranium and vanadium from mill tailings originally processed through the Uranium Corporation of America mill in Naturita, Colo. Ore was not processed. The tailings were placed in clay-lined leach tanks where percolating dilute 5 percent sulfuric acid leached the uranium and vanadium from the tailings. Slotted pipes located on top of the clay liner in the bottom of each leach tank transferred the leachate by gravity flow through a network of subsurface pipes to the extraction plant that collected the pregnant solution. The waste liquid was stored in six evaporation ponds located in the northeast quarter of the site. After operations ceased on May 22, 1979, a 2.5-foot-thick interim cover was placed over the leach tanks. Operations from 1979 to 1993 consisted of custodial care, groundwater monitoring, and some decontamination and salvage.

Hecla Mining Company merged with Ranchers in 1984 and became owners of the property. Hecla submitted a reclamation plan in October 1991 (AK Geoconsult, 1991). The department accepted this plan in May 1993. The plan was implemented and completed in 1999. Construction completion reports were submitted each year after the construction season.

3.4 Operations

The facility operated by leaching uranium mill tailings with dilute 5 percent sulfuric acid in three large earth-bermed leach tanks (Figure 2). These leach tanks are the engineered structures designed to hold the Uravan tailings while they were being leached for uranium and vanadium. They then became the disposal locations for the spent tailings. The leaching tanks were constructed of earthen dikes approximately 20 feet wide with an out slope of 2H: 1V and a 12-inch compacted clay liner. The acid

leachate containing uranium and vanadium was collected by slotted pipe at the bottom of each leach tank and transferred through a series of subsurface pipes to the extraction plant. Uranium and vanadium were removed by ion exchange and solvent extraction.

The leach tanks had a compacted 12-inch clay liner on the bottom and inside slopes. Permeability tests showed that liquids would not penetrate the liner during its active life, approximately 19 months. The compacted clays used in the liner construction had a permeability range from 9.2×10^{-7} cm/second to 1×10^{-8} cm/second (Coe & Van Loo, 1976). Each tank also contained a network of collection lines that transported the extracted uranium to the mill. The tanks were originally designed to contain 727,500 cubic yards of tailings materials. At the close of operations, tank 203 was 65 percent filled, and tanks 201 and 202 were 100 percent full.

- Tank No. LT- 201 267,300 CY
- Tank No. LT-202 287,100 CY
- Tank No. LT-203 178,100 CY

Waste liquids from the process were stored in a series of evaporation ponds located on-site.

At the conclusion of operations, a temporary soil cover was placed over tailings contained in the leach tanks. Two and one-half feet of random fill was placed on top of the leach tanks. License Condition (LC) 17.1.2 required that a minimum of 5.28 feet be the minimum cover. Measurements of the radon cover after placement indicate that the cover met all minimum criteria of the license. The evaporation ponds were left uncovered due to the amount of liquid remaining in the ponds. Uranium processing at the site resulted in the need for cleanup of contaminated soils and evaporation pond residues.

Combining the evaporation pond residues into one cell (the closure cell) and placing the plant area residues in the existing heap leach cells and closure cell avoided the proliferation of small waste sites. The disposal of all these materials at one location reduced reclamation costs and long-term maintenance costs.

The pre-existing condition and nature of the Durita site made below-grade disposal of tailings an impractical option. Below-grade disposal would bring the wastes closer to groundwater and reduce the isolation features inherent to the existing site. This location and its designed liners, covers and diversion channels are adequate to resist the long-term forces of erosion.

3.5 Design Basis of the Leach Tanks

The reclaimed leach tanks and the closure cell were designed to maximize structural stability, minimize settlement and remove the potential for liquefaction and to minimize active long-term maintenance. The soil covers for these cells were designed to reduce radon release, reduce the infiltration of moisture, reduce the effects of freeze/thaw cycles and reduce the potential for gully erosion. Leach tanks have rock on the side slopes and a vegetative cover on the top.

Runoff diversion channels were designed to withstand extreme flooding. The rock cover material for the cells and riprap for the diversion channels were selected for long- term durability.

The structural stability of the cells was evaluated using the STABL5 computer code and the modified Bishop method of stability analysis, one of several slope stability calculation methods in common use. Under the extreme hypothetical conditions modeled (an earthquake with 0.12g peak acceleration and complete saturation of all leach tank slopes and natural ground) the lowest factor of safety for the highest leach tank slope (27 feet) is 1.61. This is well above the limiting value of 1.00 for a pseudo-static factor of safety.

The leach tank tailings materials consisted of sandy soils with some silt and clay. They were unsaturated and have been in place since 1980. They were initially covered with a temporary cover of a minimum of 2.5 feet. An additional final cover of 2.8 feet was added for final closure. The additional cover would cause a surcharge of about 550 pounds per square foot. Therefore, any settlement resulting from this surcharge would be small. This was confirmed by field measurements. Settlement calculations were not done, probably based on the low load from the additional cover and the weight of equipment used for soil placement and compaction. Settlement monitors were constructed on the cells to observe changes as construction took place. During the period of waste placement and cover construction for the closure cell, from early 1996 to late 1998, total settlement was less than 1 inch.

3.6 Leach Tank Stabilization

Leach tank stabilization involved contouring and covering the three earthen leach tanks constructed in 1976 to extract uranium. The side slopes of the leach tanks were re-graded to a slope of 5H: 1V from a slope of 2H: 1V. Some of the material used in the re-grading was cut from the crest of the existing tanks and the remainder was obtained from the approved borrow sources. Process plant debris was also placed on the out slopes of Tank 201 and Tank 203. The top slopes of the leach tanks were graded to slopes of 0.5 percent

A 2.5-foot temporary cover was placed over the tailings when active operations stopped. This cover used on-site soils classified as CL or SC in the Unified Soil Classification system and was placed in 8-inch lifts compacted to 95 percent of Standard Proctor, ASTM-698. A minimum additional 2.8 feet of soil cover was placed on the leach tanks to reduce the radon emanations to less than 20 pCi/m2s. Radon testing indicated that the measured flux rate through the engineered covers, from a total of 138 measurements over the three heap-leach tanks and the closure cell at Durita, averaged 0.91 pCi/m2s. Results ranged from a low of less than 0.5 pCi/m2s

(the analytical practical quantification limit) to a maximum radon flux reading of 17.6 pCi/m2s. The materials used for the soil cover were obtained from the realignment and excavation of ephemeral channels that cross the site. Settlement monitors were constructed early in the process to assure that differential settlement was minimized. The final cover over the leach tanks has 5H: 1V rock covered slopes and utilized a vegetative top cover. Surface water diversions and erosion protection were designed to assure stability of the repository during maximum probable precipitation and/or flooding. The rock was tested for durability and properly sized for placement.

The soil-covered tops of all three leach tanks are stable as designed and constructed. The following items all indicate that the covers are stable in their current configuration:

- The design engineer (AK Consultants, Inc.) utilized the Horton NRC method, an NRC-approved analysis method for stable covers in the final reclamation plan (AD GEOCONSULT, 1991). They utilized NRC's Final Staff Technical Position — Erosion Protection Covers for Stabilization of Uranium Mill Tailings Site, August 1990 (NRC STP).
- AK GEOCONSULT designed all of the leach tank top slopes so that they were flatter than the critical slopes calculated by the Orton/NRC method. A slope flatter than the critical slope is stable from erosion. All of the leach tank slopes were designed and built at a slope of 0.005, which is 1 foot of drop for 200 feet of run.
- Acceptable cover materials were utilized during construction.
- Acceptable construction methods were observed.
- Placed cover materials passed all testing requirements.
- To date, the soil covers are performing as designed. There are no signs of wind or water erosion on top of the leach tanks.

3.7 Evaporation Pond and Raffinate Pond Stabilization-Closure Cell

Six evaporation ponds contained residual soils and liquids that were byproducts of the leachate-extraction process. They occupied an area of approximately 13.4 acres. The salts, gels and liquids were mixed and solidified and consolidated into a single 4-acre repository (closure cell) adjacent to the “Mancos Hill.” The closure cell was designed to contain these wastes for not less than 200 years.

The evaporation pond materials were mixed with Mancos Shale to solidify and neutralize the contaminants present. Laboratory tests performed in 1992 showed that mixing of the calcareous shale with the pond material would help neutralize the pond material. The materials were mixed at an approximate ratio of 1 part shale to two parts pond material by volume until it was dry enough to be placed as a soil. This mixed material was called solidified pond material (SPM). Any SPM containing moisture contents higher than those that would allow the required compaction were reworked, disked, scarified or otherwise manipulated to dry those materials to the necessary moisture content for compaction prior to their relocation and placement within the closure cell.

SPM materials that had sufficiently reacted, solidified and dried were excavated and hauled to locations within the closure cell and placed in lifts not to exceed 8-inch uncompacted lift thickness. Each lift of SPM was compacted to not less than 90 percent of maximum Standard Proctor Density (ASTM-698) before placement of subsequent lifts.

Four small (80 feet wide by 80 feet long and 10 feet deep) lined raffinate ponds were located near the north side of leach tank 201. The raffinate was mixed in place with Mancos Shale so it could be solidified sufficiently to be hauled to the evaporation ponds and mixed with the SPM and eventually taken to the closure cell.

The closure cell was constructed with a 1-foot compacted clay liner on top of scarified Mancos Shale. The liner was constructed to meet a permeability of l x l0^{-7}

cm/sec. The side slopes of the cell have a 5H: 1V slope and the top of the cell is sloped at 2 percent. A 3-foot thick soil cover was constructed on the side slopes of the closure cell. The top cover was initially to be 3 feet thick, but because additional low-level radioactive material was encountered, the cap was increased to 8.7 feet. Most of the materials placed in 1996 and 1997 placed in the cap contained significant quantities of clay that was moisture conditioned and compacted to the radon barrier or cover specifications when placed. These materials were removed from haul roads, the windblown areas, and within the evaporation ponds. A rock cover for erosion protection was also placed on the top and on the side slopes. The rock cover prevents the soil from becoming airborne and being dispersed from the closure cell. This eliminated the need to consider the air pathway for off-site exposure.

The radium-226 activity throughout the closure cell, including the solidified pond material, is low. Results from clean-up verification samples collected in 1995 and 1996 revealed that several contaminated areas remained within the old evaporation ponds. Results showed that soils contained minor quantities of radioactive materials. Only minor amounts of contaminated soils were encountered. Laboratory results from samples collected within the closure cell revealed that after excavation and transfer to the closure cell, radium-226 activity levels decreased to near background (1 pCi/g) due to the significant quantity of clean soil removed with the contaminated soil. The radium-226 activity of the SPM had an average value of 6.4 pCi/g. This level is only slightly elevated over the approved site cleanup level for radium-226 of 6 pCi/g. The measured average radium-226 activity of each layer of the upper 12.7 feet of the closure cell ranges from 1.8-2.3 pCi/g. The top 6 inches of the closure cover has an average radium-226 activity of 1.8 pCi/g. Therefore the cover radium-226 activity is essentially the same as in the surrounding surface soils. Further, a 6-inch layer of rock, which will help to maintain moisture content in the cover, overlies the cover. The cell cover meets the condition of Criterion 6 for longevity and control of radon release.

3.8 Slope Protection Measures for the Waste Repositories

Slope protection measures were constructed to protect the waste repositories. These measures included construction of a new closure cell for the evaporation and raffinate pond residues and the placement of rock cover on the side slopes of the leach tanks and new closure cell. Rock cover also was placed on top of the closure cell. The leach tanks were constructed with a relatively flat top surface slope of 0.5 percent, which is a drop of 1 foot for 200 feet of run, and re-vegetated to minimize erosion. The outer slopes were protected by a minimum 6-inch-thick rock cover consisting of rock with composite durability scores of 80 percent or more (AK Geoconsult, Inc. 1994a). Field measurements were taken of rock depth on April 19 and April 26, 1996. Measurements indicated an average rock cover of 6.7 inches and no single depth less than 6 inches on LT-201, an average depth of 6.7 inches and no single depth less than 6 inches on LT-202, and an average depth of 6.5 inches on LT-203. A small area with a depth of 4 inches was found on the west slope. The contractor later placed additional rock at this location. The size and gradation of the rock used was calculated according to guidelines provided by the U.S. Nuclear Regulatory Commission NUREG/CR 4620. All design analyses indicate that the covers will withstand wind and water erosion for more than 1,000 years.

The rock placement crew consisted of two dozer operators and a grade setter. A Caterpillar D5H dozer was used for rough grading. A Caterpillar D5LGP dozer was used for final placement and finish grading. The most effective method to thin the rock to 6 inches and leave a smooth surface was to back drag with the D5LGP. A Caterpillar 12G grader and a water truck maintained the haul routes. A front-end loader and several trucks were used to move rock from the stockpiles to the haul roads.

The Horton Method was used to evaluate the potential for gully formation and soil erosion. Based on the soils used for cover, and the slope gradients and lengths, all of the top slopes would be stable. For the side slopes, the gradients generally exceeded the critical slopes of the Horton analysis but were within the range of slopes recognized as stable under Appendix A, Criteria 4c, of part 18 of the Colorado

regulations. These slopes were provided with a rock cover to assure erosion stability. The size of the rock cover was determined using the safety factor method as described in the NRC Final Staff Technical Position (US NRC, 1990). The median size ranged from 1.0 to 1.7 inches. Two-inch rock was used for cover. CDPHE concurred with the analysis performed and agreed that the slopes would be stable. Subsequent annual inspections have shown that the slopes remain stable.

3.9 Surface Restoration

Surface restoration is the final element of the reclamation plan. This element involved re-grading and re-seeding of the process plant and ancillary areas. The tops of the heap leach repositories were vegetated to reduce infiltration through the cells. The four most important elements of the reclamation plan that control the longevity and effectiveness are:

- The stability of the evaporation pond materials placed in the closure cell;
- Low permeability of the soil cover material;
- Durability of the rock used for riprap and
- Proper alignment and protection of the runoff control channels.

The evaporation pond residues are chemically altered materials that do not behave as normal soil. Hecla performed extensive testing on the evaporation pond materials. The method selected to stabilize the materials to assure more soil-like properties was to add shale. The calcareous shale acted to chemically neutralize the acidic material and allowed for proper compaction. The method used to stabilize the evaporation pond materials provided an inert, well-compacted material.

Soil used for cover material was obtained from the excavation of clean materials to re-align the runoff control channels that cross the site. These soils were derived from the nearby rocks and contained significant amounts of clay. The interim soil covers on the leach tanks were also sampled and found to contain about 28 percent clay. The permeability of compacted samples averaged 2×10^{-7} cm/sec. The soil was also found

to be non-dispersive and acceptable from the standpoint of minimizing radon flux and infiltration of precipitation. Specifications for all soils used as cover included classification of the soil as an SC, CL or CH under the Unified Soils Classification System. During placement, compaction was specified to 95 percent of ASTM D 698, Standard Proctor Density, to assure limited permeability.

Rock cover and riprap materials were obtained from two borrow source areas. The majority of the rock comprises gravels found along the San Miguel River. A small amount of the largest riprap material was a marine limestone obtained from a quarry in La Sal, Utah. Both of these sources were tested for durability using standard engineering tests. Both materials were found to meet durability recommendations of the NRC, and did not need to be oversized. The terrace gravels used for the rock cover and riprap were located adjacent to the San Miguel River. The deposit contained primarily igneous rock that had been carried downstream some 50 miles from the headwaters of the San Miguel River. Alluvial transport of the material from the San Juan Mountains resulted in the selection and deposition of the most durable materials.

The second source of the largest rock size (over 10-inch) was a limestone member of the Upper Hermosa Formation taken from a quarry near La Sal, Utah. The rock is a Pennsylvanian-aged (300 million years old) fine-grained marine limestone. It is sound, dense and free of lineations, partings or other areas of weakness. The limestone does not contain a significant amount of minerals that will weaken the rock during its service life. Durability testing confirmed that the material met NRC guidance without the need for oversizing.

Channel alignment and the control of runoff water passing through the site was initially a serious concern. However, the conceptual design submitted by Hecla provided an innovative solution to flood routing past the repositories. The three pre-existing ephemeral channels were re-aligned to the grades that existed prior to construction of the leach tanks. The channels were widened slightly to reduce the

potential for scour. Scour protection walls and riprap blankets were designed to be placed along the edge of the flood plain to protect the upland areas from the effects of the probable maximum flood event (see Section 6.3).

3.10 Cover

The covers for the cells were constructed from soils available at the site, and found to meet the design criterion. The soils ranged in type from clayey sand to sandy clay. The hydraulic conductivity of the soils used ranged from 5 x $l0^{-7}$ to 3.7 x 10^{-8} cm/sec with an average permeability of 1.9 x 10^{-7} cm/sec. These soils are relatively impermeable, which means that they will not transmit large volumes of water or radon gas. The compacted soils were suitable for use as cover material to reduce both radon flux and precipitation infiltration.

Radon emanation was evaluated using the U.S. Nuclear Regulatory Commission RADON Model. The parameter values selected for the model also were evaluated and found to be reasonable. The RADON model resulted in an estimate of 2.8 feet of soil cover to meet the radon flux requirement of 20 pCi/m^2 s. The final cover thickness for the leach tanks was 5.28 feet thick and 8.7 feet thick for the cover/radon barrier for the closure cell (see Section 5.5 for further discussion on radon emanation).

The frost depth in the area does not exceed 2 feet according to the U.S. Soil Conservation Service and local contractors. Top slopes were designed to promote runoff. In a response to state comments, Hecla indicated that unsaturated soil will not experience frost damage and that, due to the low permeability of the compacted cover, the saturation depth will be a few inches at most. Hecla stated that a few inches of frozen soil would not alter the effectiveness of the cover as a radon barrier. In the worst case, the frost depth is not anticipated to exceed 24 inches. Nevertheless, the 5-foot plus cover thickness on the leach tanks and 8.7-foot cover thickness of the closure cell provided an adequate margin of safety to control radon and to ensure that frost heaving will not affect cover performance.

Top outer slopes were designed to promote runoff. In a response to state comments during the division's completeness review of the Durita Site Reclamation Plan, Hecla indicated the following: According to the Montrose office of the U. S. Conservation Service, there are five soil types in the area, all of which are loams. All have "low potential frost action." The actual depth of frost will vary depending on average soil moisture, which depends in turn on variables such as surface drainage and exposure to sun and wind. However, with positive drainage and good exposure provided during reclamation, the "low potential" should minimize frost depth by limiting the depth of soil saturated by infiltration of moisture.

The infiltration through the cover was evaluated using the Hydraulic Evaluation of Landfill Performance (HELP) model developed by the U.S. Army Engineer Waterways Experiment Station under a cooperative agreement with the U.S. Environmental Protection Agency. The model tends to predict more infiltration than is actually observed and thus is an appropriate model for evaluating the potential for long-term failures. In addition to reviewing Hecla's model, the division prepared its own evaluation of the data. The evaluation showed a steady-state flux of liquids through the cover. Concerns were expressed about the buildup of liquids on the liner at the bottom of the cell. However, the underdrains were dry for several years prior to the start of reclamation. Borings conducted to characterize the leach tank materials indicated that the bottom few feet of tailings might be saturated in some locations. Placing low-permeability cover material and establishing vegetation would reduce the potential for infiltration and for soil becoming airborne.

The erosion potential of the vegetated top slopes was evaluated using the Horton Method; one of the U.S. Nuclear Regulatory Commission-approved methods to evaluate gully erosion. The top slopes were designed to be less than 2 percent and were shown to be stable for flows up to the probable maximum flood event, 8.4 inches per hour of rainfall. Re-grading the side slopes to 5H: 1V reduced the potential for erosion of the side slopes. The slopes were also protected with a rock cover. The rock size was calculated to withstand the erosive forces of the probable maximum

flood. In the original design the D_{50} rock sizes varied from 4 inches to 20 inches. The plans were revised in 1997 to reduce the number of different sizes of rock needed. The D_{50} sizes either increased or remained the same.

The compacted cover for the closure cell was 8.7 feet. The evaporation pond material was mixed with Mancos Shale and was compacted into a soil-like state at a moisture content that met compaction criteria (see Section 4.3). The soils placed in 1995 through 1997contained significant quantities of clay that were moisture conditioned and compacted to the radon barrier cover specifications when placed. Therefore, the materials in the closure cell as engineered, placed and constructed are unsaturated, much denser and less permeable than are other radioactive site repositories. Because of the thickness of the engineered cap and because the materials in the closure cell are unsaturated and compacted, the closure cell is not considered to be a source for potential groundwater contamination.

During a May 2001 site visit, U. S. Nuclear Energy Division staff requested an evaluation of the top cover's resistance to erosion. Hecla Mining Company submitted a stability and sedimentation evaluation done by Monster Engineering dated Oct. 22, 2001. The state of Colorado concurred with the findings of the evaluation that the top-slope covers were stable (CDPHE, November 2001). The cover would provide long-term protection from radon emanation and erosion.

