Assessment of Hydrogeologic Conditions and
Need for Long-Term Groundwater Monitoring
at the Former Durita Uranium Mill, Naturita, Colorado
Executive Summary

Gene Peters and Randall Fedors

The Hecla Mining Company owns the former Durita Uranium Mill Tailings Site, located in Naturita, Colorado that operated from 1977 to 1979 to reprocess spent uranium ore from a nearby mill. The Durita Mill recovered additional uranium from this ore using chemical leach processes and stored liquid effluent in surface impoundments. After surface reclamation activities in the early and mid-1990s, groundwater quality was monitored at the Site perimeter until Hecla requested, and the Colorado Department of Public Health and the Environment (CDPHE) approved, in 1998 termination of groundwater monitoring. The CDPHE approved the termination request apparently based on a perceived lack of groundwater contamination and an estimated 22,000-year travel time from source to compliance boundary if groundwater were contaminated. To support the NRC license termination process, NRC hydrogeologists reviewed documentation maintained by CDPHE about Site conditions and visited the Site to observe geologic conditions to determine whether continued groundwater monitoring is warranted.

Based on our review of Site-related documents, observations, and independent calculations, we believe that additional groundwater information or monitoring at the Durita Site is necessary and appropriate to determine whether there is an unacceptable risk to human health from Site conditions. This conclusion is based on a paucity of groundwater quality data from the interior of the Site close to potential source areas; detection of soil contamination below engineered systems designed to prevent the release of contamination (during the operational period); indications suggesting the potential presence of preferential pathways for more rapid contaminant migration via groundwater; and the inadequate design of the perimeter groundwater monitoring network.

We found that the implicit conclusion made by CDPHE about the absence of groundwater contamination is unsupported by the available data. This conclusion relied on (i) a presumption of low bulk bedrock permeability that cannot be supported by Site documentation or field observations and (ii) information from groundwater monitoring wells that were located too far apart to intercept potential plumes reliably and monitored for too short a period of time, given

the range in travel times from source to boundary. The CDPHE analysis of potential contaminant travel times (22,000 years) is also unsupported by the available data. Key parameters in travel time calculations were excluded from the CDPHE analysis and others used likely are not representative of Site conditions. Independent calculations of travel time suggest more realistic values could be as low as several decades, particularly for any contamination in the vicinity of the former evaporation pond that would not have been detected by the current or former monitoring wells.

We recommend that groundwater quality throughout the interior of the Site be investigated. The principal uncertainty at the Site is whether former Site features and activities caused groundwater contamination that has remained undetected. Absent a Site interior investigation, or if contamination were to be detected, a new monitoring network at the boundary, and perhaps an inner detection monitoring network and program, would be warranted. Alternatively, a hydrogeologic investigation focused on providing support for the assumption of no preferential contaminant pathways in the subsurface would address our concerns. Note that *proving* the absence of subsurface features like preferential pathways is very difficult given the relative scales of the site, the features of interest, investigative technologies, and flow times. Either investigation would require more rigorous design than those used in the past, with more closely spaced monitoring points and consideration of source locations. If travel times are calculated, further refinement of Site-specific characteristics is necessary, particularly with respect to the role and magnitude of fracture-controlled flow. Finally, mass- and concentration-based calculations should be used to support decisions rather than solely relying on travel time calculations. Besides evaluation of the regulatory defined uppermost aquifer in the Mancos Formation, the groundwater pathway in the sediments along the top of the bedrock surface should be evaluated because of potential seepage directly to Dry Creek. If an investigation was to provide reasonable assurance that contamination is not present or that preferential pathways are not likely, there would be no compelling need for future groundwater monitoring. The known residual source material at the Site, excluding any undetected groundwater contamination, appears to have relatively low activity and is isolated from the environment adequately with engineering controls.[1]

In conducting a technical evaluation of the Durita Site, we have not made any conclusions as to the regulatory compliance of the Site; we evaluated the soundness of technical bases for

[1] An authoritative opinion on this issue is not offered and was outside the scope of our review.

cessation of groundwater monitoring and the possibility that Site conditions present a potentially unacceptable risk to human health or the environment.