3.11 Seismic Evaluation

The Durita site is located within the Colorado Plateau Seismic-tectonic Province as described by Kirkham and Rogers[3] (1981). They estimated a maximum credible earthquake (MCE) of 5.5 to 6.5 for the province, making it one of the more stable provinces in Colorado. Recent faulting according to F.M. Fox & Associates (1982) is rare in this province except for faults related to the Uncompahgre Plateau or collapse

[3] Kirkham, R. M., and Rogers, W. P., 1981, Earthquake Potential in Colorado, A Preliminary Evaluation, Bulletin 43, Colorado Geological Survey, Department of Natural Resources, State of Colorado, Denver, Colorado.

of the salt anticlines. According to the report by F.M. Fox, evidence indicates that the collapse of salt structures was active in the last 500,000 years and may be active at present. However, the faults associated with collapse are gravity faults that are generally slow moving with a low potential for generating even moderate earthquakes. There is no evidence for recent movement along faults in the immediate vicinity of the site. The site does not appear to be located adjacent to a capable fault. There is no evidence, either at the surface or in the holes drilled for monitor wells, to indicate faulting or even abrupt structural changes under the site. The MCE for the 1,000-year event would generate a peak acceleration of 0.12g. Stability analyses indicate that the repositories have more than adequate safety factors for static and pseudo-static conditions. Based upon the existing information, the site will provide permanent isolation of the tailings for the long term.

Minor earthquake activity has been reported at the northwest end of the Paradox Valley. Induced earthquakes have been reported from the Bedrock, Colo. area due to high-pressure injection of brines into the Leadville Limestone by the Bureau of Reclamation. When the injection pressure is lowered, the earthquakes stop.

The first recorded earthquake in the Colorado Plateau region occurred in 1870. The locations of pre-instrumental earthquake events are poorly defined, probably because of the sparseness of population. As a general rule, the historical record is probably reliable for moderate to large earthquakes since about 1890. Seismologists have been able to determine magnitudes of greater than 4.0 with a location uncertainty of 30 miles since the 1950s. For magnitudes of 3.5 or greater since 1963, the instrumental record is probably reliable with a location uncertainty of 12 miles. Published estimated maximum earthquake magnitudes based on regional source zones are presented below (DOE, 1998):

Estimated Maximum Earthquake Magnitude, Intensity and Acceleration for the Site Region

Source	Magnitude	Region	Intensity/ Acceleration
Liu & De Capua (1975)	7.0	Utah	0.02g
	6.5	Colorado	IV
Algemissen et. al. (1982)	6.1	Paradox Basin	0.07g
	7.2	Uncompahgre/San Juan Mountains	0.12g
Thenhaus (1983)	6.0	Paradox Basin	Not given
	6.5	Uncompahgre/San Juan Mountains	Not given
Kirkham & Rogers (1981)	5.5 – 6.0	Colorado Plateau	Not given
	6.0 – 6.5	Western Mountains	Not given

Geologic Suitability and Site Stability: Additional Information

For the purpose of comparison, DOE proposed constructing a disposal cell for the Naturita tailings on a site called Dry Flats located approximately one mile due east of the Durita site. They prepared a report that evaluated geologic stability and suitability, geomorphic stability and tectonic stability. Their evaluation determined that geomorphic processes are not likely to affect the long-term stability of the disposal cell. Potential geologic events, including seismic shaking, liquefaction, on-site rupture, ground collapse and salt core flow, are ruled out as potential disturbing forces on the disposal cell because the geotechnical design of the cell is formulated to resist such forces (DOE. 1994).

The geology report indicated that the site lithology, stratigraphy and structural conditions were suitable for the disposal cell. Based on their evaluations, DOE concluded that the site was geomorphically stable and would continue to be stable for the performance period of the disposal cell. There is little likelihood of salt core flow inducing and developing collapse structures adjacent to the site, given the present stable nature of the region and of the Colorado Plateau. The site was little disturbed

by the Tertiary activity that developed Coke Oven Valley and Paradox Valley because it lies on the flanks of the salt core structure.

The DOE determined that the disposal site and cell design would provide long-term stability during seismic events by analyzing the anticipated ground motion at the site as a result of those events. They analyzed potentially active faults and the remote seismic sources with the calculated maximum earthquake (ME), as well as the estimated ME of previous studies. The criticality of these faults was evaluated using the appropriate attenuation relationships for the site region. Four fault groups were shown to be within critical distance and to have critical length regardless of known capability. One salt core structure was also determined to be in the critical group.

In a brief summary, the design earthquake for this site was determined to be an M_L = 7.1 event occurring at a distance of 24.1 kilometers from the site based on the conservative assumption that the largest critical tectonic fault was capable. Seismic design parameters are presented below. The acceleration attenuation relationship of K. W. Campbell[4] (1981) was used to derive the on-site horizontal acceleration.

Design Criteria

- Long-term slope stability seismic coefficient: K=0.17 (two-thirds of peak horizontal acceleration).
- Short-term slope stability seismic coefficient: K=0.13 (one-half of peak horizontal acceleration).
- Liquefaction analysis: Ground surface acceleration, a_{max} = 0.24 g.

The seismic potential for the site had a design of 0.25g peak horizontal acceleration. “Because of the stability of the bedrock that underlies the cell foundation, the potential for failure of the foundation is considered negligible.” (DOE, 1994)

[4] Campbell, K. W., 1981, Near source attenuation of peak horizontal acceleration, *Bulletin of Seismological Society of America*, 71, 2039-2070.

"On the basis of the site characterization described in this section and supporting documents, and the provisions for stability included in the design of the disposal cell, the DOE concludes that there is reasonable assurance that the regional and site geologic conditions have been characterized adequately to meet 40 CFR Part 192." (DOE, 1994)

3.12 Liquefaction Potential

The liquefaction potential of the cells was considered during design. Liquefaction requires saturated fine sand or silt under conditions where confinement is inadequate or where it could be lost, leading to dilation of soil due to pore-liquid pressure sufficient to destroy the continuity of soil solids and to suspend soil solids in liquid (liquefaction). Conditions preventing this from occurring in the leach tanks are: a) absence of a saturated zone (these cells were designed to drain as heap leaches and were dry for 15 years prior to final cover placement) b) total confinement laterally by dikes and vertically by a thick section of unsaturated tailings and cover material, and c) low seismicity of the area. The pond residues in the closure cell were also evaluated for liquefaction potential. Although initially a wetter material, the addition of large amounts of Mancos Shale to the residues resulted in the creation of a dry, chemically altered, heterogeneous material, with concrete-like properties.

4.0 Site Remediation

Hecla submitted a final reclamation plan for the site in October 1991, which was approved by CDPHE in May 1993. Decommissioning began shortly afterwards with demolition of the process plant and tailings preparation equipment. When leach tank drainage ceased, the collection pipes at the base of the leach tanks were plugged with concrete. The interim top and out slope covers over the leach tanks were replaced with engineered earthen radon barriers and out slopes received 6-inch layers of rock for erosion protection. The clay radon barriers were also compacted to reduce water infiltration from precipitation and were sloped to facilitate runoff. The tops of the leach tanks were re-vegetated.

Liquids in the raffinate ponds and the evaporation ponds were neutralized and solidified with Mancos Shale and the solidified material was consolidated and placed in an 8-acre engineered closure cell built to isolate the contaminated material from the environment. Demolition debris and radionuclide contaminated soils were also placed in the closure cell. The cell is imbedded in the Mancos Shale formation, has a compacted clay liner, and an engineered cover to reduce radon and infiltration of precipitation. The cover has been graded and contoured to promote runoff.

4.1 Implementation of the Reclamation Plan

Reclamation of the Durita site took place during the period from 1992 to 1999. Implementation of the reclamation plan started in 1992 with the testing of evaporation pond residues to determine the best means of solidification. Testing of the methods to solidify the pond residues continued in 1993. Cleanup of the process plant and tailings preparation areas at the site started during the 1993 construction season. In 1994, solidification of the pond material commenced and removal of contaminated soil was undertaken. The state of Colorado performed oversight of reclamation activities during 28 site visits and inspections between 1992 and 1999, including independent verification surveys and sampling.

The 1995 construction season saw the removal of the remaining debris from the process plant and tailings preparation areas. Removal of the majority of contaminated soil was completed across the site. Solidification of the pond material continued and the liner for the new closure cell was constructed. Placement of solidified pond materials in the closure cell started in 1995. The leach tank outer slopes were contoured to a 5H:1V slope. Contouring was performed through a combination of placement of contaminated soil and debris and re-grading of the remaining cells, pits, dikes and other topographic features. Other work completed in 1995 included sealing the leach tank underdrain system and establishing temporary settlement monitors on the leach tanks and the closure cell.

Removal of contaminated soil continued during 1996. The contaminated soils were placed in the closure cell. Rock was placed on the out slopes of the leach tanks. The thickness of the rock already placed was confirmed during the 1996 construction season. Settlement monitors were placed on the leach tank tops in early 1996. Measurements commenced in March 1996.

Activities in 1997 included removal of contaminated soil from the evaporation pond area, continued with placement of this material in the closure cell. Other work conducted during the 1997 construction season included re-grading of some leach tank out slopes, re-grading work on the east and central diversion channels, placement of rock cover material on the slopes of the leach tanks, and re-grading of areas where contaminated soil removal had taken place.

During the 1998 construction season, work continued on re-grading of channels, placement of rock cover on the leach tanks and re-grading of the old evaporation pond area. Rock cover was also placed on the closure cell. Riprap and scour protection were placed on the closure cell during this period.

The last major construction season was 1999. Work included re-grading of various areas across the site including the diversion channels, placement of riprap and rock cover material, and seeding of the tops of the leach tanks. In 1999, representatives from the state of Colorado performed confirmatory gamma surveys.

After construction was completed in the spring of 1999, a series of intense storms passed through the area. A routine inspection of the site in August 1999 indicated that concentrated runoff adjacent to the rock cover aprons on leach tanks 201 and 203 caused some erosion. The potential for a similar situation also existed in the channel between tanks 201 and 202. Upland flow near tank 203 was also washing down behind the riprap curtain along a 20-foot portion of the east side of the central diversion channel. In response to these observations, Hecla repaired the erosion problems

noted and constructed additional measures to handle the areas where concentrated runoff was noted. A follow-up site visit in November showed that Hecla had repaired the problem areas and performed additional work. This work included the construction of additional length to the 201/202-diversion channel, improvements to the channel below the west end of tank 201 and improvements to the runoff collection channel above the closure cell. None of the repairs or improvements needed resulted from riprap failure due to water flowing through the diversion channels, but resulted from channelized upland flows. The re-grading of the upland areas and placement of additional rock aprons will preclude future problems.

4.2 Design Changes and Modifications

During construction, conditions encountered in the field led to the need for design changes or minor modifications to the reclamation plan. The majority of the changes and modifications took place during the 1995 construction season. A detailed description of the design changes and modifications is found in the 1995 annual report and subsequent annual reports. More than 25 minor modifications were made to the plan. The most significant ones involved relocation and widening of diversion channels, minor decreases to leach tank elevations and reduction in the number of rock gradations. Six design changes were made, including changes to cell configurations, diversion channel grades and configurations, location of contaminated soil placement and disposal location for some process plant debris. Design changes and minor modifications that affected reclamation plant design were prepared by a registered professional engineer and submitted for department approval. Where needed, appropriate calculations confirming the performance of the change were submitted for review. All modifications were reviewed and approved by the department prior to construction.

4.3 Specifications and Quality Control

Each element of the reclamation activities was performed according to written specifications that were submitted by Hecla as outlined in the 1991 Reclamation Plan

(AK Geoconsult, 1991) and presented in detail in a series of 1994 submittals (AK Geoconsult, 1994a,b,c,d,e,f). Quality control for the project involved assurance that the specifications were met. The quality control framework was implemented through the establishment of Quality control procedures and a construction verification program. Quality control procedures established specifications for testing, inspection and documentation. Construction verification provided the framework for independent quality assurance and the preparation of construction completion reports and drawings. Various contractors performed quality control procedures. Quality assurance for the construction work was performed by an independent contractor (Monster Engineering Inc).

Annual updates were provided to the Colorado Department of Public Health and Environment each year for the previous year's reclamation activities. These updates included a description of the work performed, construction verification and quality control, test results, and a summary of modifications. Daily activity logs and a summary of all quality control work were included in the annual reports.

Initial cleanup of contaminated soil was governed in the field by gamma radiation surveys. Gamma meters were used to guide field removal of contaminated materials. Uncorrected field readings of 30 μR/hr together with visual evidence were used to determine the need for removal. Conformance with soil cleanup standards was verified through soil samples taken on 100-square meter grids. Soils cleanup verification was described and documented in a report entitled "Soil Cleanup Verification Report" (Hecla Mining Company, Nov. 14, 1996).

Standard earth moving equipment and methods were used on site for soil removal, transportation, disposal, placement and compaction. Equipment included backhoes, end loaders and scrapers, as well as trucks for hauling materials and machinery for placement and compaction. Equipment used during reclamation was included in reports submitted to the department, and the reports are available for review at the

Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division Record Center.

Placement of contaminated soils was controlled through the use of proper compaction. Stabilization of the leach tanks involved placement and compaction of contaminated soils, debris and clean soil on the outer slopes and within the cells. The material density was controlled through the thickness of the layer placed and compaction. Layer or lift thickness was limited to 8 inches. Compaction was tested using Standard Proctor Density. The specification for placement of contaminated material was 90 percent of Standard Proctor Density. The lift thickness for the clean soil cover was also 8 inches. Compaction of the cover material was specified as 95 percent of Standard Proctor Density, with moisture contents of +/- 2 percent of optimum. Compaction was tested once every 10,000 cubic yards.

The type of material used for the radon barrier portion of the cover was specified as a clay or silty clay. Material type was confirmed using standard soil engineering tests. The final grade of the leach tank outer slopes and top slopes were confirmed using land survey equipment. Rock cover was placed on top of the final soil cover. Rock durability was tested for each 1,000 cubic yards of material. The tests used included specific gravity, absorption, sulfate soundness and Los Angeles abrasion test. Rock size and proper placement were observed in the field. Rock layer thickness was evaluated with land survey data and verified by digging test pits. Design documents, specifications, quality control data including compaction tests and locations, gamma survey results, laboratory test results, and annual reports describing activities on the site are available for review at the Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division Record Center.

4.4 Field Quality Control Testing Included the Following Frequencies:

4.4.1 Soils

4.4.1.1 Soil classification: For soils used in the containment berms, clay liners and radon barriers and for contaminated soils, not less than one per 10,000 cubic yards (c.y.) or at least one per each two acres of borrow area, whichever is greater.

4.4.1.2 Standard Proctor Density (ASTM D-698): At least one per 10,000 c.y. for soils used in the containment berms, clay liners, radon barrier and diversion channels, for SPM and contaminated soils.

4.4.1.3 In-place density tests: At least one per 5,000 c. y. per ASTM D-1556 for all compacted materials. ASTM method D-2992 may be used if sufficient correlation with method D-1556 can be established based on not less than 10 comparative tests.

4.4.2 Rock

4.4.2.1 Rock quality testing (sodium sulfate soundness per ASTM C88, specific gravity and absorption per ASTM C97).

4.4.2.2 Rock size and gradation: One test per 1,000 c.y. of each gradation using ASTM C-136 or other approved method.

4.4.2.3 Rock layer thickness: Leach tank out slope cover and closure cell: One measurement per 4,000 square feet.

4.4.3 Channel Riprap Placement

4.4.3.1 Visual inspection of rock screening operations and rock placement was performed at least once daily.

4.4.3.2 Rock quality testing (sodium sulfate soundness per ASTM C88, specific gravity and absorption per ASTM C97): One test per 1,000 c.y.

4.4.3.3 Rock size and gradation: One test per 1,000 c.y. of each gradation using ASTM-136 or other approved method for rock sizes exceeding the range of applicability of AST-136.

4.4.3.4 Rock layer thickness: One measurement for each 200 feet of length.

Evaporation pond stabilization involved construction of a containment berm as part of the closure cell, construction of the clay liner for the cell, placement of contaminated pond residues and placement of a radon barrier. A rock cover was placed on top of the radon barrier. Containment berm specifications included material type, size, and soil compaction range and layer thickness. Size of individual clasts could not exceed 6 inches, within an 8-inch lift. Compaction was set at 95 percent of Standard Proctor Density, with a moisture content of +/- 2 percent of optimum. The clay liner specifications included a clay-only material type, individual clast size of 3 inches and compaction of 90 percent Standard Proctor Density. The contaminated pond residues and contaminated soils were subject to lift thickness and compaction requirements, specifically, 8-inch lifts and 90 percent of Standard Proctor Density.

The specification for Solidified Pond Material (SPM) called for mixing of the pond residues with shale until all chemical reactions had taken place and the material took on a dry, soil-like consistency capable of being compacted in the closure cell. Laboratory tests performed in 1992 showed that mixing of the calcareous shale with the pond material would help neutralize the pond material. The materials were mixed at an approximate ratio of 1 part shale to 2 parts pond material by volume until it was dry enough to be placed as a soil. This mixed material was called solidified pond material. Any SPM-containing moisture contents higher than those that would not allow the required compaction were reworked, disked, scarified or otherwise manipulated so as to dry those materials to the necessary moisture content for compaction prior to their relocation and placement within the closure cell. These conditions were verified by visual observation in the field. Outer slope grades were

confirmed through land survey to determine conformance with the 5H: 1V slope requirements. Rock size and proper placement were observed in the field. Rock layer thickness was checked by digging test pits and through land survey data. Rock durability testing was performed as described previously.

Development of surface water control structures involved excavation and placement of fill in floodplains and channels, construction of scour protection trenches and specifications for riprap material to be placed in the trenches. Excavation was controlled by tolerances to the design drawings as observed in the field. Placement involved compaction of 12-inch lifts by at least three passes of a D8 bulldozer. Thickness of the scour protection features and the size of rock used were measured in the field during construction. Rock durability was tested for each 1,000 c.y. of material, according to the tests discussed previously.

Erosion protection involved specifying the placement, thickness, gradation, size and extent of rock cover and riprap materials (rock) for all aspects of the project. Seeding of the disturbed areas included specifications for the mixture, time of year and requirement to mulch after seeding.

4.5 Soil Cleanup Plan

Soils contaminated with radioactive materials and/or metals associated with operations were excavated from locations around the process plant, tailings preparation areas and on-site roads and disposed of within the out slopes of the leach tanks or the closure pond materials containment cell as described in Revision 1 of Hecla's reclamation plan. The cleanup standard for radium was based upon U.S. Environmental Protection Agency standard, 40 Code of Federal Regulations Part 192, of 5 pCi/g over background for contamination in the upper 15 cm, and 15 pCi/ g for soils at a depth greater than 15 cm. Soil metals including arsenic, cadmium, lead, molybdenum and selenium were cleaned down to background ranges. Background values for radium and metals associated with plant operations were based upon

samples taken from several locations as described in Volume 1 *Text, Tables, and Figures* of the *Final Reclamation Plan* (AK Geoconsult, Inc., 1991). This information was also contained in the report entitled “Soil Clean-up Verification Report” Hecla Mining Company, Durita Site, and Nov.14, 1996.

4.6 Settlement and Cover Cracking

The settlement of the leach tank cells was evaluated based upon time-dependent consolidation of the materials. The small surcharge to the leach tanks added an additional 550 pounds per cubic foot to the load. Settlement monitors were constructed on the cells to observe changes as construction took place. During the period of waste placement at the leach tanks, total settlements for each tank were less than one half inch. In a letter report (Hecla, 1966), it was concluded, “Based on all available data the following is evident:

- “Settlement on the closure cell has been very minor over the past four years;
- “Settlement rates will continue to decrease and
- “Total settlement from this point forward will be insignificant.”

An Aug. 10, 2000 letter from CDPHE to Hecla Mining Company stated: “The settlement data for the closure cell monuments indicate that total settlement since 1996 has been insignificant (less than 0.1 foot) and has not changed over the last two years. Based upon these findings, settlement monitoring is no longer necessary or required under License Condition 17.3.” (CDPHE, 2000).

5.0 Radiation Cleanup and Control Including Oversight

5.1 Background Soils Cleanup Criteria

A gamma survey of the Durita site was made on Nov. 24, 1976,. The counter model was SC 131-A, Serial # 348; readings were made with a time constant setting of 4 seconds. Readings from the site and immediate vicinity varied from a median 2.5 count per second (cps) near the top of the knoll to 1.65 cps in the southeast comer of the site. This correlates to a conversion of cps to μR/hr, using a multiplication factor of 4.4, of 7.3μR/hr to 11.0 μR/hr. (Four Corners Environmental Research Institute,

February 1977). A gamma/ radium correlation determined that an uncorrected gamma reading of 35 μR/hr corresponded to 6 pCi/g Ra-226. This correlation is discussed in the *Final Reclamation Plan Durita Site, Volume I - Text, Tables and* Figures report (AK Geoconsult, Inc., 1991). In a letter from CDPHE-HMWMD to Hecla, it indicated that the 35-μR/hr-gamma correlation represented the radium cleanup limit with little margin for error. It was recommended to use a field gamma screening level of 30 μR/hr as a guide for directing cleanup activities. This would be in keeping with the ALARA principle and would create little or no additional cleanup work. By so doing, the chance of missing areas requiring cleanup would be reduced (CDPHE, 1994a).

Soil cleanup criteria was described in Hecla's May 1995 Health and Safety Procedure C-1.2. Areas would be considered clean when the cleanup criteria for radium-226 and/or thorium-230, as is applicable, have been achieved. Cleanup criteria for these two radionuclides will be 5 pCi/g above background, or 6 pCi/g for radium and 5.8 pCi/g for thorium-230.