Assessment of Hydrogeologic Conditions
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1. Purpose and scope of assessment

This report summarizes an assessment of hydrogeologic conditions at the Durita former uranium ore processing mill (Site) in Naturita, Colorado to determine whether long-term groundwater quality monitoring is necessary at the Site. The Site is regulated by the Colorado Department of Public Health and the Environment (CDPHE) and awaits transfer to the U.S. Department of Energy (USDOE) for long-term management in accordance with Title II of the Uranium Mill Tailings and Radiation Control Act of 1978 (UMTRCA). This assessment comprised a review of available documentary material provided and maintained by CDPHE and a site reconnaissance visit conducted by U.S. Nuclear Regulatory Commission (NRC) staff on July 12, 2006. Photographs of the Site and vicinity taken during this reconnaissance visit are presented in Appendix A with a detailed log.

2. Site operations

The former Durita uranium mill is a 160-acre site located approximately 2.5 miles southwest of Naturita Colorado. The area immediately north of the Site is undeveloped and owned by the U.S. Bureau of Land Management (BLM), beyond which is a private parcel referred to as the Coke Oven Ranch (Figure 1). Land immediately west, east, and south of the Site is undeveloped. The Site is owned by the Hecla Mining Company (Hecla), which acquired the Site from the Rancher's Exploration and Development Co. (Rancher's), who operated the mill from approximately 1977 to 1979. Rancher's used a heap leach process to extract uranium from previously processed ore that had been transferred from the nearby Naturita Mill, also in Naturita, Colorado. Figures 1 and 2 are topographic maps at various scales showing former prominent site features; Figure 3 is a contemporary aerial photograph of the Site.

The Site is dominated by Mancos Hill, a nearly circular, natural feature located near the center of the Site. During the Site's 18-month operation phase, ore was brought from the Naturita mill for re-processing. The first step in this process was amendment of ore with sulfuric acid in the area immediately south of Mancos Hill, as shown on Figure 2. The agglomerated, amended ore was transferred to one of three Leach Tanks in the southern portion of the Site, for leaching with

dilute sulfuric acid. The sulfuric acid solubilized labile uranium and other metals and the pregnant solution was captured in an underdrain system in the leach tanks, which reportedly were lined. The pregnant solution was conveyed to the mill area in the western portion of the Site (Figure 2) through a system of subgrade pipes. After a series of chemical processing steps, the solution was stored temporarily in four, synthetic-lined raffinate ponds for re-use. Once the leach solution was chemically exhausted, it was transferred to a series of six clay-lined evaporation ponds in the northern portion of the Site (Figure 2).

3. Reclamation

After Rancher's ceased operating the mill in 1979, the Leach Tanks were capped with a 2- to 2.5-foot soil cover to prevent infiltration of precipitation and direct contact with the ore tailings. Other features remained, through the transition to Hecla in 1984, until further reclamation began in 1992. According to anecdotal information from CDPHE, the raffinate and evaporation ponds remained uncovered and went through cycles of wetting from precipitation and evaporative drying. In 1992 and 1993, the buildings and above-grade structures were demolished and most removed from the Site; concrete was reportedly buried. The radionuclide- and metal-contaminated materials in and below the evaporation and raffinate ponds were excavated and consolidated, along with radionuclide- and metal-contaminated soil removed from throughout the Site, into a Closure Cell located immediately north of Mancos Hill in the south-central portion of the former evaporation pond complex. The Closure Cell was constructed on the liner(s) of the former evaporation pond. Additional reclamation activities between 1993 and the present include re-grading, creation of diversion and improvement of drainage channels, and re-vegetation.

4. Site Characteristics

4.1. Geology

The geologic characteristics of the site and region are described in detail by Fox (1982). Hydrogeologically relevant details are reprised in this assessment. The Site is located in the Colorado Plateau physiographic province, southwestern Colorado, at the southeastern margin of the Paradox Basin. The Paradox Basin formed more than 300 million years ago as a result of movement along adjacent faults. The Basin gradually filled with marine evaporate deposits, clastic sediments shed from eroding highlands on its margins, and a variety of sedimentary materials of marine and freshwater origin. Portions of these materials were deposited subaerially during sea-level lowstands and include eolian (wind-deposited) silts and sand,

bentonite clays (chemically altered volcanic ash), and minor amounts of coal. The Site is located on the southeastern side of the Paradox basin; basin-fill materials generally thicken toward the Basin center north and northeast of the Site. Principal geologic units below the site are tabulated below, presented in order from ground surface downward, and discussed in greater detail:

Table 1 – Relevant Geologic units at the Durita Site

Geologic Unit	**Thickness**	**Description**[2]
Quaternary alluvium	0 to 15 feet	Heterogeneous mixture of clay, silt, sand, and gravel, unconsolidated, deposited by colluvial, alluvial, and eolian processes. Surficial unit north of Site.
Mancos Shale	0 to 180 feet	Lithologically diverse mixture of alternating, interbedded fissile marine shale, claystone (also described as mudstone and siltstone), limestone, and sandstone of marine origin. Forms gradational intertongued contact with underlying Dakota Sandstone.
Dakota Sandstone	185 to 205 feet	Variable assemblage of fluviatile sandstone, occasionally conglomeritic, interbedded with non-marine carbonaceous shale and coal beds, with a coarse basal conglomerate.
Burro Canyon Fm	150 to 160 feet	Fluvial sandstone and conglomerate interbedded with lacustrine siltstone, shale, and mudstone.

The NRC site reconnaissance provided an opportunity to assess the physical characteristics of the relevant geologic units at a scale not readily discernable from the published reports. A more detailed geologic description of the Alluvium, Mancos Shale, and Dakota Sandstone units is presented below, with a more quantitative treatment of their hydrogeologic characteristics presented in Section 4.2.

Quaternary Alluvium: Within the site boundaries, the alluvium was observed, but was not laterally continuous over the site. Where present, the alluvium appeared consistent with the geologic materials described in Fox (1982) and other site-related documents. Given its unconsolidated and non-indurated nature, the alluvium will permit infiltration and transmission of groundwater. Where in contact with less permeable materials below, the alluvium might allow formation of perched groundwater and preferential flow paths along a paleotopographic surface.

Mancos Shale: The Mancos Shale is present at the ground surface over portions of the Site, particularly in the vicinity of Mancos Hill and in the former process areas, where Site development, reclamation activities, and natural erosion might have removed overburden material. Where exposed and for some depth below grade, the Mancos Shale is heavily weathered into small friable shale particles, frequently intercalated with more resistant claystone layers, shown in the site photographs in Appendix A. Original texture is preserved at depth. The shale components of this unit are fissile and exhibit horizontal to subhorizontal bedding planes, frequently cut by near-vertical joints and fractures. Joints, fractures, and bedding planes occasionally contain evaporative salts, veins and lenses of calcite exhibiting millimeter- to centimeter-scale crystals, and iron staining; the calcite and iron staining might be evidence of water infiltration. The decimeter-scale claystone layers appear without visible bedding planes and form laterally extensive ridges, shown on the side of Mancos Hill (Appendix A). While likely to be less permeable than the shale components, the claystone layers are cut by fractures and joints that will permit vertical water flow. Volumetrically, the claystone components appear to be less significant than the shale components. The final lithologic constituent of the Mancos Shale is inter-layered sandstones. These sandstone layers are more commonly encountered down-section and are exposed in stream channels north of the site. Given their occurrence near the base of the Mancos Shale, the sandstones interbed and form a gradational contact with the underlying sandstones and shale of the Dakota Sandstone. Where exposed in outcrops in the bed of Dry Creek north of the site and down-section, the sandstone layers are heavily bioturbated, poorly- to well-indurated, and friable in the less well-indurated components. The apparently fault-controlled bed of Dry Creek appears, in portions at least, to form a laterally extensive sandstone layer that might be formally assigned to either the Mancos or Dakota units. A prominent sandstone layer forms the caprock for a small cataract for Dry Creek (Figure 4; Appendix A photos). As with the other constituents of the Mancos Shale, the sandstone is cut with near-vertical fractures of meter-scale length and longer, some with millimeter-scale aperture (see photographs in Appendix A). Bedding planes, partings, fractures, joints, and occasional faults within all lithologic subunits of the Mancos Shale provide conduits for infiltration and groundwater flow; the juxtaposition of more and less-permeable components might also allow formation of perched groundwater. Depending on