Achieving cleanup levels at/or below the background mean plus three standard deviations for the metals of concern was a goal of cleanup (18.5 mg/L-arsenic, 84.8 mg/L-lead, 450 mg/L-vanadium, 5 mg/L cadmium, and 1.1 selenium). It should be noted that cleanup goals for the metals are not considered specific cleanup criteria, but levels, which pose no health risk to the public. As lead values were consistent with all feed samples and associated with pure tailings, it was determined that any cleanup of tails, resulting in a reduction of radium-226 to the 6 pCi/g cleanup standard would result in almost all if not all of the lead associated with the tails being removed. Due to the strong correlation between lead (Pb) and radium (Ra), it was decided that a separate lead cleanup standard was unnecessary. (Hecla, 1992).

In 2003, the Hazardous Materials and Waste Management Division established a soils cleanup standard for lead of 400 mg/kg (CDPHE, April 2003). The lead in the samples

obtained at the Durita Site varied from 93 mg/Kg to 130 mg/Kg, well below this soil standard.

5.2 State Oversight

Oversight by the state of Colorado was conducted under the requirements of the Colorado Rules and Regulations Pertaining to Radiation Control. Conformance with the regulations was assured through establishment of license conditions for the reclamation activities, review and approval of the reclamation plan, quality control program and construction verification program. The elements of the reclamation plan were required to meet the criterion of Appendix A of Part 18 of the regulations. The license conditions assured that proper documentation was submitted. Oversight also consisted of a series of site visits and formal license inspections. State personnel recorded a total of 28 visits to the site, during the period from spring of 1992 to the fall of 1999. Many of these site visits involved observation of construction activities such as placement of cover material, excavation of runoff control channels and preparation and placement of contaminated evaporation pond material. State personnel also reviewed the annual reports submitted each year. A construction verification summary for each year was included in those reports. Observation of remedial activities, groundwater sampling techniques, soil sampling procedures and gamma soil surveys were performed during remediation activities and after they were completed.

Hecla Mining Company had a commendable record of compliance with the conditions of its Durita site radioactive materials license. Results of inspections during the reclamation period from 1995 to 1999 showed no items of non-compliance.

Hecla submitted a report discussing the closure cell cover and compliance with Criterion 6 of Appendix A of the Colorado Rules and Regulations Pertaining to Radiation Control (Hecla l 999). In a letter dated Jan. 28, 2000, the department determined that the closure cell, as constructed, met the requirements of Criterion 6

of Appendix A, Part 18 of the Rules and Regulations Pertaining to Radiation Control (CDPHE, 2000).

Post construction inspections were performed in 2000, 2001, 2002 and 2003. Two areas of minor erosion were noted in 2000. These areas were re-graded and rock was added in one instance. The fall of 1999 and the spring of 2000 featured numerous intense thunderstorms. The 2001 inspection found no areas of erosion in spite of intense thunderstorms in early 2001. Settlement monitoring data collected during and after cover construction was reviewed in 2000. The results indicated that settlement has ceased.

The 2002 inspection noted that erosion areas observed during previous inspections had been repaired and were found to be in good condition. There was no evidence of erosion. The top slopes of the leach tanks were stable and free of gully erosion. Vegetation was in good condition. The rock on side slopes appeared durable with no sign of breakdown.

The 2003 inspection showed that the fence was intact. There was no new evidence of erosion on the constructed structures. Mancos Hill had slight erosion, which was entering the channel between the hill and the closure cell. Channels and side slopes were intact. Rock durability was good. Vegetation on top of the leach tanks was good. Groundwater wells had been plugged and the settlement monuments, except for one, had been removed. Vehicle tracks were observed on the top of the closure cell; however the licensee had the contractor rake these over.

5.3 Discussion of Results of State's Site Closure Inspection(s).

CDPHE-HMWMD has performed site closure inspections over the years as the site remediation moved from one phase to the next. CDPHE-HMWMD has employed inspection staff with geotechnical and geo-hydrological training or provided specialized consultants from the Colorado Geological Survey to review and verify virtually every aspect of site closure.

CDPHE-HMWMD's site inspections were conducted to ensure that the site reclamation activities were performed as required by regulations and license conditions. For significant aspects of reclamation, Hecla Mining Company submitted detailed plans and specifications for the work. These plans were reviewed and approved by CDPHE-HMWMD. In these cases, CDPHE-HMWMD inspectors performed frequent field inspections to verify conformance of site activities to approved plans, particularly for reclamation construction of the disposal structures, diversion channel, and thick, vegetated cover. Of particular emphasis was inspection of soil, rock, vegetation and groundwater monitoring well surface completions.

Monitoring during site closure has continued to evaluate environmental media and site performance. Hecla Mining Company has been required to perform this monitoring and to report results annually. CDPHE-HMWMD and Hecla have performed annual inspections since remediation has been completed. Minor repair of grading, fencing, drainage and erosion have been completed.

5.4 Final Status Survey

Staff from the CDPHE-HMWMD and the Colorado Geological Survey performed gamma surveys during site inspections in areas that were reported to be cleaned up. At times it was determined that additional work was required. Confirmation soil-cleanup surveys were performed on May 18 and 19, 1997; August 7, 1997; October 7, 1997 and in May 1999. Confirmatory testing included doing gamma surveys with Ludlum Model 19 scintillometers and taking core samples. A gamma/ radium correlation determined that an uncorrected gamma reading of 35 μR/hr corresponded to 6 pCi/g Ra-226. This correlation is discussed in the 1991 AK Geoconsult, Inc. *Final Reclamation Plan Durita Site, Volume 1- Text, Tables and Figures* report. A field gamma screening level of 30 μR/hr was recommended as a guide for directing cleanup activities. This level would be in keeping with the ALARA principle and would create little or no additional

cleanup work. By so doing, the chance of missing areas requiring cleanup would be reduced (CDPHE, 1994).

A confirmation-verification survey was performed after receiving Hecla's Soil *Verification Report* in November 1996 (Hecla 1996). A memo to the CDPHE- HMWMD files describes confirmatory gamma surveying and soil sampling that was done on March 18 & 19, 1997 (CDPHE, 1997). Four state representatives used Ludlum Model 19 Micro-R-Meters for gamma monitoring and traversed the site by walking a grid at a 10-foot-wide spacing and walking side-by-side. The team walked all areas reported in Hecla's *Soil Verification* Report and also traversed unreported areas as a further check on cleanup. Whenever a 30 μR/hr level was exceeded, a preliminary assessment level used by Hecla to guide cleanup, the spot was flagged for later inspection and possible soil sampling. It was determined that most of the site was below the 30 μR/hr cleanup objective, but that the evaporation ponds and fresh water pond area needed additional work. During reclamation of the evaporation ponds, 801 composite soil samples were taken by the contractor (Monster Engineering, September 1997).

Nine soil samples were obtained and all were tested for radium-226. Five samples were tested for thorium-230 and three samples were tested for metals (arsenic, lead, selenium, vanadium and cadmium). Soil sampling indicated that the carbon pit, raffinate ponds and process plant areas were adequately cleaned up. In the slime pit area, radium-226 was low, but thorium was high. Hecla requested re-analysis of the material for thorium. Additional work indicated that the tailings preparation area and haul road next to the tailings preparation area needed additional cleanup (HMWMD, April 1997). Hecla performed additional cleanup and verification sampling in 1997. Verification test results indicated that six of the seven areas met the cleanup criteria (calculated radium- 226 activity of 6 pCi/g at 1,000 years) and required no additional cleanup. One area had a calculated radium -226 activity of 7.2 pCi/g at 1,000 years, and was covered with at least 1 foot of clean soils compacted with a minimum of three passes with a CAT dozer equivalent (MEI, July1997). Analytical results from the

thorium-based samples collected in the slime pond and for all radium based samples were well below the cleanup criteria for radium-226.

Analysis of soils was either thorium- or radium-based. The basis of analysis was dependent on past processing and current reclamation activities. Thorium-based analysis entailed collecting samples from 30 foot grid points, compositing samples from distinct areas, splitting samples and analysis for thorium-230, arsenic, cadmium, lead, selenium and vanadium. Radium-based analysis entailed preliminary assessment with a field gamma survey instrument at 30-foot grid spacing. There followed a random collection of samples from 20 percent of the grid points, sample splitting and analysis for radium-226, arsenic, lead, selenium, and vanadium. Areas that demonstrated thorium-230 activity levels above 5.8 pCi/g (background level plus 5 pCi/g) were also analyzed for radium-226 activity to ensure that the radioactive decay of thorium-230 above 5.8 pCi/g would not result in radium-226 activity levels above 6 pCi/g in 1,000 years' time (background level plus 5 pCi/g).

Areas in which sample collection and analysis were thorium-based included the evaporation ponds surrounding the closure cell and the raffinate pond area. The character of the solutions and materials processed or stored in the carbon pit and slime pit areas indicated that the level of thorium-230 after cleanup was assessed in addition to radium-226 in these areas. Generally, these were areas that were considered to be potentially contaminated from waste leach solutions and solids.

Upon being considered initially "clean" by a visual assessment for physical evidence of products or waste from leaching operations, a 30-foot grid pattern was laid out for the specific areas to be sampled; 30-foot grid spaces were established by pacing and recorded on maps provided with each cleanup documentation form. The carbon pit and raffinate pond area were tested as distinct areas because of their relative size. Composited samples from thorium-based analyses comprised as few as four grid point samples to as many as 30 grid point samples depending on the physical characterization of the distinct area.

Areas in which sample collection were radium-based included the former process plant area, the tailings preparation area, haul road areas, and other areas where tailings management activities were evident, generally identified by gamma instrument surveys. Preliminary assessments of distinct radium-based areas were conducted with a field gamma survey instrument. Field readings for all grid points were measured on a 30-foot grid pattern at approximately 2 inches above the soil surface. A radium-based area was considered clean if all grid point field gamma readings for the distinct area were at or below 30 uR/hr — an approximate equivalent of 6 pCi/g radium-226. Cleanup activities were conducted in 1995, 1996 and 1997. The 1995 cleanup is documented in the Durita Site Reclamation and Construction Verification Report, included as Section 3 of the 1995 annual report for the site. Cleanup activities conducted during 1996 and 1997 are discussed in the annual reports for the site for each respective year. A summary of the cleanup activity for each area is provided below:

- <u>Process plant area:</u> All excavated soils were disposed in the closure cell. Thorium-230 results ranged from 1.1 to 6.1 pCi/g. The 6.1 pCi/g sample result was obtained at mill point B-13 that also yielded a radium-226 activity of 4.3 pCi/g. Accounting for decay of the radium-226 activity and in growth of radium-226 from the thorium-230, the radium-226 activity in 1,000 years is calculated to be 4.9 pCi/g, which is below the 6 pCi/g clean-up level.
- <u>Raffinate ponds:</u> Solidified pond material from the four-raffinate ponds were relocated to the closure cell in 1995. Additional soils were also excavated in 1996. Analytical results for metals are consistent with the cleanup goals for the site. Final radium-226 activities are all low, ranging from 1.1 to 2.3 pCi/g. Thorium-230 activities were slightly elevated above the 5.8 pCi/g cleanup criterion in three of the six sampling areas. However, all three areas demonstrated radium-226 activities below the 6 pCi/g cleanup level after 1,000 years of radioactive decay.
- <u>Carbon pits:</u> Waste carbon from processing, approximately 2 feet to 5 feet deep, was covered with several feet of on-site soils. This material was placed

on the north out slope of LT-201, and in the closure cell. Radium-226 results ranged from 0.5 to 3.3 pCi/g, all below the cleanup criterion of 6 pCi/g. Thorium results were generally low except for one location where it was 7.1 pCi/ g. When the current thorium-230 activity and radium-226 activity of 1.2 pCi/g is decayed for 1,000 years, a radium activity of 3.3 pCi/g was calculated.

- Slime pits: This was material that resembled tailings slimes. A layer of material approximately 1 foot thick was buried under 6 feet to 8 feet of clean overburden. These materials were transported to the closure cell. Samples were generally below the cleanup goals for metals and radionuclides. In two areas the thorium-230 activity was 6 pCi/g and 7.1 pCi/g. However when the current thorium-230 activity and the radium-226 are decayed for 1,000 years, radium activity of 2.75 pCi/g and 3.14 pCi/g were calculated for the respective areas.
- Haul roads: These were roads on which tailings were transferred on-site by truck. All excavated soils were placed in the north out slope of LT-203 or in the closure cell. Sample results were all below the cleanup criterion for radium-226 and the cleanup goals for metals. The results demonstrate that the three haul roads had been cleaned up to metals and radionuclide levels that require no further action.
- LT-203 areas: Two areas near LT-203 required soils excavation as a result of slightly elevated gamma readings. The areas were the south berm at the southwest comer of the leach tank and the area along the south side of the leach tank at and adjacent to the silt fence. Materials were placed on LT-203 and the closure cell. Sampling results were all below the cleanup criterion for radium-226 and for the cleanup of metals.
- Tailings preparation area: The largest area requiring cleanup on the site, this area was located directly south of Mancos Hill. Tailings from the Naturita Mill were initially brought to and processed in the area. All excavated soils were placed in the closure cell. The radium-226 results were all below the cleanup criterion of 6 pCi/g with an overall average of 2.9 pCi/g. Measured metal concentrations were all below the cleanup goals with the exception of five

selenium values. They were slightly above the cleanup objective. The overall average selenium concentration for the ore preparation area was <0.88 mg/kg, which is below the cleanup criteria.

- Truck load out: This area was located west of the tailings preparation area. All analytical results were below the cleanup criterion for radiun-226 and the cleanup goals for metals.
- Acid pit: This area was located immediately west of the tailings preparation area at the base of Mancos Hill. It appears that tailings and soils were placed as backfill material to create a level storage area for large acid storage tanks. Contaminated soils were excavated to bedrock from this area and placed in the closure cell. All analytical results were well below the cleanup criterion for radium-226 and the cleanup goals for metals with the exception of four selenium results taken in the Mancos Shale. Significant selenium concentrations occur naturally in many Upper Cretaceous and Tertiary geologic formations in Colorado. The Mancos Shale in western Colorado is one of the most selenium-rich formations in the state[5]. The acid pit excavated area was backfilled with clean material to the existing grade.
- Evaporation ponds: There were six original evaporation ponds that contained approximately 2 feet to 4 feet of solidified pond material (SPM) after mixing. SPM was excavated from the six ponds and relocated to the closure cell. Analytical results were consistent with the cleanup goals for the site with the exception of cadmium results from three sampling areas that were slightly elevated above the cleanup goal of <5 mg/kg for this metal. The cadmium concentrations were 5.3 mg/kg, 5.2 mg/kg and 5.3 mg/kg. However, the average concentration for the entire evaporation pond area of 4 mg/kg was below the cleanup objective. Some areas did not meet the radium-226 cleanup objective when the thorium in-growth was considered. Areas were further cleaned up to meet the radium- 226 objective. It should be noted that the

[5] Tuttle, M. L. W., Fahy, J. W., Eliot, J.G., Grauch, R. I., and Stillings, L. L., 2014, *Contaminants from Cretaceous black shale: II. Effect of geology, weather, climate, and land use on salinity and selenium cycling, Mancos shale landscapes, Southwest United States*; Applied Geochemistry, Volume 46, pp 72-84.

evaporation area was backfilled and covered in place with at least 1 foot of clayey soils compacted with a minimum of three passes of a Cat dozer. This ensures that the area will meet Criterion 6 of Appendix A of Part 18 of the Colorado Rules and Regulations Pertaining to Radiation Control, which allows up to 6 pCi/g radium-226 in the upper 6 inches of soil and 15 pCi/g radium-226 in soils 6 inches or more below the surface.

Detailed sample test results can be found in the *Soil Cleanup Verification Report*, Hecla, 1996) and the annual reports. A second phase of confirmatory sampling was done on Aug. 7, 1997 (CDPHE, August 1997). Two representatives of the state performed a gamma survey, similar to the previous survey. The 30-µR/hr cutoff was used. Most readings were below 25 µR/hr. Seven soil samples were taken from the evaporation pond area and the slime pit area because these were thorium-contaminated areas and the survey meters would not indicate the presence of thorium. All seven samples were tested for thorium; four were tested for radium-226 and two were tested for metals (arsenic, lead, selenium, vanadium and cadmium).

Two of the soil samples from the evaporation pond did not meet cleanup objectives for thorium. An additional 4 feet of material removed from the evaporation pond was placed in the closure cell. On Oct. 7, 1997, two CDPHE-HMWMD representatives performed confirmation gamma surveys and obtained two confirmation soil samples from the remediated areas. Gamma scintillometer readings were near background. One soil sample was tested for thorium-230, radium-226 and for cadmium. The other soil sample was tested for thorium-230 and radium-226. Test results were near background and met cleanup criteria.

On May 20, 1999, two representatives from HMWMD-CDPHE performed gamma surveys at 10-meter intervals on the tops of leach tanks 201, 202 and 203 and on top of the closure cell (see Figure 3). Gamma readings ranged from 10 µR/hr to 16 µR/hr. It was concluded that the gamma scintillometer readings obtained on top of the three leach

tanks and on the outer slopes and top of the closure cell were the same as background readings in the area (CDPHE, May 1999).

In summary, when field and laboratory data showed that areas did not meet cleanup objectives, the contractor returned and removed the contaminated materials. These areas were re-tested and showed that they met cleanup objectives.

5.5 Radon Emanation

5.5.1 Radon 222 Measurements:

Hecla Mining Company submitted a reclamation plan, which provided the design of a cover system that would reduce the radon-222 flux to 20 picocuries per square meter per second (pCi/m^2s) or less. Use of a published radon flux model with the design information provided by the licensee confirmed the radon flux reduction provided by the cover system. Hecla Mining Company also demonstrated that the cover system would continue to reduce radon flux for 1,000 years or at least 200 years by using the NRC Radon model Version 1.2 to confirm that the cover system would perform adequately. The calculations took into consideration such factors as moisture content (10 percent - 15 percent), soil density (1.61 g/cm^3 - l.86 g/cm^3), soil porosity (0.30-0.39), and emanation coefficient (model default emanation coefficient value of 0.35) and layer thickness (15 cm to 300 cm) of deposited material and cover materials. Radon emissions from cover material were considered in the calculations.

Calculations performed by the model gave the following results for radon flux from the closure cell surface: Current conditions 1.4 pCi/m^2s and conditions at 1,000 years 6.5 pCi/m^2s. Exit flux for both conditions is well below 20 pCi/m^2s.

The radon cover for the 5.5-acre closure cell was tested twice. From Aug. 27 through August 1996, a total of 22 flux measurements were taken on the closure cell, demonstrating flux measurements of <0.5 pCi/m^2s to 1.19 pCi/m^2s, with an average of 0.55 pCi/m^2s. Of the 22 measurements, 12 demonstrated results below the detection level. The second set of readings was done from Aug. 7 to Aug. 9, 1997. This

additional testing was conducted because soils were placed on the closure cell after completion of the initial testing. Ten additional measurements were conducted, demonstrating results of <0.5 pCi/m^{2}s to 0.5 pCi/m^{2}s. Nine of 10 measurements were below the method detection limit.

The cover was placed in accordance with approved plans and schedules. After completion of the cover system, Hecla Mining Company made radon flux measurements using the radon flux measurement methodology [Appendix B, Method 115, 40 CFR Part 61). Monitoring was conducted according to Hecla's May 1996 Radon-222 Flux Monitoring Plan, Revision I, and a supplemental plan for the closure cell, July 22, 1997. The approved radon testing plan originally called for placing 128 charcoal canisters (collectors) on the 31.5 acres of cover of the combined leach tanks and closure cell or approximately four per acre of radon cover. An additional 10 canisters were placed on the slope of LT-201 where materials had been buried against the original slope. The reports show that the measured flux rate through the engineered covers, from a total of 138 measurements over the three heap leach tanks and the closure cell at Durita, averaged 0.91 pCi/m^{2}s. Results ranged from a low of less than 0.5 pCi/m^{2}s (the analytical practical quantification limit) to a maximum radon flux reading of 17.6 pCi/m^{2}s. This measurement is well below the regulatory standard of 20 pCi/m^{2}s in Criterion 6 of Appendix A to Part 18 of the Colorado Rules and Regulations Pertaining to Radiation Control and is consistent with the design based on analytical evaluations.

<u>5.5.2 Conclusion:</u>

The combination of the RADON modeling for current conditions, conditions in 1,000 years, and the radon-222 flux monitoring demonstrates that the as-constructed closure cell satisfies the radon-222 emission stipulations of Criterion 6, and specifically, that the radon-222 surface exhalation from the closure cell is not significantly above background.

CDPHE approved the radon flux measurement reports and accepted the findings of the reports that document compliance with the standards stated in Criterion 6 of Appendix A to Part 18 of the regulations in a letter to Hecla Mining Company dated Jan. 28, 2000.

6.0 Surface Water Hydrology and Erosion Protection

6.1 Erosion Protection

Erosion protection work was necessary to:

- Limit the extent of nominal flow channel erosion during high flow periods;
- Protect floodplain banks during PMF discharge; and
- Protect leach tank outer slopes and cell cover from erosion. Containment facility rock cover placement included:
- Leach tank outer slopes: A minimum of 6 inches of rock cover was placed over all outer slopes on all three leach tanks. Rock thickness was not less than 6 inches.
- Closure cell top and outer slopes: A minimum of 6 inches of rock cover was placed on all closure cell slopes (top and outer slopes). The top surface and flatter outer slopes (20 percent and 13 percent) were covered with D_{50} = 2 inch rock. The steeper outer slopes (3:1) were covered with D_{50} = 3.6 inch rock. Rock thickness averaged 6.8 inches and was not less than 6 inches. Riprap and scour protection placement work was divided into the closure cell, the main diversions, and tributary areas as follows:
- Closure cell scour protection- a minimum of 12 inches of scour protection rock was placed along the cell's west, north, and east out slope toes.
- Main diversion riprap and scour protection: Riprap and scour protection
- rock sizing varies based on location (station) within each of the diversions. In general, rock size decreased with increasing stationing (going downstream), as the width of the diversions increases, and as the slope decreased.
- Tributary area riprap: Areas where significant erosion had occurred since work was completed in 1995 were re-graded and covered with riprap. Two of these areas were covered with 1 foot of rock (D_{50} = 6 inch). Near the toe of LT-201 —

the transition between the northwest toe of LT-201 and the arroyo immediately north of the toe was riprapped with two types of rock. The bottom of the slope (and narrowest area where flows concentrate) was covered with on-site boulders and rock (maximum diameter of approximately 4 feet). Immediately above this area where the slopes flattened to 5:1, riprap transitioned to D_{50} = 2 inch rock. Subsequent inspections have shown no new areas of scour.

Erosion protection project requirements were provided in Reclamation Plan specifications B7 (AD Geoconsult, 1991) and Construction Specifications 9014-S3 and 9014-SS (AD Geoconsult, 1994c and 1994e). Changes and modifications to rock sizing specifications are referred to in the 1998 Durita Site Reclamation and Construction Verification Report (Monster, 1998). These documents are available for review at the CDPHE-HMWMD records center.

6.1.1 Protection Against Flood Plain Scour:

Due to the terrain and spatial constraints imposed by the site, it was not possible to provide protection against all erosion under all flow conditions. Normal flow channels will experience some bed and bank erosion during periods of high flow but should recover most, if not all, of the bed scour during subsequent periods of declining flows when sedimentation occurs because of the widened channel beds. Under peak PMF discharge, scour will occur along the bed of the flood plain. Using methods developed by the U. S. Bureau of Reclamation (Pemberton and Lara[6], 1984), scour depths were calculated for reaches along both flood plains. Three methods were used and the results were averaged, as recommended in the referenced document, to determine design scour depths along the flood plain banks. Rock-filled trenches from channel bed elevation to the calculated vertical scour depth protected each reach of flood plain that is formed by soil and is adjacent to the containment structure. These scour trenches were excavated to the design depth and slope, then backfilled with rock to a

[6] Pemberton E. L. and Lara, J. M., 1984, *Computing degradation and local scour*, Technical Guideline for Bureau of Reclamation, Engineering & Research Centre, Bureau of Reclamation, Denver, Colorado, USA.

thickness of not less than 18 inches as described in the specifications. (AK Geoconsult, Inc. 1991)

6.1.2 Riprap:

A riprap blanket was used to protect flood plain banks in soil from lateral erosion under conditions up to the PMF discharge. Those portions of the banks cut into rock did not require riprap protection. The riprap was applied to the banks in the same locations specified for scour protection, adjacent to containment structure areas. The riprap layer was a minimum of 18 inches thick and was placed on 2H:1V slope. The riprap was sized in accordance with methods described by the NRC (1990) et. al. Those methods generally relied on the calculation of shear stresses at the protected boundary and on the use of the Corps of Engineers or the Stephenson method to determine the D_{50} size of rock needed to resist movement under the PMF peak velocity. The calculations indicate that the largest rock needed, D_{50} = 18.3 inches, was placed against soil exposed along the left bank of the central channel from station 0+00 to Station 5+22. The maximum D_{50} of rock along the downstream reaches of the central flood plain range from 5.6 inches to 11.7 inches. Along the east flood plain the maximum D_{50} is 10.2 inches along soil exposed in the left bank from Station 0+00 to Station 2+05 and downstream the D_{50} will range from 3.8 inches to 9.6 inches. Maximum rock sizes were 1.5 times the D_{50}. (AK Geoconsult, Inc. 1991).

Input data and calculations include the following subjects:

- Slope Stability Analysis,
- Radon Analysis for Leach Tank Covers,
- Radon Analysis for Evaporation Pond Covers,
- Hydrologic Parameters and Equations,
- Pre-Reclamation Surface Water Channel Gradients,
- PMP/PMF Event Hydrologic Analysis,
- Tributary-Area Surface Water Discharges from PMP within the Site,
- Diversion Channel and Flood Plain Line, Grade and Dimension Control,
- Calculation of Depth of Scour at the Toe of Flood Plain Banks Due to PMF Flow,

- PMF Erosion Protection Analysis,
- Rock Gradations to Erosion Protection Applications, and
- Leach Tank and Evaporation Pond Cover Erosion Protection (AK Geoconsult, Inc., October 1991).

Note: Registered professional engineers prepared these documents.

6.2 Surface Water Diversion and Flood Flow

Surface water diversion elements involved realignment and re-grading of the wide ephemeral draws that are adjacent to the site. Prior to the construction of the site in 1977, five small drainages to Dry Creek had watersheds that started upstream or south of the Durita site. All of the watersheds above the site are less than one square mile. Site construction caused the consolidation of drainages from the two eastern watersheds, East 1 and East 2, into one channel that is now called the East Channel. The other three watershed channels have remained essentially unchanged in their upstream portions during and after the Durita site construction, with the exception that the west channel has been diverted around the southeast comer of LT-202. The reclamation plan used a unique approach to protect the leach tanks. The original incised narrow channels existed within the wide ephemeral draws and conveyed normal storm and snowmelt runoff. The narrow incised channels were 5 feet to 10 feet wide and up to 14 feet deep. The wide draws, 100 feet to 300 feet wide, acted as the floodplains for these channels. Calculation and routing of the probable maximum flood (PMF) show that the wide draws act as the floodplains for the ephemeral channels, and contain the flood flows. The reclamation plan called for placing rock revetments in trenches at the edge of the draws in order to control PMF flows at the floodplain margins. Re-grading and re-establishment of runoff channels were also undertaken to assure proper control of flood flows.

It was not possible to re-establish the channels to their pre-1977 gradients along the same drainage courses in all locations on the site because of the location of the leach tanks. Therefore, the reclamation design included the design of new normal flow

channels in the vicinity of the leach tanks that would re-establish, as nearly as possible, the pre-1977 gradients and also allow alignments that would provide offsets from the leach tanks sufficient to protect the leach tanks from erosion due to normal flow as well as lateral migration and meander development that might evolve over long periods of time. The reclamation design for normal runoff will slightly reduce the overall gradient of the combined West, Mid-1, and Mid-2 channels (the central channel) to approximately 0.021 over the controlled channel length of 2,643 feet. The west channel drained the largest of the upstream watersheds and had a pre-1977 gradient of 0.026 within the Durita site and slightly greater, 0.027, if the channel several hundred feet upstream is included.

In addition to a slightly flattened overall gradient, this new channel has a 10-foot base width, wider than the average width of the existing or pre-1977 channels. The original channels were V-shaped with narrow channel bottoms, usually less than 5 feet to 10 feet wide and up to 14 feet deep. The greater width compensates somewhat for the shallower gradient by helping to reduce normal flow depths in the channels, thereby suppressing low velocities and shear stresses on the channel bed.

The same design approach was used for the east channel. However, for the east channel it was possible to re-establish the pre-1977 gradient of 0.037 along the established alignment. This channel was also 10 feet wide at the base. Although not as necessary as a 10-foot width on the central channel, the 10-foot width on the east channel is more of a construction expediency, i.e., the minimum practical width for dozed or scraper excavation. It also allowed normal flows to be diverted with shallower flow depths and, therefore, lower peak velocities and shear stresses than would have been the case in the previous natural channels.

The overall effect of the widened normal flow channels was to reduce the potential for scour and enhance the conditions for aggradation, i.e., for sedimentation of traction and suspended load derived from upstream erosion. Conditions favoring

aggradation of the channel beds provide additional protection against potential erosion during runoff events.

6.3 Probable Maximum Flood (PMF) Runoff Control

The most severe storm event, the one-hour local probable maximum precipitation (PMP) event applicable to watersheds up to one square mile, was derived from HMR 49 (Hansen et. al., 1984). All watersheds above the site are less than 1 square mile in size. This storm event would produce rainfall depths with one-hour total rainfall of 7.81 inches on the upstream watersheds and 8.15 inches on the site. The runoff, or probable maximum flood (PMF) resulting from the storm was calculated using the Rational Method per NUREG/CR-4920.

The PMF parameters are tabulated below:

Hydrologic Parameters of Upstream Watersheds

PARAMETER	WEST	MID 1	MID 2	East
Area, acres	494	32.5	122	155.7
Longest flow path (channel) ft.	14500	3950	6900	9150
Maximum change in elevation, ft.	1705	469	904	1050
Longest flow path gradient	0.1176	0.1187	0.1310	0.1148
Time of concentration, tc, hrs	0.47	0.17	0.26	0.34
PMP 1-hour storm rainfall depth in tc, inches	6.85	4.7	5.85	6.4
PMF peak discharge, cfs	4280	528	1667	1780
Flow concentration factor	3	3	3	3

Note: The two east watersheds were combined.

The largest PMF rises in the west watershed, 4,280 cubic feet per second (cfs). The PMF combines at the south side of the site with the PMFs of the Mid-1 watershed (528 cfs) and the Mid-2 watershed (1,667 cfs). It is conservative to assume that all PMF flood peaks arrive at the site at the same time, giving a combined PMF for the central channel of 6,475cfs. The east watersheds cover approximately 156 acres and have a combined PMF discharge of 1,780 cfs. The PMFs of the combined central and the east watersheds were used for the design of the PMF runoff controls within the site, to

which were incrementally added the flows of on-site drainage areas. It was also conservative to assume that each drainage area within the site adds its peak PMP runoff to the watershed at the same time as the control structure was carrying the PMF discharge from upstream runoff, producing progressively larger peak discharges from south to north across the site in both combined watersheds. In reality, concurrence of individual PMF peaks is extremely unlikely, making a cumulative peak discharge a true worst-case value. The normal runoff control provides containment of normal flow within a constructed channel. For PMF control the peak discharge will be contained within a wide shallow channel that lies above and to each side of the normal flow channel. In effect, the PMF channel is really the flood plain of the normal flow channel. This flood plain is designed to keep the PMF peak discharge within the design boundaries.

The flood plains terminated at locations sufficiently downstream or laterally separated from containment structures to preclude the risk of erosion of these structures from the PMFs in the flood plains. The central flood plain ends downstream of the leach tanks and the reclaimed area and is topographically down slope from those locations. This flood plain widens after it passes through the constricted area between the leach tanks, then discharges onto the northwest quadrant of the site, which has no containment structures and consists of natural channels separated by unobstructed, relatively flat terrain. The east flood plain terminates north or down slope from the leach tanks and in the direction of a system of deep natural channels adjacent to the east of the property line of the site. The closure cell is protected from the PMF of either flood plain on the upstream side by the Mancos Hill and laterally by at least 300 feet of terrain that was sloped away from the cell and towards the flood plain.

The following is an analysis performed for completion of LT-203. The U. S. Army Corps of Engineers HEC-1 model was used to determine peak runoff from a 500-foot-wide section of LT-203. The watershed was composed of two basins: The first 205 feet long with a slope of 0.5 percent and the second 205 feet long with a slope of 20 percent.

An SCS curve with a number of 80 was selected for both basins. This curve number is representative of soil group D with good pasture and soil group C with fair pasture. A curve number of 80 is believed to be representative of the slope area because even though the slope will essentially be bare ground, the 6-inch layer of rock should have a storage capacity similar to a vegetative cover.

The 1-hour probable maximum precipitation (PMP) was determined from storm depths listed in other Durita documents. Listed PMP values were: Elevation = 5, 000 ft., depth = 8.4 inches and elevation = 6,450 ft., depth = 7.8 inches. A PMP depth of 8.1 inches was interpolated for a site of 5,700 feet. The storm was distributed using an SCS type II storm distribution. The following table lists peak flow values determined with the HEC-1 model.

Summary of HEC-1 Results

Hydrograph Station	Peak Flow	Time at Peak (Hours)
Basin 1	38	0.47
Route to Slope Crest	34	0.53
Route to Slope Toe	33	0.55
Basin 2	75	0.35
Node	79	0.35

The combined peak flow at the bottom of the slope due to runoff from basins is comparable to the peak flow from the slope basin, primarily due to a longer lag time for the top basin compared to the slope basin. This is shown by a time to peak of 0.47 hours for the top and a time to peak of 0.35 hours for the slope. The peak flow estimated from the HEC-1 model was analyzed using Manning’s formula to determine depth and velocity of flow. Flow velocities were used to determine routing parameters utilized in the HEC-1 model.

Peak discharge per unit width and test data from the in-place rock were analyzed with Stephenson’s method to calculate a suitable D_{50} median diameter for rock at the north slope toe of LT-203. Typically, a concentration factor is included to account for surface variability producing areas of concentrated flow. Concentration factors of up

to three were recommended, however given the 20 percent grade of the tank outer slope, a concentration factor of 3 may be overly conservative. The following table lists calculated D_{50} sizes for concentration factors of 1, 2, and 3.

Summary of Riprap Sizing Calculations

Concentration Factor	**1**	**2**	**3**
Flow (cfs) 500 feet	79	158	237
Flow (cfs/ft)	0.16	0.32	0.47
Rock Fill Porosity	0.3	0.3	0.3
Specific Gravity	2.68	2.68	2.68
Slope (%)	20	20	20
Friction Angle	46	46	46
Empirical Factor	0.22	0.22	0.22
Olivier's Constant	1.2	1,2	1.2
Calculated D50 (in)	0.95	1.52	1.96

Note: Empirical factor and Olivier's Constant Values are those recommended for rounded gravel.

It should be noted that methods for calculating rock stability analyze flow over the top of the rock, which is not expected to be the case for leach tank outer slopes. With calculated flow depths (less than 0.2 feet for a concentration factor of 3) being significantly less than the thickness of the rock layer (0.5 feet), the additional confining force of overlying rock is ignored in the stability calculation (Dan Williams P.E. March, 1997).

6.5 Rock Durability and Gradation

Rock durability and gradation were evaluated during construction to meet approved construction design plans and specifications. Field and lab testing frequencies were based on those required by the 1997/1998 reclamation plan (Monster Engineering, 1997a and 1998). Sufficient tests were conducted to satisfy each frequency. Erosion protection was tested by ASTM methods C136 and Dl 559 (gradation), C88 (sodium sulfate soundness, and C97 (specific gravity and absorption). The gradations were within the specifications for each respective rock type. Bulk specific gravity (SSD) varied from 2.98 gm/cc to 2.67 gm/cc. Absorption ranged from 0.77 percent to 1.15 percent and sodium sulfate loss varied from 0.08 percent to 0.19 percent. The

average percentage of rock types in samples was 97 percent igneous, 1.5 percent limestone and 1.5 percent sandstone. The composited rock quality scoring ranged from 83.9 percent to 88.3 percent (Monster Engineering, 1998). Lambert and Associates of Montrose, Colo. conducted erosion protection durability testing and the on-site project manager performed on-site testing.

The durability of the rock used for covering the slopes and for drainage channel riprap was evaluated using field observation and testing of the material and the U.S. Nuclear Regulatory Commission's rock scoring criterion. Rock that scored higher than 80 was used at the site. Field-testing during construction showed that the rock scored between 80.6 and 96 (Hecla 1999b). Two sources of rock were used: Stream terrace gravel adjacent to the San Miguel River and a massive limestone from a quarry near La Sal, Utah. The rock was found to be sound and dense, to meet the requirements of continued wetting and drying.

6.6 Vegetative Cover

Reclamation at the Durita site was completed in 1999. As part of the reclamation, Hecla Mining Company must show adequate vegetative cover on the Durita site. Bamberg Associates prepared a document (Bamberg Associates, 1998) to determine proposed standards for revegetation and methods for monitoring. They completed two years of monitoring in 2000 and 2001 (Bamberg Associates, 2001).

Proposed vegetation standards were based on vegetation types surrounding the site and the environmental conditions on the reclaimed areas. The standard for desirable plant cover in the reclaimed surface areas was set at 20 percent for the native grass and shrub cover on thin soils adjacent to the site. On-site and adjacent areas were sampled concurrently during the 2000 and 2001 monitoring periods. The sampling methods used were a combination of quantitatively measured transects and qualitative assessment of conditions.

Monitoring results showed a stable, increasing trend in desirable vegetative cover, and a proportional reduction in weeds and bare ground. Desirable plant cover in the quantitative sampling on the site averaged 22.5 percent. Off-site vegetation cover averaged 33.3 percent for comparison and standards. Comparison of 2000 average plant cover (12.3 percent) with 2001 average plant cover (22.5 percent) showed increasing desirable plant cover and general site stability for the Durita site. The vegetation was stable and self-sustaining and met the proposed standards. Trends in the vegetation indicate successful plant growth and the existing cover values equal or exceed the proposed standards. Therefore the Hecla Mining Company has met the vegetation requirements for release of the Durita site (Hecla, 2000a).

Rock, soil and vegetative cover materials met the testing requirements in the approved reclamation plan and other appropriate documents.

6.7 Sedimentation

During a May 21, 2001 NRC site visit, NRC commented that the sediment accumulation in the channel upgradient of the closure cell should be evaluated and that the top slopes of the leach tanks should be evaluated using the stable slope equations in the NRC guidance. Hecla Mining Company responded with a stability evaluation of the leach tanks and the closure cell diversion for the Durita site (Hecla, 2001b).

In doing this evaluation, Douglas Gibbs, P.E. used the following documents:

1. Nuclear Regulatory Commission's Final Staff Technical Position (STP) on the Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites (NRC, 1990)
2. AK Geoconsult, Inc.'s Final Reclamation Plan (AK Geoconsult, 1991)
3. Monster Engineering's construction verification reports (Monster Engineering, 1996 and Monster Engineering 1997 through 1999) and his experience with the Durita site cover materials, construction activities and materials testing.

It was concluded that the soil-covered tops of all three leach tanks are stable as designed and constructed. The following items all indicate that the covers are stable in their configuration:

- AK Geoconsult utilized an NRC-approved analysis method for stable slope covers in the Final Reclamation Plan (AK Geoconsult, 1991). This was the Horton/NRC Method.
- AK Geoconsult designed all of the leach tank top slopes so that they were flatter than the critical slopes calculated by the Horton/NRC method. A slope flatter than the critical slope is stable from erosion. All of the leach tank top slopes were designed and built at a slope of 0.5 percent, which is 1 foot of drop in 200 feet of run.
- AK Geoconsult's analysis appears to be reasonable and accurate. In particular AK Geoconsult's Hydrologic Parameters and Equations (calculation C l 14), and Leach Tank and Evaporation Pond Cover Erosion Protection (calculation C12) from the Final Reclamation Plan (AK Geoconsult, 1991) were reviewed and determined to be reasonable and accurate.
- Acceptable cover materials were utilized during construction.
- Acceptable construction methods were observed.
- Placed cover materials passed all testing requirements.
- Subsequent inspections have shown that the soil covers are performing as designed. There are no signs of erosion on top of the leach tanks.
- The success of the reclamation on the tops of the heap tanks is dependent upon the vegetation. Both the flat slopes and the vegetation on the tops of the leach tanks contribute to erosion stability. Revegetation has been successful on top of the leach tanks.

It was concluded that no erosion had occurred on the leach tank covers, and no significant erosion is likely to occur in the future.

Sediment had been observed in the closure cell diversion channel located between the north side of the closure cell and Mancos Hill, an uneroded geologic remnant of

the Mancos Formation located south of the channel. Silt and clay sediments were deposited into the channel from Mancos Hill after a very large precipitation event. Erosion was exacerbated by the required removal of vegetation from the north face of Mancos Hill during construction of the diversion in 1995 and 1997.

The estimated average depth and quantity of sediment deposited into the diversion was 3 inches and less than 0.5 cubic yards, respectively. A recent cut area made during the 1995 and 1997 construction seasons funneled concentrated runoff though a bowl-shaped area. Total quantity of sediment coming off the hillside was relatively small due to the short flow distance and competent shale bedrock material through which it flowed.

Although the Mancos Shale does weather at the surface, it becomes dense and moderately indurated at shallow depths (typically 2 inches to 4 inches). The following shows evidence of this competence:

Mancos Hill is still protruding up approximately 100 feet higher than all of the surrounding areas on the project site

Erosion channels from the large precipitation event, several years after the completion of the diversion were fairly shallow (1 to 3 inches).

The cut area and the bowl-shaped area and an additional area directly upslope from the original channel were covered with a uniform graded, rounded river rock with a D50 of approximately 2 inches. It is the opinion of the professional engineer evaluating this area that no significant erosion will occur at this specific location on Mancos Hill and very little sediment will be deposited into the closure cell diversion in the future from similar events. Subsequent inspections have shown no sediment in the channel.

6.8 Conclusion

It was determined that no additional significant erosion will occur at this specific location on Mancos Hill and very little sediment will be deposited into the closure cell diversion in the future from similar events. After a site inspection by NRC staff in May 2001, a request was made to evaluate the closure cell runoff control cell channel. Monster Engineering evaluated the sedimentation and concurred with their findings that there is little likelihood of further sediment entering the channel. Annual inspections by the U. S. Department of Energy will ensure that future sediment buildup is not excessive. The evaluation was deemed acceptable as written (CDPHE, 2001).