[2] Material summarized from Fox (1982) and other sources.

the amount of infiltrating water and the lateral extent of the perched bodies, a stratified flow system could develop in the Mancos Shale.

Dakota Sandstone: The Dakota Sandstone is the oldest and stratigraphically lowest unit exposed in the vicinity of the Site. As the unit name implies, the predominant lithologic component of the Dakota is sandstone, but thick sequences of shale and conglomerate occur within the upper part of the Dakota. Thinner layers of bentonite and clay also occur in the upper portions of the Dakota. The upper portions of the Dakota are conformable with and create a gradational contact with the overlying Mancos Shale unit. The Dakota-Mancos contact is exposed in the vicinity of the small cataract north of the site and at the road cut, as shown in photos (Appendix A).

The structural evolution of the Paradox Basin may shed light on the characteristics of the Mancos Formation at the Durita Site. The fracturing and faulting noted in the description of the Mancos (see above) is consistent with the structure evolution. Paradox Basin was the location of a salt dome that forced its way upward, then collapsed as the salt was dissolved and migrated away. It is reasonable to expect that the uplift and collapse would lead to a (possibly) fractured and synclinal structure found at the Durita Site.

Regarding its geomorphic evolution, the lower Mancos is present at Durita as a remnant; the upper majority of the Mancos Formation has been eroded away. The remnant is present as a doubly plunging syncline. The Dakota Formation, which is stratigraphically lower, is the mapped unit surrounding the Mancos outcrops. The major axis of the syncline trends west-northwest and crosses the northern part of the Durita site. Based on borehole cuttings, the thickness of the Mancos from the saturated sand layers to the ground surface at Durita approximately varies from 40 to 70 ft thick. This thickness would be a lower bound estimate of the Mancos Formation at Durita because the boreholes were completed only to the saturated sand horizons.

4.2. Hydrology and Hydrogeology

The Durita site is located in a semi-arid climate at an elevation of approximately 5500 ft above sea level. Ground surface slopes are gentle at the site except for the slopes of Mancos Hill, which lies in the middle of the site. Operations surrounded Mancos Hill but did not occur on the hill. The watersheds encompassing the Site extend upslope to the south where ground slopes are moderately steeper. Part of the reclamation activity included excavating drainage channels

through the site that would reduce the effect of runoff impacting the leach pits and evaporation pond impoundments. Downslope of the site, Dry Creek would intercept intermittent surface water flow from the site and is ephemeral, though ponded water was observed locally in the streambed.

The groundwater system consists of: (i) an unsaturated zone on the order of 10 to 60 ft thick, (ii) potentially a saturated zone within the colluvium and alluvium overburden above the bedrock, (iii) a local upper aquifer within the Mancos Formation and the transition zone to the Dakota Formation, which is the regulatory defined uppermost aquifer, and (iv) a lower aquifer in the Dakota Formation or upper Morrison Formation, which is tapped by the water well at the Coke Oven Ranch. The CDPHE has designated the upper aquifer for monitoring purposes to be the small aquifer lying within the basal portion of Mancos Formation and the transition zone to the Dakota Formation.