In conclusion, CDPHE-HMWMD's review of surface water hydrology and erosion protection has found the Durita site to be in conformance with all Colorado regulatory requirements of criteria l, 3, 4, and 6 in Part 18 Appendix A of the regulations.

7.0 Groundwater detection monitoring

This section will examine the appropriateness and utility of the groundwater monitoring program and the evidence for a potential release of raffinate. Was the groundwater monitoring sufficient to have detected a major release of liquids from the site if it had happened? Did the operations have a release that could impact monitor wells?

The Durita site was chosen, it part, for its intrinsic ability to isolate tailings and raffinate from the environment. The physical and chemical characteristics of the site and how these characteristics affect the ability of any surface releases to impact groundwater are described in this section.

7.1 Geology

The Durita site is located on gently north sloping terrain within a valley formed by the Coke Oven Syncline as shown in Figure A. This valley is at the southeast end of a

collapsed salt dome called the Paradox Valley. A late Cretaceous-age marine organic shale called the Mancos Shale directly underlies the site with a maximum thickness of shale and interbedded sandstones of 70 feet. Below the Mancos Shale is the Cretaceous-age Dakota Formation, which is composed of marine sandstone, conglomerate and shale. At least one sandstone layer at the bottom of the Mancos is water bearing under the site. Below the Dakota Formation lies the Cretaceous-age Burro Canyon Formation consisting of sandstone and shale and the Jurassic-age Morrison Formation consisting of various interbedded shales, sandstones and limestones. The Morrison Formation has been mined locally for uranium. In fact, uranium mines are visible in the terrain above and south of the Durita site.

Field reconnaissance and monitoring well drilling revealed no discernible faulting or other abrupt structural changes under the Durita site. A fault bisects the Coke Oven syncline from southwest to northeast and is, more or less, coincident with Dry Creek. Most of the site is blanketed with alluvium and colluvium composed of sandy clay up to 20 feet thick. Gravel and cobble deposits are found in some locations as shown in the test borings performed by F. M. Fox & Associates (1977). The soil contains variable amounts of rock fragments of primarily sandstone. Near the east-central portion of the site, an erosion-resistant remnant or outlier of the Mancos Shale forms a hill some 100 feet above than the local terrain. Mancos Shale is exposed at the surface at several places in the southern half of the site.

The Mancos Shale is clay rich with abundant kaolinite, sepiolite, illite, gypsum, carbonate and organic material. The formation is strongly chemically reducing below the weathered surface zone and above the lower saturated interval. Iron sulfides have been observed in this interval and show a strongly reducing, or oxygen-poor, environment. An environment capable of reducing iron from the Fe^{+3} to Fe^{+2} oxidation state will also reduce uranium from the soluble U^{+6} to the insoluble U^{+4} oxidation state.[7]

[7] Dragan, J., 1988, The Soil Chemistry of Hazardous Materials, Hazardous Materials Control Research Institute, Silver Spring, Maryland.

A geotechnical Investigation from F. M. Fox and Associates (1977) reports the findings of 32 exploration boreholes and 32 percolation tests. Laboratory hydraulic conductivity tests on compacted soils measured in the range from 8.6×10^{-8} to 2.6×10^{-9} cm/second. This report also gives the soil densities for clays, shales and mudstones of the Mancos Shale Formation. Hydraulic conductivities from percolation tests in the upper 15 feet of the site media range from 5.6×10^{-5} to 7.6×10^{-6} cm/second, with an average value of 2.6×10^{-5} cm/second, or 7.4×10^{-2} foot/day. Deeper conductivity tests conducted by Fox (1982) in the un-oxidized Mancos show measured results between 1.5×10^{-5} cm/sec to below a measurable value with a sensitivity of approximately 8×10^{-8} cm/sec.

Conceptually, the Durita site sits on one side of a structural syncline, or shallow bowl. The surface of the bowl is made of the Mancos Shale formation. See Figure 7.1 for a general cross-section of the syncline. Wind and water surface sediment deposits occur across the site. Weathered Mancos Shale occurs in places at the surface of the southern half of the site. The upper sedimentary layers at the site are a triad of an upper weathered zone of alluvium, colluvium and oxidized Mancos Shale; a middle zone of very low permeability, very dense, Mancos Shale rock in a chemically reducing state; and a lower water-saturated interval associated with the Mancos Shale – Dakota Sandstone conformable contact. Figure 7.6 shows this relationship in cross section form.

The bore hole descriptions, permeability measurements and geophysical logging reported by F. M. Fox (1982) (Figure 7.2) on and near the Durita site show a consistent pattern of very low hydraulic conductivity in the shale above the Mancos/Dakota contact. Several of the measured conductivities were below measurable flow. This zone acts to physically and chemically isolate water flowing in the upper Dakota and basal Mancos formations from surface waters at the Durita site. There is a clay layer directly above this lower shale consistent in the geophysical

measurements that are described as bentonite in the lithologic description for borehole B3.

7.2 Field Capacity

Field capacity is the percentage of water saturation retained by the soil after the soil has been saturated and then allowed to drain. It is an innate characteristic of soil. The fate of a potential water release from the leach tanks is that it will move down through the soil (if the field capacity is exceeded) and some portion will remain suspended due to capillary forces. Cadmus Group (2011) prepared a report that relates, in part, the grain sized distribution of soil to field capacity. Using this report the characteristics of Durita site soils (Fox, 1977) are compared to the field capacity. It appears that the Durita soils will have a field capacity between 0.26 and 0.31 cm3 water/cm3 soil. This value is greater than the porosity values used in calculating groundwater velocities, but is a more realistic and less conservative value. This means that in a volume of soil with water moving down through the soil, a portion of the water will be retained in the soil and not be transmitted. That portion is the field capacity. If, for example, 100 liters of water are released into a cubic meter of soil with a field capacity of 0.15 then only 25 liters will be transmitted through that volume. Capillary forces within the soil will retain the rest of the water.

7.3 Geochemistry

The chemical characteristics of the Mancos Shale play an important part of understanding the isolating properties of the site. The low permeability characteristics of the Mancos Shale have isolated the rock from oxidation. It is organic rich and chemically reducing. Boring logs describe a black to grey shale with iron sulfides (pyrite or marcasite) resident in the formation. This part of the formation separates the closed leach cells and disposal cell from the water-saturated interval at the base of the Mancos Shale. The iron oxides adsorb uranium and the reducing environment will immobilize and precipitate uranium. High levels of sulfate in the oxidized Mancos Shale will precipitate the dissolved radium. The calcium carbonate in the shale will neutralize the acidic nature of leachate liquids and the dissolved radionuclides will precipitate because of the change in pH.

The Coe & Van Loo report (1976) has Mancos Shale carbonate content measured at near 2 percent. Chemical analysis of the Mancos Shale on a regional basis shows an average about 20 percent carbonate (DOE, 2011). Clay minerals in the shale are kaolinite, illite, and sepiolite. On-site shale was mixed with the evaporation pond residues to neutralize the acidity and to immobilize metals and radionuclides (Geochem for AK Geoconsult, Inc., 1993).

Choosing a conservative set of circumstances, an estimated leakage from the leach tanks can be calculated. And the ability of the native soil to neutralize any potential leachate release can be evaluated.

To calculate a conservative estimate of potential release, consider that the leach tank liner is 30 cm thick (1 foot). Actual measured compactions for material tested with a 5 percent sulfuric acid concentration range between 8.2×10^{-8} and 2.5×10^{-8} cm/second (Coe & Van Loo, 1976). The head on the liner is 6 meters (maximum possible head), and the duration of the head is eight months. A lower-than-measured average permeability of 1×10^{-7} cm/sec. was used to calculate possible liner flow rates. This is a conservative assumption and will overestimate the potential flow. The maximum calculated leakage from Darcy's Equation is approximately 0.189 cubic meters per square meter of the liner, or 189 Kg of water. The concentration of sulfuric acid used during the leaching process was 5 percent by weight. This is the maximum possible concentration. Thus the amount of H_2SO_4 in a hypothetical worst-case event that could be released is approximately 9.5 Kg per square meter of the liner maximum.

The Mancos Shale contains approximately 2 percent by mass calcium carbonate ($CaCO_3$). At 20 percent porosity this is approximately 54 Kg of calcium carbonate per cubic meter of soil. This is approximately six times the calcite needed to neutralize the amount of sulfuric acid that could be found in leachate from the leach tank.

The above estimate of the behavior of leachate from the lined leach tanks is consistent with the findings under the evaporation ponds during the liner removal and soil characterization and remediation. There were spotty areas of increased radioactivity confined to the upper meter of soil. They were easy to detect and remedy (Monster, 1996). The effectiveness of the liner system used at the Durita site has been demonstrated.

Once the acidity of the raffinate is neutralized, then the arsenic, lead, thorium, radium and polonium in the solution will precipitate in the neutral, sulfate-rich environment. The uranium content of released leachate into a calcium carbonate-rich environment can precipitate as uraninite or remain a mobile species depending on the Eh of the environment (NUREG 7014, 2010). Strongly reducing environments precipitate uranium oxide. The cadmium and zinc can remain mobile in the +2 valence state as a sulfate, or will precipitate as a sulfide, carbonate or oxide depending on oxidation-reduction potential. The CRC Handbook of Chemistry & Physics (1974) was used to evaluate solubility for different inorganic and/or radioactive species.

After the operational period the leach tanks were drained of liquid. The disposal cell contents were placed at minimum moisture. The driving force for the transfer of additional liquid through the liners of these structures was eliminated and the cover was constructed according to the approved reclamation plan.

7.4 Hydrology

Groundwater is present locally throughout the Western Slope in several of the formations that underlie the site including the Mancos Shale, Dakota Sandstone, Burro Canyon Formation and the Morrison Formation. The Mancos Shale is not generally identified as an underground source of drinking water, nor is it an exempted aquifer. If potable water is obtained from this formation it can be used, although natural groundwater quality in the Mancos Shale is generally of poor quality and not suitable

for potable water use (Environmental Sciences Laboratory for DOE, 2011). No beneficial-use wells near the site obtain water from the Mancos Shale Formation.

7.4.1 Surface Water:

There is no perennial surface water at the site. Ephemeral water flow is associated with precipitation and drains to the north. Natural drainages on the site have been modified to protect the disposal areas. Some areas of Dry Creek west of the Durita site show evidence of continuous near-surface water saturation by the presence of phreatophytes. Figure 7.5 shows the drainage and the location of some cottonwood trees.

The nearest permanent surface water is the San Miguel River approximately 2.1 miles northeast of the site. The Dolores River is approximately 15 miles west northwest of the site.

7.4.2 Groundwater

7.4.2.1 Conceptual Site Model for Groundwater

The relevant subsurface hydrogeology media at the Durita site is composed of three layers:

1. Unit A: The upper oxidized zone of surface alluvium, slope-derived colluvium and the weathered Mancos Shale. This zone represents the unconfined water-table aquifer at the site and is the upper-most water bearing unit.
2. Unit B: The un-oxidized, un-weathered Mancos Shale. This zone is an aquitard underlying the site and effectively separates units A and C.
3. Unit C: Represents the confined aquifer beneath the site. It is comprised of the water-saturated lower Mancos Shale and upper Dakota Sandston contact zone.

The characteristics of the three layers are as follows:

Table 7.1

Attribute	Unit A: Weathered Mancos and alluvium	Unit B: Unweathered Mancos	Unit C: Lower Mancos/Dakota Sandstone contact
Weathering	Highly weathered at the surface and grading to unweathered	Unweathered	Unweathered
Fracturing	Weathered Mancos Shale exhibits significant fracturing.	Minor local fracturing that is vertically discontinuous	Minor local fracturing: A 1.7-foot fracture noted in sandstone from one drill core.
Fissility	Mancos Shale strata often are fissile.	Local intervals show fissile nature.	None noted
Hydraulic conductivity	Relatively conductive: 5.6 x 10^{-5} to 3.4 x 10^{-6} cm/sec. Average of 2.7 x 10^{-5} cm/sec.	Relatively low: 2 x 10^{-5} cm/sec to not measurably conductive, geometric mean of 2.6 x 10^{-7} cm/sec. not conductivity in the lower section	Relatively low: 7 x 10^{-7} cm/sec to not measurably conductive.
Effective porosity	0.73 to 0.21, average of 0.31	None measured	None measured
Color	Light brown, tan, light gray, gray-brown, yellow, red-brown,	Dark gray to black, dark olive gray	Dark gray to light gray, mottled gray, gray-green, white
Characteristic minerals	Oxidized species as sulfate, ferric iron, calcite, gypsum	Reduced species of ferrous iron sulfides, calcite, bentonite	Reduced species of ferrous iron sulfides
Hydrostratigraphic Unit Type	Shallow, spacially and temporally discontinuous aquifer	Aquitard, dry	Confined saturated aquifer
Redox conditions	Oxidizing	Reducing	Reducing
Sediment assemblage	Sands, silts, clays, gravel, cobbles	Shale, claystones, siltstones, limey siltstone, silty sandstone	Sandstone, shale, mudstone, pebble conglomerate
Blow counts (average)	10 to 37 blows for 12 inches, average is 24/12"	50/0' to 50/12" average of 50/5"	None available
Other		Fossiliferous layers	Bioturbated layers

Unit A is composed primarily of the unconsolidated and weathered sediments at and near the surface. Water moving through this media is unconfined. The lower contact with the unweathered Mancos shale can be sharp and a non-conformity or gradual and conformal. Within the weathered sediments is a continuous interface of higher hydraulic conductivity sitting atop a surface of lower hydraulic conductivity. This

surface may represent the Unit A/Unit B contact or conductivity boundary caused by uneven weathering in the upper Mancos Shale. Any waters moving down from the surface and not dissipated by capillary forces or evaporation/transpiration would collect on this aquitard surface and flow according to the slope of this surface. Figure 7.4 shows a plot of this aquitard surface picked from the F. M. Fox (1977) descriptions and the monitoring well drill-log descriptions. While, presently, Figure 7.4 is a computer-generated plot, it does indicate the topography of this surface and that it does mimic the general surface drainage of the site. The test holes and monitoring wells are located on the figure. Monitor wells MW-1 through MW-7 were only surface-sealed and any water moving along the aquitard surface could be sampled by these first seven wells.

7.4.2.2 Unit A Water Sampling and Analysis Results

The results of the analytical results from monitor wells MW-2 through MW-7 are discussed in this section and the potential for a release discovery evaluated. These wells were sealed at the surface, but left open below the surface seal so as to collect water from the unconfined groundwater environment. This includes any unconfined water that may have been impacted by site activities. There is a data gap between the third quarter 1981 and the second quarter 1985 for the monitoring results. This gap is due to loss of records and is not a lapse of the monitoring program.

The most interesting result of the data analysis is the spike in chloride concentration found in monitor well MW-4. During the interval between January 1988 and October 1989 the chloride data showed a statistically significant increase in concentration from data taken before and after this interval. Attachment 7.1 shows the data graphed and an analysis of variance (ANOVA) evaluation of the data. The duration of the chloride of 22 months is approximately the duration of operations at the Durita facility. There is no other realistic source for the chloride spike found in MW-4 other than the process plant.

Sodium chloride and ammonium chloride were used in the Precipitation, Filtration & Packaging Building during operations. The chloride would have been part of the waste stream. Chloride is a conservative compound for tracing groundwater flow rate.

If the chloride was released from the Precipitation Filtration & Packaging Building at the beginning of operations in the fourth quarter 1977 then it took approximately 7.75 years to travel approximately 920 feet. That is a rate of approximately 120 feet per year. In the 14 years of monitoring between the fourth quarter 1977 and fourth quarter 1991 water would have, at a minimum, traveled approximately 1,700 feet. This is the conservative assumption. If the release occurred after the fourth quarter 1977, then the rate of travel would be faster.

Using the apparent rate of travel, a release of material from the Durita process plant or from the eastern portion of leach pad LT-201 would be detected by MW-4. A release of material from the western portions of leach pads LT-201 and LT-202 would be detected by monitor well MW-3. A release from leach pad LT-203 would have been detected by monitor well MW-6.

Using the conservative assumption, a release of material from the eastern part of leach pad LT-202 is not within the sampling envelope for monitoring well MW-4 if that is the downgradient well. This portion of leach pad LT-202 is within the sampling envelope of monitoring well MW-3 if it is the downgradient well.

The conservative assumption for hydraulic conductivity and travel time may not be the most realistic assumption for material in the eastern part of LT-202. The base of the weathered section in this area is composed of gravels and cobble. This type of deposit has a larger hydraulic conductivity than the clayey, silty sands found at the base of the weathered surface in the MW-3 and MW-4 areas. Even an increase of one order of magnitude hydraulic conductivity in these gravel deposits greater than the clayey silts found near MW-4 would put any potential release from LT-202 within the

sampling envelope of monitoring well MW-4. This is a reasonable and conservative assumption about the conductivity and travel time of water moving in the gravels.

An evaluation of the flow data using a gradient of 0.033 and an apparent water velocity of 120 feet per year using the equation velocity = hydraulic conductivity time gradient divided by porosity (v= (k/n)(dh/dl)) yields an apparent hydraulic conductivity between 7 x 10-4 cm/sec and 1 x 10-3 cm/sec. This is the range of conductivities for a clayey, silty sand as is found in this part of the site (Freeze & Cherry, 1979). The gradient is taken from the general site gradient and from the slope of the shallow aquitard between MW-3 and MW-4 shown on Figure 7.4. Porosity is varied between 0.2 and 0.3 The sandy gravels found beneath the area of LT-202 will have a hydraulic conductivity greater than 1 x 10-1 cm/sec. based on the same source. Using this analysis, the eastern area of LT-202 is within the sampling envelop of MW-4 during the monitoring period.

Regarding the other groundwater constituents, it appears that the concentrations of zinc, ammonia and dissolved solids show relatively constant concentrations over time. In the third and fourth quarter of 1979 elevated concentrations of uranium are reported in monitor wells MW-2, MW-3, MW-4 and MW-7. Elevated concentrations of uranium are reported in the third quarter 1979 for monitor wells MW-5 and MW-6. The distribution and timing of these elevated uranium concentrations is typical of laboratory, or analytical contamination. Up gradient and down gradient monitor wells are impacted simultaneously.

Radium-226 and lead-210 results show elevated activity in 1978 and 1980 that are distributed among several monitor well, both up gradient and down gradient of the leach pads. Again, this is indicative of laboratory contamination. Please bear in mind that the radium and lead travel primarily attached to solid particles and not as the dissolved phase. There is a reported spike in sulfate in the fourth quarter 1980 in MW-6 that is not supported by a corresponding increase in dissolved solids. Again, this appears to be a laboratory artifact.

Monitor well MW-3 also shows an increasing concentration of chloride beginning in the 4th Quarter 1987. This well is cross gradient from the process plant.

Releases of leachate from the leach tanks or the evaporation ponds significant enough to impact groundwater in the unconfined aquifer would have been detected by the monitoring program in place between 1977 and 1991. There is no evidence from this program of a significant release of contaminants of concern.

7.4.2.3 Unit B Aquitard/Aquiclude

Between the weathered near-surface Mancos Shale and the basal Mancos Shale/Dakota Sandstone is the un-oxidized Mancos Shale. Consisting primarily of black shale, mudstones, sandstones, siltstones, limestones, and bentonite. Standard penetration tests classify the material as dense to very dense. This layer is an aquitard or aquiclude that effectively isolates and confines the lower saturated Unit C.

The drilling logs for monitor well MW-8 through MW-14 show the un-weathered Mancos Shale to be dry between units A and C. The geophysical logs, Figure 7.2, reported by F. M. Fox (1982) show a distinct basal Mancos Shale signature above the Dakota Sandstone. This basal shale feature is topped with a bentonite clay layer about 3 feet to 4 feet thick. Three in-hole conductivity tests were performed in this basal shale. No measurable conductivity was reported for the measurements conducted in boreholes B-5, B-6, and B-8. These are boreholes on or close to the Durita site.

Two hydraulic conductivity measurements were performed in the basal shale in borehole B-1 with values of 8.2 x 10-8 cm/sec and 3 x 10-5 cm/sec. The drilling log of B-1 indicates that the conductivities were done in an oxidized zone. The basal Mancos Shale is at a shallower depth than the other measured boreholes. Borehole locations are shown in Figure 7.4.

Bentonite clay has a very low-permeability , especially when wet. It is used for landfill and impoundment liners. Measured hydraulic conductivities on the order of 10-9 cm/sec are common for compacted bentonite. The layer of bentonite clay above the basal shale is an effective hydraulic seal. That the elevation of water in monitor wells MW- 9 through MW- 11 and MW-14 rises above the elevation of water saturation is evidence and a demonstration of its ability to confine the saturated interval in Unit C.

Monitoring well MW-12 is at the eastern edge of the site and only has about 6 feet of Mancos Shale above the Dakota Sandstone. It is not hydraulically confined and at this point Unit A sits atop Unit C. There may be some influence from surface water flowing in the east drainage, but no groundwater contamination has been found in this well.

7.4.2.4 Unit C Confined Groundwater

Groundwater at the site occurs continuously at, or near, the base of the Mancos Shale and into the Dakota Sandstone. The source of the water is infiltration of precipitation and runoff into the surface exposures south of the Durita site and on the slopes of Naturita Ridge. The exposed re-charge area is on the southern limb of the Coke Oven Syncline. Water in the Dakota Sandstone moves north, and down dip, under the site. It is covered by the aquitard/aquiclude of the Unit B Mancos Shale and thus becomes a confined aquifer under the Durita site. Figure 7.1 shows a cross-section across the site. Figure 7.2 shows the geophysical logs and permeability measurements made during this investigation. Figure 7.3 shows the shallow aquitard contours; Figure 7.4 shows the test hole location map where soil borings were installed by F. M. Fox (1982) Figure 7.5 shows a satellite photograph of the Durita site with major features labeled.

Soil boring descriptions and geophysical logs for boreholes B-1, B-5, and B-6, show a sandstone interval in the upper Dakota Sandstone. There are three measured hydraulic conductivities measured in this section ranging from 3 x 10-7 cm/sec to no measurable conductivity. Figure 7.6 and Figure 7.7 show the hydrostratigraphic section from south to north across the Durita site showing well screen intervals and

static water heads. Figure 7.8 shows the locations of the wells and boring shown in Figures 7.6 and 7.7.

The measured horizontal gradient of groundwater is north and northwest towards Dry Creek. The static head in the wells is above the level of saturation noted in the drilling logs and of the well screen interval noted in the completion report. This is demonstrated by the drilling and installation of monitor wells MW-8 through MW-14, but not MW-12. That the lower saturated interval shows a piezometric water elevation above the level of saturation is direct evidence of hydraulic confinement of the lower saturated interval. In these wells, the drilling logs indicate dry rock in the B Unit.

Most wells drilled into the lower saturated interval show a groundwater potential higher than the elevation of the saturated section. MW-12 shows that the first saturated interval it penetrates has a free-air potential and is not confined. The first saturated interval in MW-12 is a 1-foot thick sand within the Mancos Shale at 20 feet below ground surface (bgs). The drilling log does not indicate that any separate lower saturated interval was encountered. Groundwater elevations taken between 1991 and 1998 in MW-12 appear to show a seasonal rise in water elevation in the second quarter of the year. It happened in four of six years when measurements were made. This seasonal rise may indicate evidence from MW-12 of a connection between a saturated sandstone interval and the surface. This connection, if it exists, appears related to the unnamed drainage along the east site of the site. However, the chemical analyses of water from MW-12 shows high levels of total dissolved solids (TDS) and dissolved sulfate consistent with the monitor wells known to be confined. It is also consistent within the range of natural sulfate and TDS found in the Mancos Shale as per DOE, (2011). The concentrations are among the highest on the site. This is inconsistent with recharge of fresh water from the surface. Please refer to Figure 7.7 for a hydrostratigraphic section along the east side of the Durita site.

Groundwater monitoring wells drilled beneath the Durita site indicate that there are two rock units in the lower Mancos Shale formation that appear to be hydraulically connected and may constitute a single water-bearing stratum. Beneath most of the site, the continuously-saturated uppermost water-bearing unit is a sandstone-claystone up to 19 feet thick. Along the north side of the site the uppermost unit is a 1-foot-thick sandstone known to be saturated in MW-12. These two zones appear to represent a single hydrologic unit as the piezometric surface between the two layers is continuous.

State Engineer records show a well completed in the upper Dakota Sandstone approximately 2,900 feet at East 11° South of the southeast corner of the site also exhibited confinement of the aquifer below the Mancos Shale. This well was abandoned in 2003. (Well permit No. 221025.)

Dry Creek occupies the topographic low of the syncline and drains northeast towards the San Miguel River. The associated fault coincident with Dry Creek provides a zone of higher permeability for the transport of groundwater out of the syncline. It is the outlet for the bowl of the Coke Oven Syncline and provides the exit for water moving in the lower Mancos Shale saturated interval. It is the energy low of the hydraulic potential system.

7.5 Conclusions

There is no evidence of a completed transport pathway for releases from the leach tanks or disposal cell to leave the Durita site. The disposal cell was closed dry. The leach pads were closed dry. Any releases of acidic leachate from the leach tanks during operations were neutralized by the carbonate content of the soil beneath the leach pads. Also, any liquid moving through the soil is subject to the capillary forces and retention within the soil. The potential amount of liquid release from the leach tanks and the chemical and physical characteristics of the soil indicate no potential for the accumulation and movement of contaminated water in the shallow subsurface.

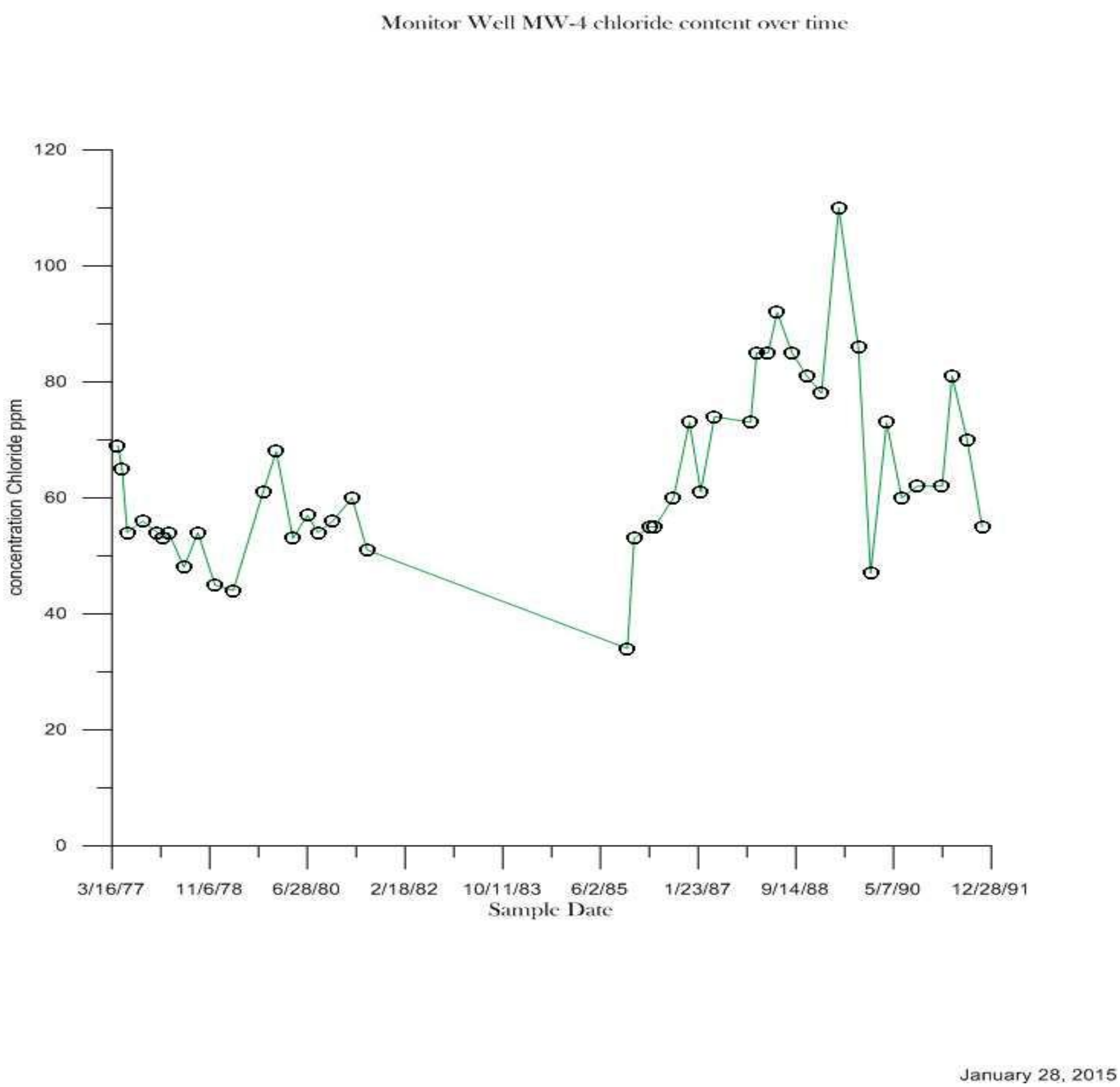
There is no evidence of a release of chemicals of concern or radionuclides to shallow, unconfined groundwater. The liner system was effective in preventing significant releases to the subsoil.

The water-saturated interval at the Mancos Shale-Dakota Sandstone contact is isolated from any potential release from the leach pads by a layer of Mancos Shale with very low to unmeasurably low hydraulic conductivity. The Mancos Shale interval is also chemically adsorptive and strongly reducing and would precipitate soluble uranium and other chemicals of concern. There is no evidence of a release of chemicals of concern or radionuclides to groundwater beneath the Durita site.

The monitoring network was adequate for the site and the uranium recovery operations conducted there. The groundwater monitoring program performed at the site was adequate to meet regulatory requirements.

Attachment 7.1

ANOVA analysis of groundwater chloride content over time in monitoring well MW-4
Plot of chloride content in well MW-4 over time 1977 to 1991.



ANOVA: Results

The results of a ANOVA statistical test performed at 10:18 on 28-JAN-2015

Source of Variation	Sum of Squares	d.f.	Mean Squares	F
between	5922.	2	2961.	32.73
error	3709.	41	90.47	
total	9632.	43		

The probability of this result, assuming the null hypothesis, is 0.000

Group A: Number of items= 24
34.0 44.0 45.0 48.0 51.0 53.0 53.0 53.0 54.0 54.0 54.0 54.0 54.0 55.0 55.0 56.0 56.0 57.0 60.0 60.0 61.0 65.0 68.0 69.0

Mean = 54.7
95% confidence interval for Mean: 50.79 thru 58.63
Standard Deviation = 7.52
High = 69.0 Low = 34.0
Median = 54.0
Average Absolute Deviation from Median = 4.96

Group B: Number of items= 12
61.0 73.0 73.0 74.0 78.0 81.0 85.0 85.0 85.0 86.0 92.0 110.

Mean = 81.9
95% confidence interval for Mean: 76.37 thru 87.46
Standard Deviation = 12.1
High = 110. Low = 61.0
Median = 83.0
Average Absolute Deviation from Median = 8.58

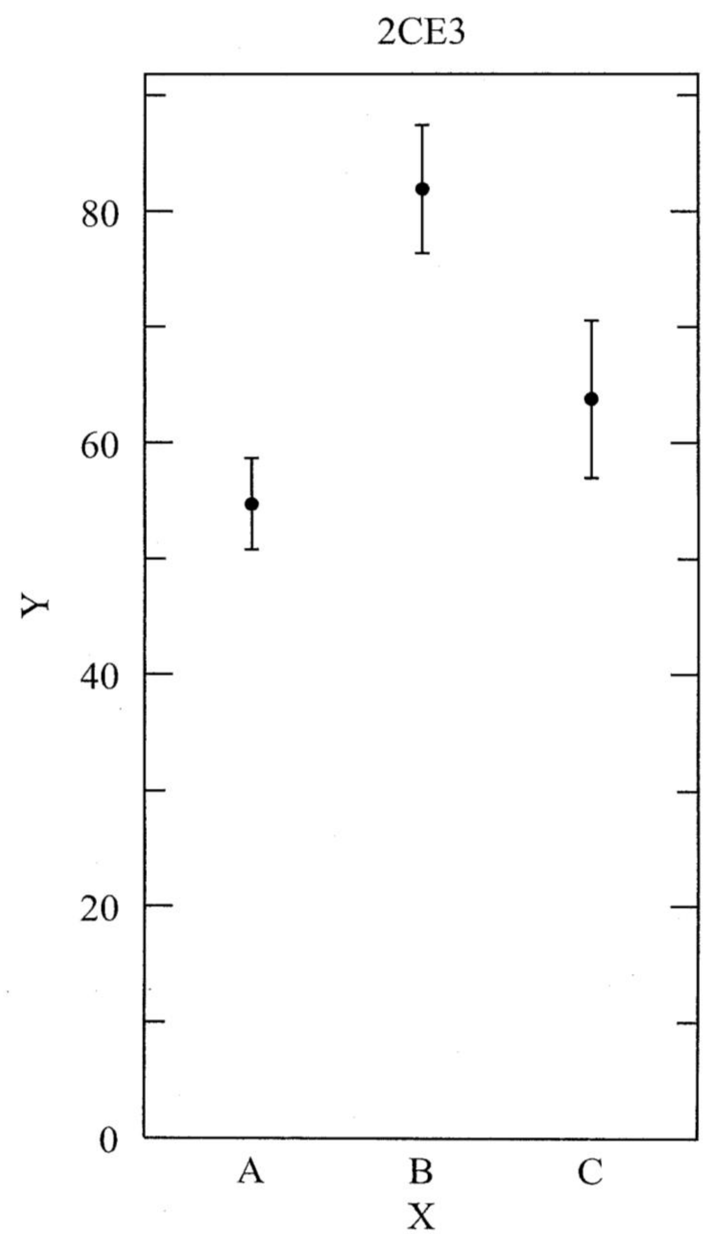
Group C: Number of items= 8
47.0 55.0 60.0 62.0 62.0 70.0 73.0 81.0

Mean = 63.8
95% confidence interval for Mean: 56.96 thru 70.54
Standard Deviation = 10.7
High = 81.0 Low = 47.0
Median = 62.0
Average Absolute Deviation from Median = 7.75

Data Reference: 2CE3

Plot the Group Means with 95% Confidence Intervals

Plot of means with 95 percent confidence interval of the chloride content populations for monitor well MW-4. Population A is the analyses from April 1977 to August 1986. Population B is the analyses from November 1986 to October 1989. Population C is the chloride analyses from December 1989 to November 1991. Population B shows a distinct statistical character from population A and C.



8.0 Compliance with License Conditions

The conditions of the radioactive materials license, Amendment 12 that control the design and construction were:

LC 11.2 Final Reclamation Plan

- The Final Reclamation Plan was submitted in October 1991. CDPHE approved the Final Reclamation Plan in May 1993.

LC 11.6 Quality Control Procedures and Construction Verification Program

- The Quality Control Procedures and Construction Verification Program for the Durita Site Reclamation were submitted March 24, 1995. (McCulley, Frick & Gilman, 1995)

LC 17 Design and Engineering

The following documents were submitted:

- AK Geoconsult Inc. 1994 Specification for Construction of Erosion Protection of Containment Structures, Durita Site, Colorado prepared for Hecla Mining Company. January 26, 1994.
- AK Geoconsult Inc. 1994 Specification for Excavation and Disposal of Contaminated Soil, Durita Site, Colorado prepared for Hecla Mining Company. August 20, 1994.
- AK Geoconsult Inc. 1994 Specification for Site Re-grading and Revegetation, Durita Site, Colorado prepared for Hecla Mining Company. January 26, 1994.
- AK Geoconsult Inc. 1994 Specification for Surface Water Control Structures, Durita Site, Colorado prepared for Hecla Mining Company. January 26, 1994.
- AK Geoconsult Inc. 1994 Specification for Closure of Evaporation Ponds and Raffinate Ponds, Durita Site, Colorado prepared for Hecla Mining Company. August 20, 1994.

- AK Geoconsult Inc. 1994 Specification for Leach Tank Outer slopes and Radon Barrier Construction, Durita Site, Colorado prepared for Hecla Mining Company. August 20, 1994.

LC 28.2 Annual Reclamation Report

- Monster Engineering, Inc. (MEI). 1996. 1995 Durita Site Reclamation and Construction Verification Report prepared for Hecla Mining Company. January 25, 1996.
- Monster Engineering, Inc. (MEI). 1997. 1996 Durita Site Annual Reclamation Report prepared for Hecla Mining Company. February 20, 1997.
- Monster Engineering, Inc. (MEI). 1998. 1997 Durita Site Reclamation and Construction Verification Report prepared for Hecla Mining Company. February 20, 1998.
- Monster Engineering, Inc. (MEI). 1998. 1998 Durita Site Reclamation and Construction Verification Report prepared for Hecla Mining Company. November 5, 1998.

A decision analysis for the proposed amendment to renew the license was completed in 1999 (CDPHE, 1999). The decision analysis determined that license conditions were in place to assure adequacy of equipment, facilities and procedures to protect public health and safety and property. License compliance was monitored by the department through annual license compliance inspections. Compliance was also monitored through periodic site visits, review of the licensee's annual ALARA reports and review and approval of procedures in the Hecla Mining Company Health and Safety Program (Hecla, 1990).

CDPHE-HMWMD has determined that the Hecla Mining Company has complied with the license conditions for site reclamation.

9.0 License Termination Conclusion

CDPHE-HMWMD has determined that the Hecla Mining Company has complied with the Colorado Rules and Regulations Pertaining to Radiation Control and other state and federal regulations with regards to decommissioning. CDPHE-HMWMD staff have determined that by inspections, communications and review of documents and reports that reclamation at the Durita Site was done to the following:

- Work was performed according to the approved plans, specifications, and practices;
- That any deviations from the approved plans, specifications and practices were identified and corrected promptly;
- That variances from the approved plans, specifications and practices were evaluated and justified sufficiently to support acceptance prior to implementation;
- Hecla Mining Company prepared a long-term monitoring and maintenance report (March 2000). This report discussed transfer of the Durita site to the U.S. Department of Energy;
- That the Durita site in Montrose County, Colo. can be released to DOE; and
- That the Colorado Radioactive Materials License RML-317-02 can be terminated.

In conclusion, CDPHE-HMWMD believes that the Hecla Mining Company's Durita site has met all applicable standards and requirements. With a determination by NRC, as required by Section 274c. (4) of the Act, that all applicable standards and requirements have been met, the Colorado Radioactive Material License 317-02 may be terminated.

In a letter dated April 12, 1996 to DOE, Gov. Roy Romer declined the Colorado State's option to be custodian of the Durita site and the Umetco site known as Maybell. In a letter dated Feb. 27, 2001 from Gary Gamble to DOE, notification was given that they

planned to transfer the site to the U.S. DOE by June 30, 2002. On Jan. 18, 2002 Ann Robison of Hecla wrote a letter to DOE regarding transfer of the Durita site to the United States Department of Energy (DOE). Pending acceptance of this CRR and an approved long-term surveillance plan, it is anticipated that the Durita site can be transferred to the DOE.