The presence of the Mancos Shale underlying the Durita site was likely an attractive feature for siting the leach pits, evaporation ponds, and general operations. In general, the Mancos Shale has low bulk permeability, particularly when undeformed and the thick sequence has not been eroded. The Mancos Shale is a regionally pervasive layer of marine shales, claystones, and lesser sandstones. Where the Mancos Shale is thick and undeformed, it is a prominent aquitard that commonly separates productive aquifers. The Mancos Shale is also a source for hydrocarbons, which are released and migrate to gas reservoir traps. Fracturing of the Mancos Shale provides a more efficient release of the hydrocarbons and is a feature gas companies search for in their exploration. A key question in this review revolves around the nature and character of the Mancos Shale at the Durita Site, described in Section 4.1, and its ability to transmit (or resist the flow of) water.

In the subsections below, details of the hydrology and three potential pathways for migration of water from the Durita site to the boundary (the property fence, not Coke Oven Ranch) are described. After precipitation, the three pathways are:

- Surface water flow
- Vertical flow to bedrock/colluvium contact, then lateral flow to Dry Creek
- Vertical flow into the interbedded lower Mancos Formation shales to designated uppermost aquifer, then flow off-Site to the north

First, the general climate and the local precipitation from a nearby meteorological station are briefly described.

4.2.1. Precipitation

The Durita Site lies to the east of the Great Basin and on the western edge of the west slope of the Rocky Mountains. The semiarid climate of Durita is similar to that of the Great Basin, which is dominated by Pacific air masses passing over the intermontane region between the Sierra Nevada and Rocky Mountains. Being on the western edge of the west slope, the orographic effect of the Rocky Mountains to the east does not play an prominent role in climate of Durita.

The closest government-based meteorological station is at Uravan, Colorado, which is approximately 10 miles northeast of Durita. Because Uravan is approximately at the same elevation and is in a similar type terrain, it is considered a good analog site for larger-scale temporal precipitation patterns. Figure 5 and 6 contain data for the Uravan station downloaded from Western Region Climate Center of NOAA (www.wrcc.dri.edu). The Uravan meteorological station is part of the NOAA/NWS Cooperative Observer Network Inventory. The elevation of the Uravan station is 5010 ft above mean sea level, whereas Durita is between 5550 and 5600 ft above mean sea level.

An average precipitation of 13 in/yr occurred at Uravan for the period of reclamation and groundwater monitoring activities at Durita, 1991 through 1999. Spatially isolated storms, especially in the summer months, are normal, thus there may be some differences in precipitation between the two sites. Grand Junction, the nearest large city, had an average precipitation of 10 in/yr for the same period. Without additional stations, spatial variations are difficult to delineate. We also know that precipitation in the Great Basin and West Slope is a function of elevation, thus the increased precipitation is consistent with Uravan’s higher elevation compared to Grand Junction.

Monthly values (Figure 5) suggest that precipitation occurs throughout the year, though June is moderately drier and late summer into early winter is moderately wetter than the other months. The presence of fall and winter precipitation is generally important in semiarid climates because evapotranspiration rates are reduced during these seasons, thus leading to the most prominent period for recharge. In the groundwater section, we will describe our search for indications of a seasonal signal in recharge as recorded in water levels in monitoring wells.

Annual and quarterly values of precipitation at Uravan, our analog for Durita weather, are plotted in Figure 6. A prominent feature illustrated by the annual values, though difficult to distinguish in the quarterly data, is the trend of increasing precipitation for the later part of the period (1995 through 1998). In the groundwater section, we will also describe our search for indications of an increasing trend for recharge as recorded in water levels in monitoring wells for the 1995 through 1998.

4.2.2. Surface Water

There is a surface elevation drop of approximately 100 ft across the site, leading to an approximate surface gradient of 0.04. The dissected landscape upslope from the Site transitions to the alluvial/colluvial plain approaching Dry Creek, which is downslope of the Durita Site. Runoff from upslope locations, subsurface lateral flow, and precipitation directly onsite all could possibly contribute to water infiltrating groundwater below the Site. Water infiltrates onsite into the overburden sediments (alluvium and colluvium) and might possibly percolate further down to the sand layers in the lower portion of the Mancos Shale Formation.