IV Figures

Completion Review Report for the Durita Site, 2015

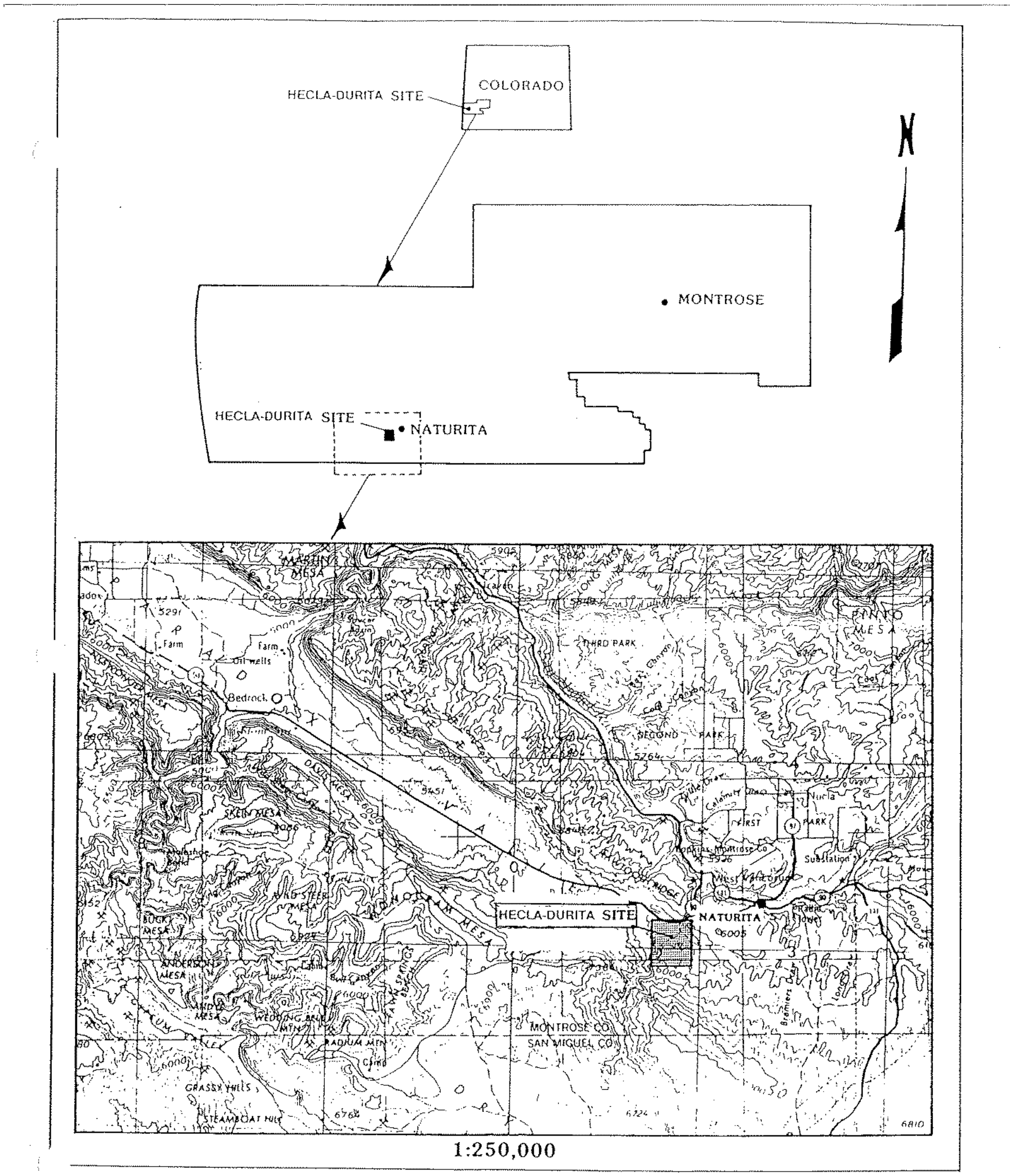
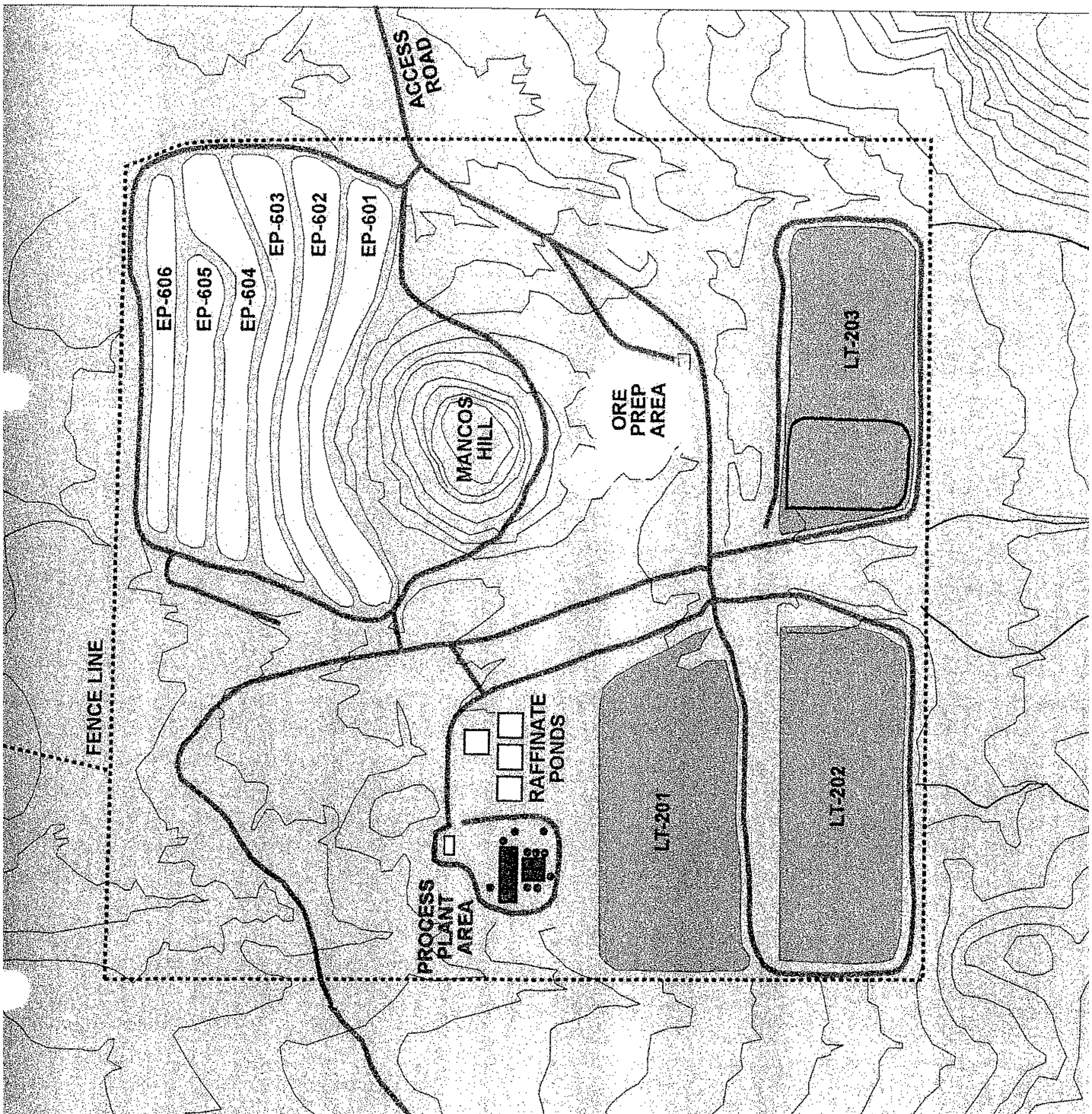


FIGURE 1
SITE LOCATION MAP DURITA SITE

FIGURE 2
DURITA
PRE-RECLAMATION
SITE
CONDITIONS



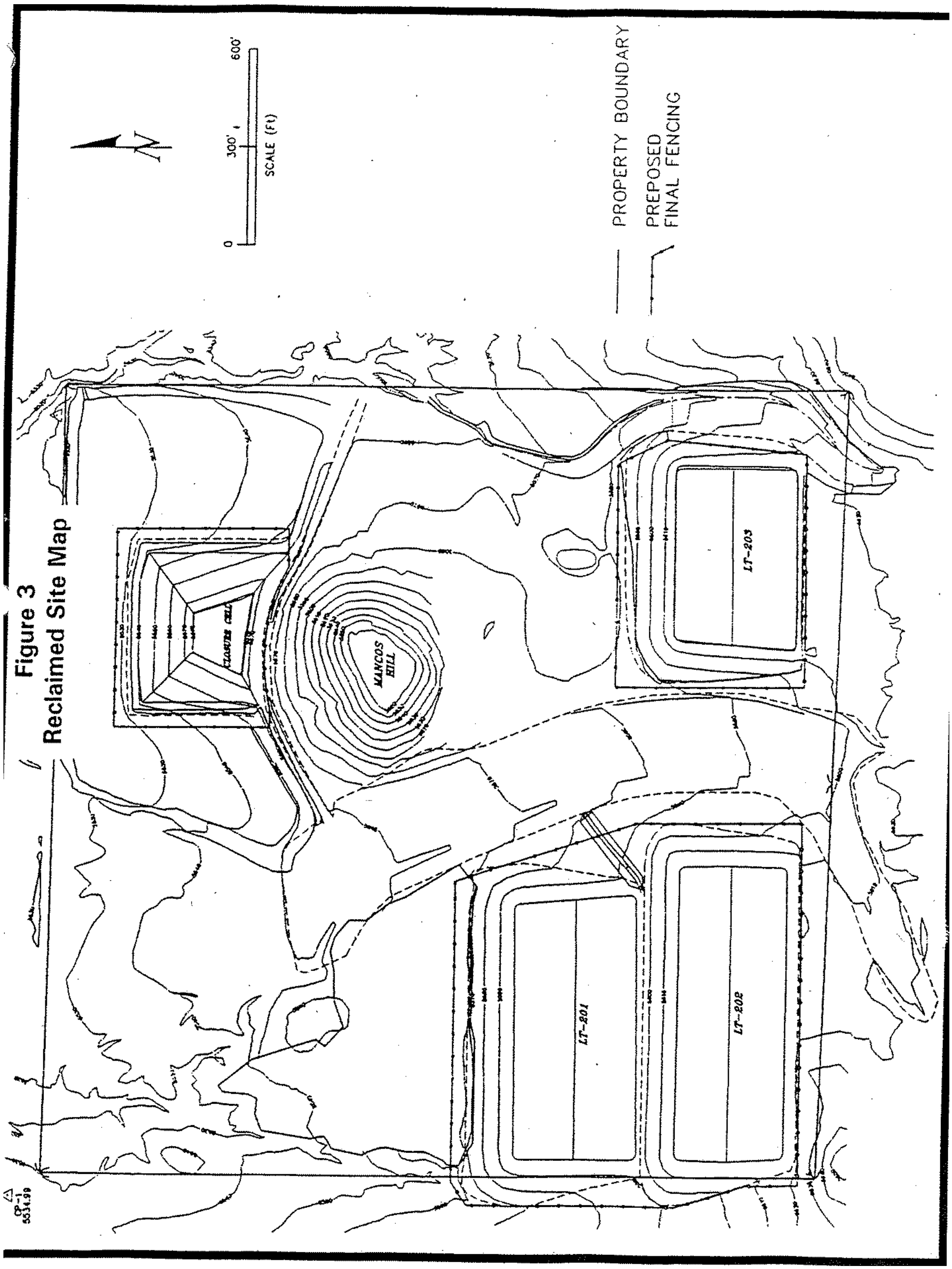


Figure 3
Reclaimed Site Map

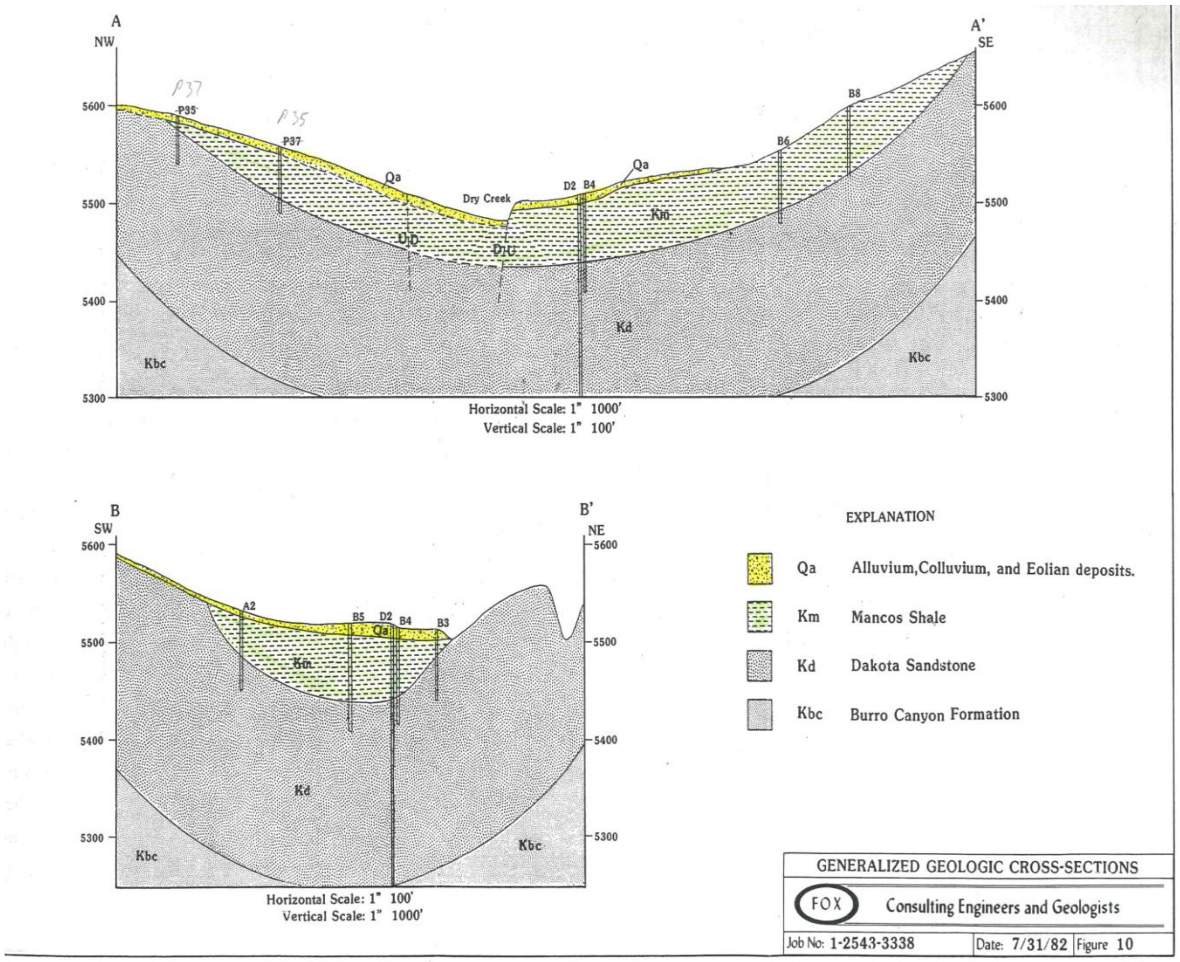


Figure 7.1
Generalized cross section across the Coke Oven Syncline. From Fox 1982

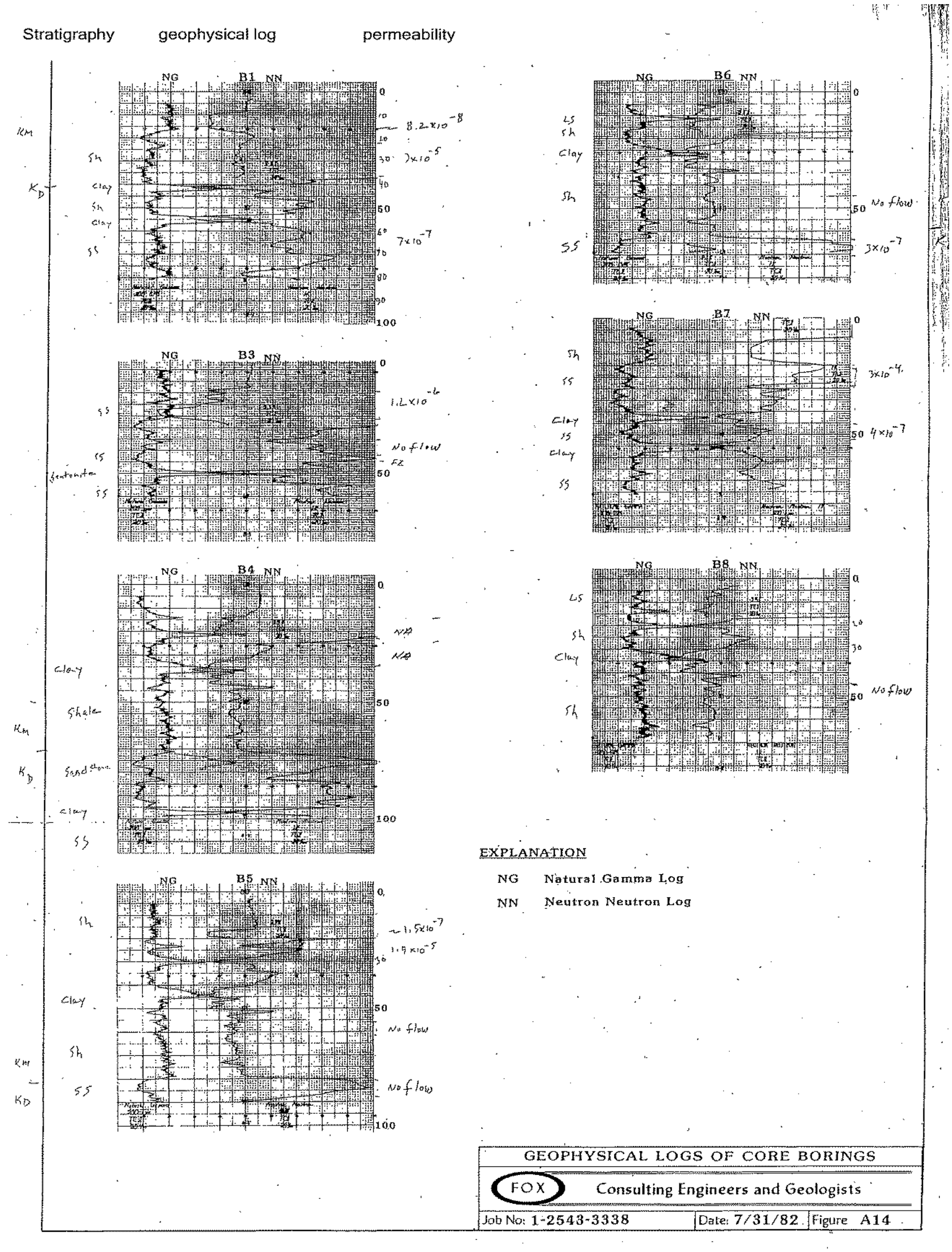


Figure 7.2

Stratigraphy and measured permeability plotted against the natural gamma and neutron-neutron geophysical measurements. From Fox 1982.

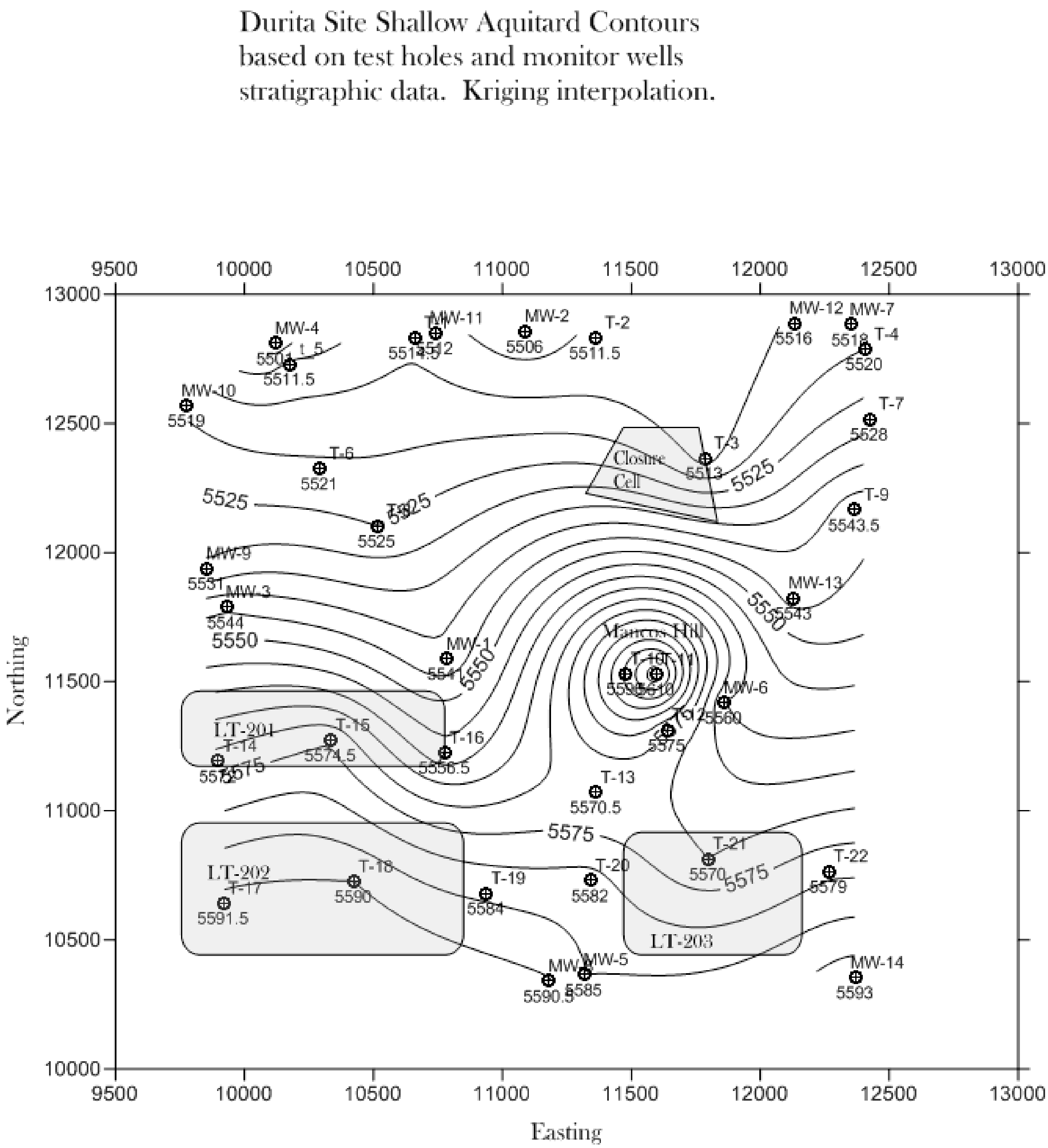


Figure 7.3. The drilling description of MW-1 shows the presence of unconfined groundwater at this interface. MW-1 appears to be in the channel of this aquitard surface. This aquitard-surface channel appears to go from the vicinity of MW-8 through MW-1 to the vicinity of MW-4 and MW-10. This channel collects the unconfined flow from the area between T-22 and T-15. Water in the low point of the aquitard surface was seen during the drilling program conducted in Four Corners Environmental Research and reported in 1977. Because of the location of test holes, the prominent positive feature associated with Mancos Hill is displaced to the south.

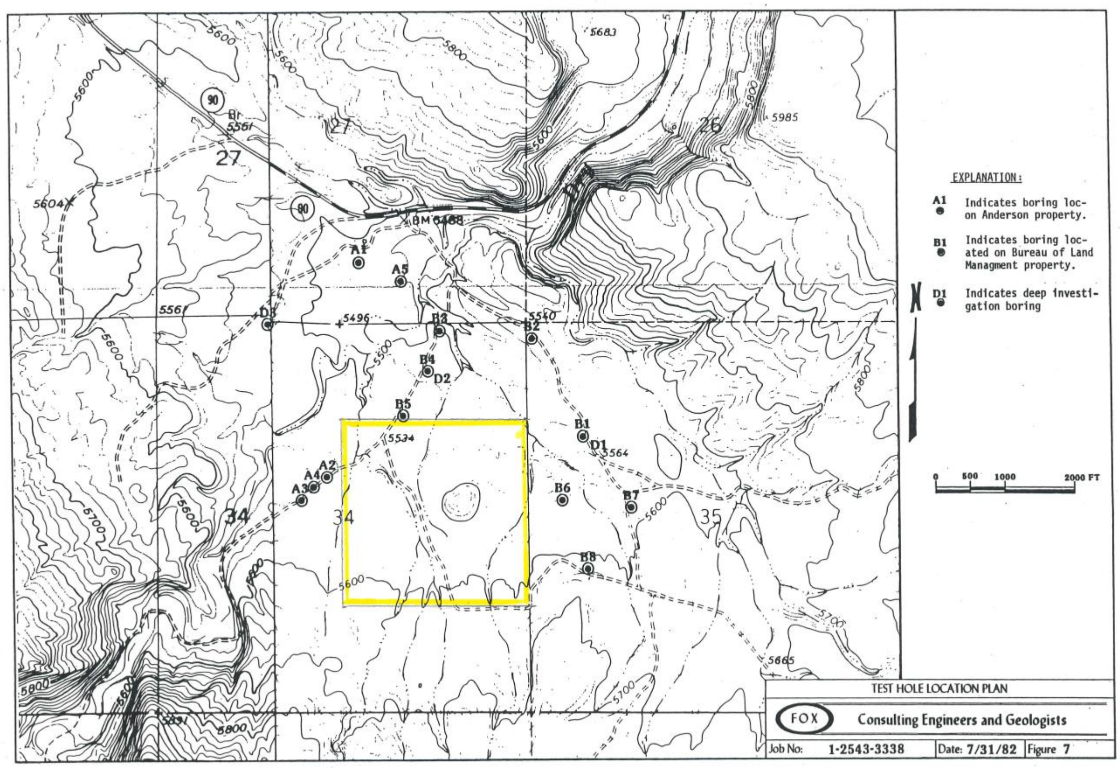


Figure 7.4 Test hole location map from Fox 1982. The Durita site is outlined in yellow.

Satellite Images Durita

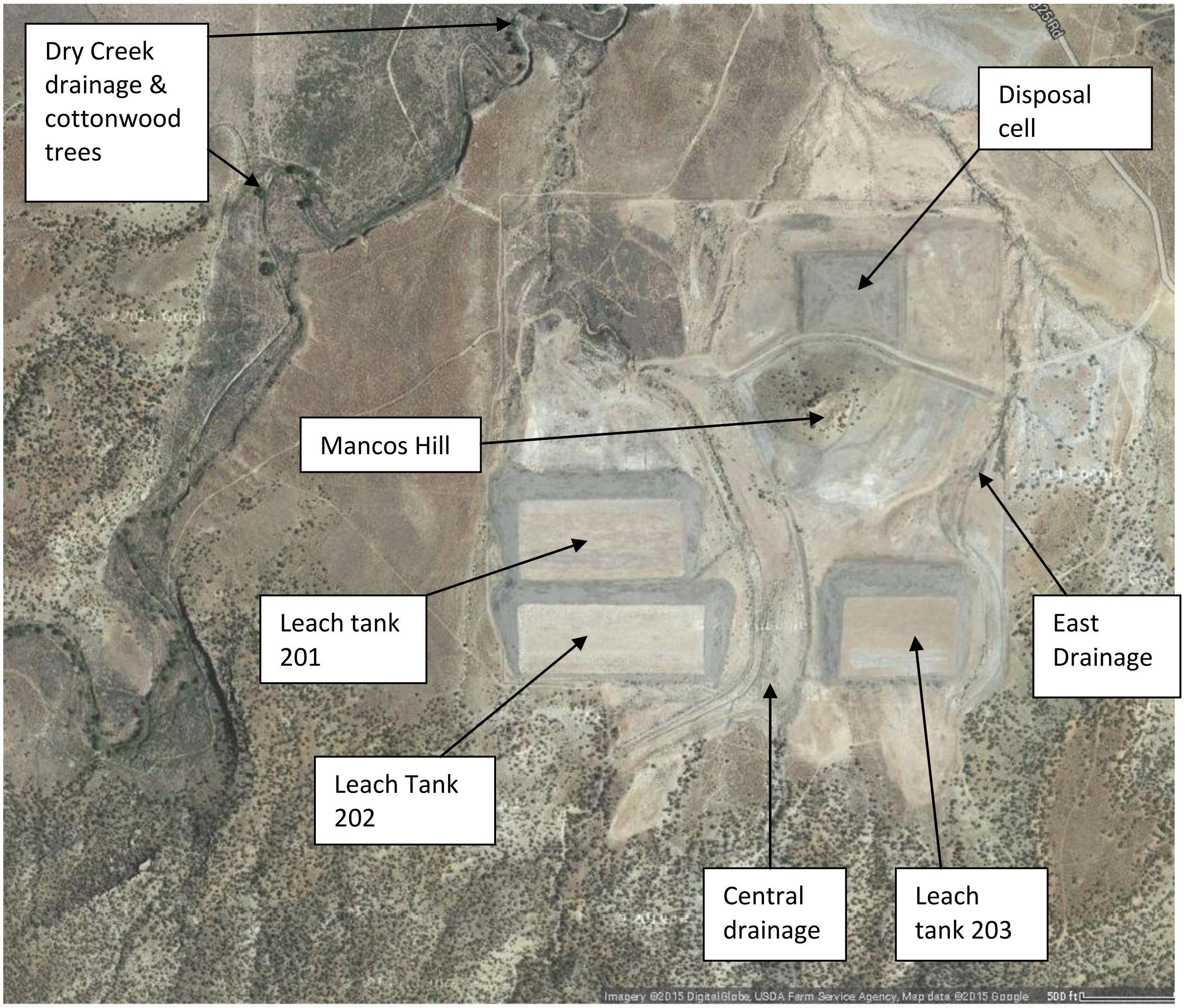


Figure 7.5 Satellite image of the Durita site area with major features identified.

Figure 7.6

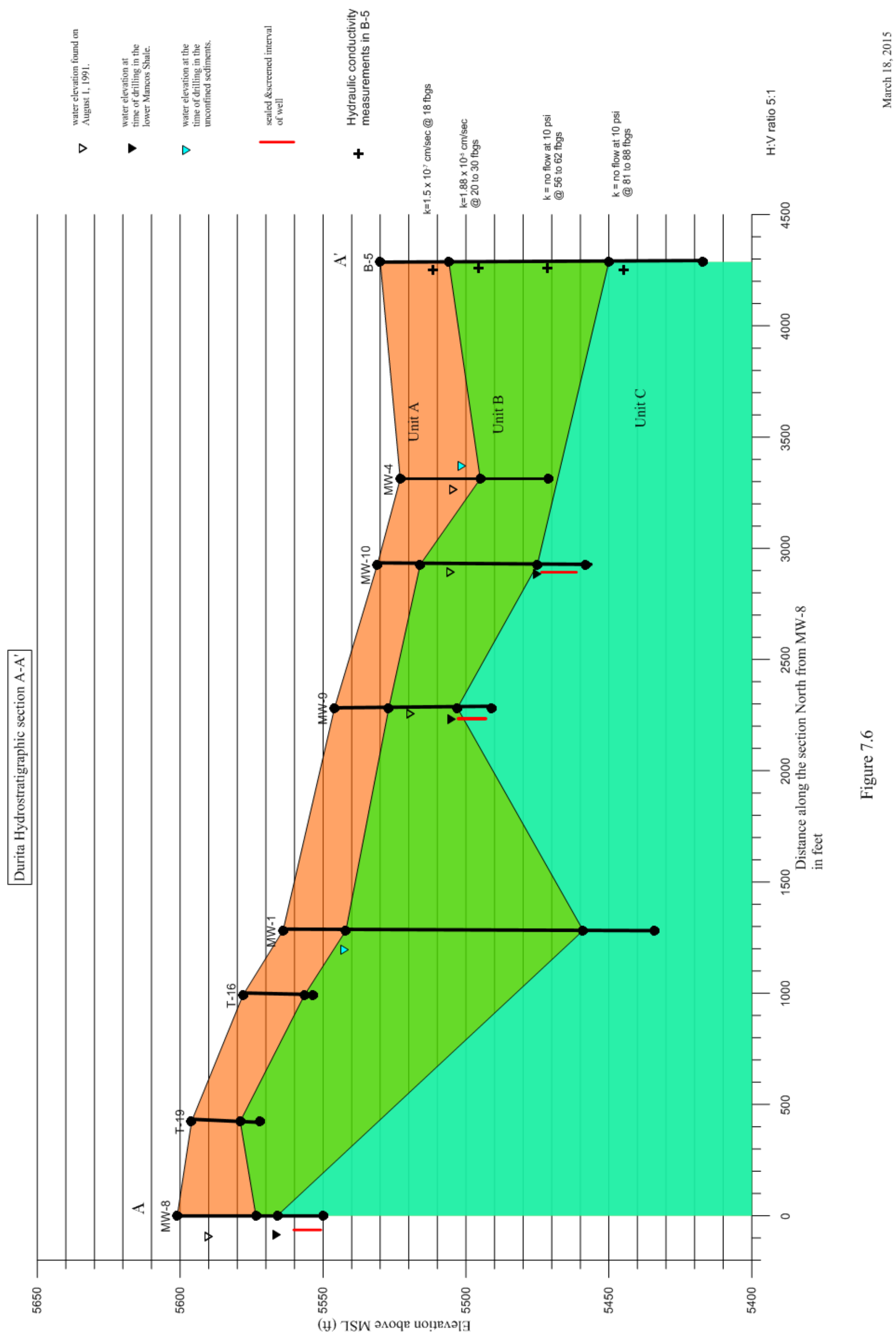

Durita Hydrostratigraphic section A-A'
water elevation found on August 1, 1991.
water elevation at time of drilling in the lower Mancos Shale.
water elevation at the time of drilling in the unconfined sediments.
sealed &screened interval of well
Hydraulic conductivity measurements in B-5
k=1.5 x 10⁻⁷ cm/sec @ 18 fbgs
k=1.88 x 10⁻⁵ cm/sec @ 20 to 30 fbgs
k = no flow at 10 psi @ 56 to 62 fbgs
k = no flow at 10 psi @ 81 to 88 fbgs
H:V ratio 5:1
March 18, 2015
A
A'
MW-8
T-19
T-16
MW-1
MW-9
MW-10
MW-4
B-5
Unit A
Unit B
Unit C
Elevation above MSL (ft)
5650
5600
5550
5500
5450
5400
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Distance along the section North from MW-8 in feet
Figure 7.6

Figure 7.7

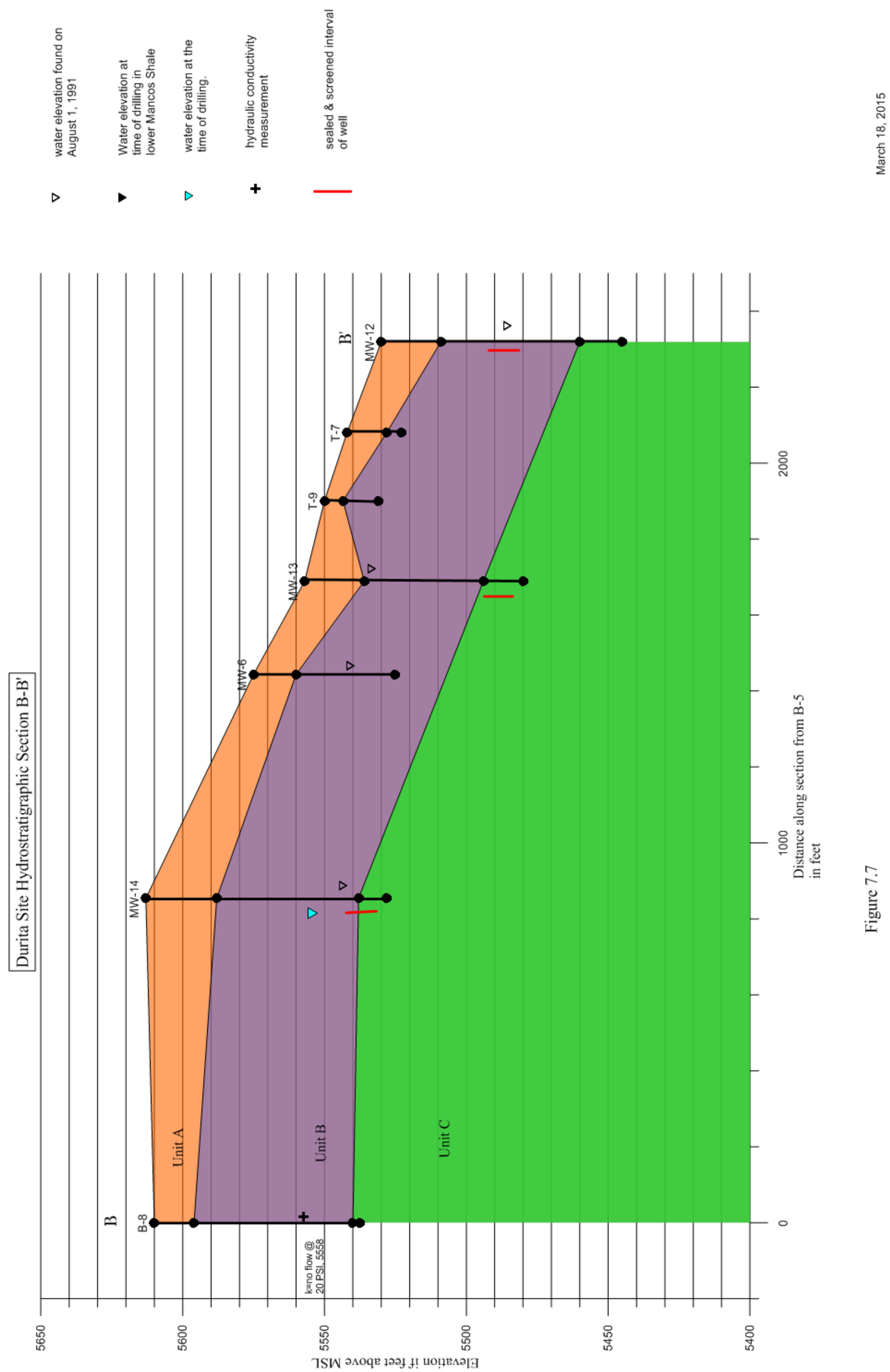
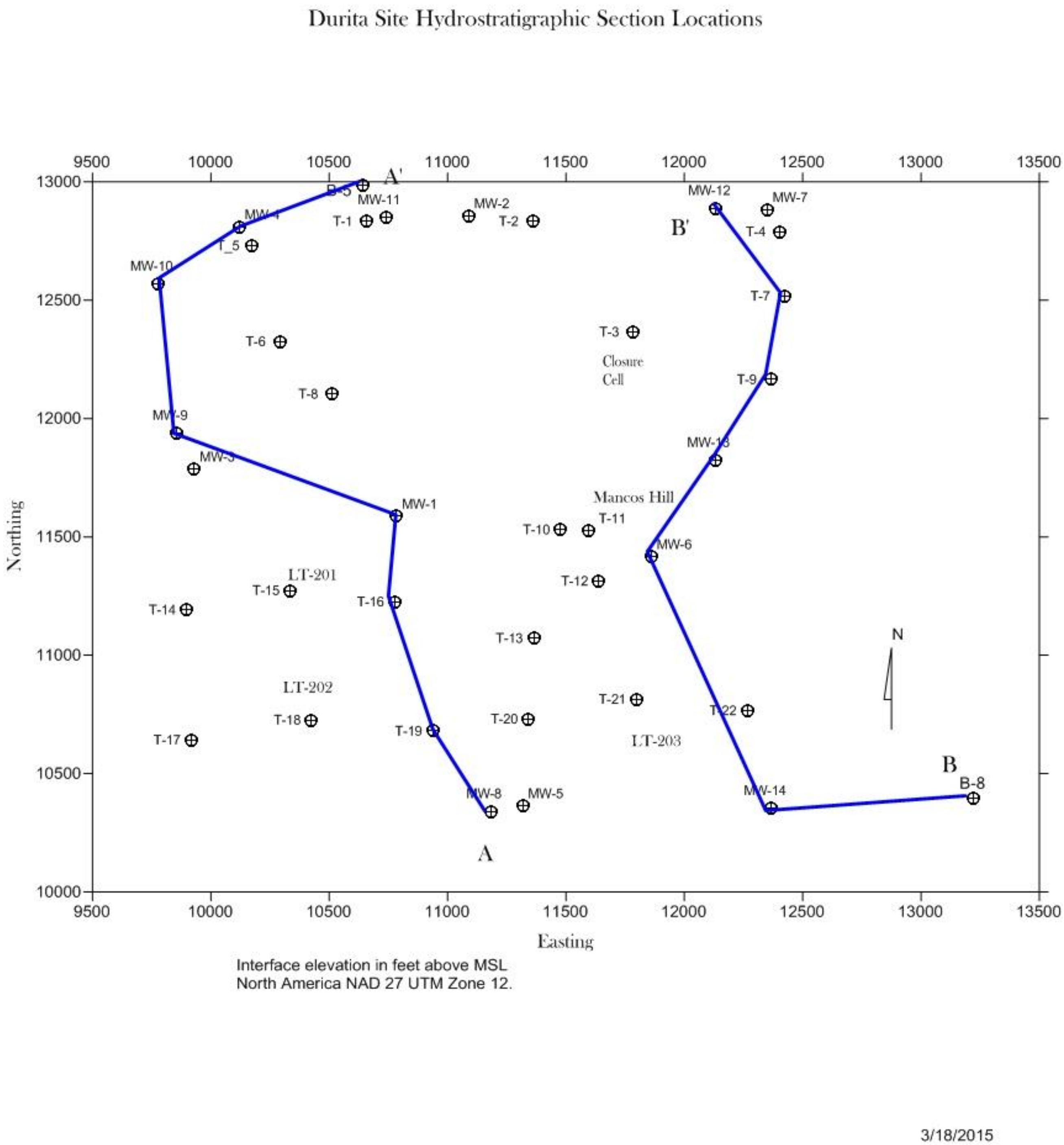


Figure 7.7

Figure 7.8


Durita Site Hydrostratigraphic Section Locations
A'
B-5
MW-11
MW-2
MW-4
T-1
T-2
T_5
MW-10
T-6
T-8
MW-9
MW-3
MW-1
LT-201
T-15
T-14
T-16
LT-202
T-18
T-17
T-19
MW-8
MW-5
A
MW-12
MW-7
B'
T-4
T-7
T-3
Closure Cell
T-9
MW-13
Mancos Hill
T-11
T-10
MW-6
T-12
T-13
T-21
T-20
T-22
LT-203
N
B
B-8
MW-14
Northing
Easting
9500
10000
10500
11000
11500
12000
12500
13000
13500
10000
10500
11000
11500
12000
12500
13000
Interface elevation in feet above MSL
North America NAD 27 UTM Zone 12.
3/18/2015

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VI List of Acronyms and Abbreviations

Acronyms or Abbreviation	Meaning
A	area
The Act	Colorado Radiation Control Act (Title 25, Article 11, Part 101 et. seq.)
ALARA	as low as reasonably achievable
a_{max}	maximum ground acceleration
ANOVA	analysis of variance statistical test
ASTM	American Society for Testing and Materials
bgs	below ground surface
Bi	bismuth
CCR	Colorado Code of Regulations
CDPHE	Colorado Department of Public Health and Environment
cfs	cubic foot per second
cfs/ft	cfs/foot
cm/sec	centimeter per second
CRR	Completion Review Report
CY	cubic yard
D5LPG	Caterpillar bulldozer model D5-LPG
D_{50}	median stone diameter
dh/dl	gradient, or change in head per unit length
DOE	Department of Energy
Eh	The potential of a half-cell, measured against the standard hydrogen half cell, typically reported in units of millivolts, synonymous with oxidation/reduction potential or redox potential.
FR	Federal Register

FSME	Federal and State Materials & Environment Management Program
g	earth's gravitational acceleration of 32 feet/sec^2
g/cc	gram per cubic centimeter
HEC-1	U. S. Corps of Engineers river flow estimator from precipitation.
Hecla	Hecla Mining Company
HELP	EPA Model: Hydrologic Evaluation Landfill Performance
HMWMD	Hazardous Materials & Waste Management Division
H: V	horizontal to vertical ratio
k	hydraulic conductivity (cm/sec)
K	seismic coefficient in slope analysis calculations
LC	license condition
MCE	maximum credible earthquake
ME	maximum earthquake (calculated)
µ R/hr	micro Roentgen per hour
µ REM/hr	micro Roentgen Equivalent Man per hour
mg/Kg	milligram per Kilogram
M_L	local magnitude earthquake on Richter Scale
MSL	mean sea level
n	porosity
NRC	U. S. Nuclear Regulatory Commission
NUREG	NRC Regulatory Guide
Pb	lead
pCi/g	picoCuries per gram
Po	polonium
PMF	probable maximum flood
PMP	probable maximum precipitation
Q	water flow rate
Ra	Radium

Ranchers	Ranchers Exploration and Development Corporation
RAP	remedial action plan
Rn	radon
The Regulations	Colorado Rules and Regulations Pertaining to Radiation Control 6 CCR 1007-1
SPH	solidified pond material
STABL5	Spencer method of slices slope stability computer model (Carpenter 1986)
STP	State and Tribal Programs
tc	time of concentration in hours
Th	thorium
UMTRCA	Uranium Mill Tailings Radiation Control Act of 1978