The potential for runoff from dissected upslope locations to affect the onsite impoundments led to reclamation activities (Section 3) that included creation of a large diversion channel through the center of the site and a diversion channel that routes water from the steep slopes of Mancos Hill away from the evaporation pond impoundment. Improvements were also made on a minor diversion channel in the southeastern corner of the Site. Primary remediation of the Durita Site during 1992 and 1993 included re-grading of surface rocks and sediments, and creation and subsequent improvement of diversion channels crossing the center of the site. Later minor modifications and improvements occurred after periodic inspections. The purpose of the landscaping was to route water through channels traversing the center of the site, thereby avoiding runoff affecting the leach pits and evaporation pond impoundment. Runoff from upslope of the Durita operations will still cross the Site and flow through the sculpted and riprap-supported channels. The adequacy of the diversion channels for keeping runoff away from the leach pits and evaporation pond impoundments was not assessed as part of this review.

Intermittent water in the diversion channels will contribute to infiltrating water that could feed the alluvial/colluvial water system or percolate further, through the Mancos to the screened

intervals. Direct precipitation onsite and some amount of local runoff also potentially might contribute to flow in the subsurface at the Durita Site.

Dry Creek is a prominent surface water feature north of the Durita Site. Water flowing at the ground surface or laterally near the ground surface in the subsurface at the colluvium/alluvium contact with the bedrock will flow directly into Dry Creek.

4.2.3. Ground Water at Colluvium/Alluvium and Bedrock Contact

A pathway not considered in the travel time calculations is infiltrating water on the site that might readily flow along the bedrock surface through the colluvium or alluvial sediments. The sediments are highly transmissive compared to the matrix of the Mancos Shale, though fracturing of the Mancos would lead to predominantly vertical percolation rather than lateral flow along the bedrock contact. Episodic precipitation combined with the high permeability of the alluvium/colluvium would lead to highly variable flow rates at the bedrock surface. Water flowing laterally downslope in the colluvium/alluvium along the bedrock contact surface would seep into Dry Creek.

Fox (1982) stated “several holes drilled northwest of Dry Creek encountered this shallow ground water; none of the test holes drilled for this project, or by previous investigators (Dames and Moore 1980), encountered saturated alluvium.” As described in Dames and Moore (1980), a single hole west of the Durita site, but near Dry Creek, was included on maps. However, no discussion on saturation state of the hole was found in Dame and Moore (1980).

In our judgment, lateral flow at the alluvium/colluvium contact with the Mancos Shale bedrock could be occurring. Besides being highly episodic, this flow also would be highly variable spatially. The bedrock topology may reflect paleotopography. Exposures at Dry Creek north of the Durita site provide an indication that the paleotopography did include channels. A highly altered sand layer was exposed in the bank of Dry Creek, with the alteration possibly indicating significant flow, either from water flowing along the bedrock surface or seeping out of the sand layers in the lower portion of the Mancos. Also, the south and north sides of Dry Creek are in different geomorphic positions. The south side (near Durita) extends down from a hillside and incision into the bedrock and channeling would be expected for the paleotopography. On the north side of Dry Creek, where the topography is flatter, the smaller slope would lead to a more

stable saturated thickness in the alluvium. Thus, it is a reasonable scenario that water would flow along the bedrock surface and seep into Dry Creek.

We conclude that a saturated thickness of water, probably localized in paleochannels on the bedrock surface leading down to Dry Creek, could exist. Logic supports this conclusion and there does not seem to be evidence to discount it. One reason a saturation thickness of water might not exist in the alluvium/colluvium is if the bedrock is highly fractured, thus allowing for percolation into the Mancos shale units and to the regulatory defined upper aquifer.

4.2.4. Ground Water in Uppermost Aquifer

The CDPHE designated the saturated water in the lower part of the Mancos Formation as the uppermost aquifer for regulatory purposes. The uppermost aquifer comprises sand layers alternating with shale and claystone in the lowermost portion of Mancos Formation at Durita, based on cuttings from boreholes. Above the saturated sand horizons, shale and claystone dominate. The boreholes were drilled with a rotary drill and the cuttings were logged to give a general idea of the type of stratigraphic layers present below the site. The presence, of lack thereof, of fractured bedrock cannot be ascertained from cuttings. Near surface bedrock was fractured, as NRC staff observed (see Section 4.1). Thus, there is uncertainty in the character, specifically the hydrologic properties, of the Mancos Formation below the Site.

The gradient of the water table is northward towards Dry Creek, but is ill-constrained because it is only defined by seven wells installed along the property boundaries. The seven boreholes outlining the permit area (Figure 7) were drilled into the uppermost aquifer, cased, and screened for monitoring purposes. The monitoring wells are labeled MW-8 through MW-14. The screened intervals intersect the sand layers in the lower portion of the Mancos Formation. Wells MW-1 through 7, mentioned in Fox (1982), were completed during leaching operations in the late 1970s. These wells, however, were improperly completed; thus no data were reported in the available documents.

Of the seven wells monitoring wells constructed in the early 1990s, three are designated as downgradient monitoring wells (MW-10, -11, and -12), two are cross-gradient wells (MW-9, -13), and proximal to sources, and two are upgradient background monitoring wells along the southern Site boundary (MW-8, -14).

4.2.4.1. Water Levels

Water levels were monitored from 1991 to 1998 approximately quarterly during at first, but annually for the final years. There are a number of observations that help to shed light on the validity of several scenarios that could describe the subsurface hydrology; specifically, whether a hydraulic connection exists between the ground surface and the sand layers composing the uppermost aquifer.

Most of the wells suggest the uppermost aquifer might be under confined conditions (Table 2) if the Mancos shales are assumed to be relatively impermeable. One well is close to being under unconfined conditions (MW-12). Because the wells were screened over the apparently transmissive horizons; however, the wells might not be under confined conditions and the water levels could be higher in the possibly fractured shale and claystone horizons, indicative of saturated conditions at higher stratigraphic positions. Water levels vary by about 100 ft elevation across the site, which is approximately the same as the change in ground surface elevation.

Table 2. Estimated Unsaturated Zone Thickness, Mancos Thickness, and Extent Confinement for Each Monitoring Well

Monitoring Well	Minimum Mancos Thickness[a] (ft)	Extent of Confinement[b] (ft)
MW-8	51	22.0
MW-9	42	18.4
MW-10	60	35.6
MW-11	70	29.3
MW-12	70	1.5
MW-13	62	54.8
MW-14	70	26.6

[a]Lower bound estimate because boreholes completed within Mancos Formation; calculated assuming 15 ft overburden except for MW-8, which is in diversion channel
[b]Calculated using maximum water level elevation

Temporal and spatial variations are reflected in the water level data, including a response to reclamation activities. Variations in water levels over time illustrate several important features described below.

Water levels during the reclamation period, 1992 and 1993, are highly erratic. A prominent downward spike occured in six of the eight wells late in 1992 (Figures 8 and 9).
The implication is that ground surface activities at the site impacted the water levels. One hypothesis, if preferential flow pathways are presumed to exist, is that re-grading or diversion channel development may have temporarily clogged the flow pathways. Other explanations may be just as reasonably postulated; regardless, it is clear that ground water levels were affected by surface reclamation activities.

Temporal variations caused by climate stresses are evident when precipitation patterns are overlaid on the water level data (Figure 10 and 11). Two prominent observation are evident. First, a seasonal precipitation pattern is tracked by the water levels, particularly the downgradient (MW-10, MW-11, MW-12) and cross-gradient wells (MW-9 and MW-13). There is a significant dampening of the precipitation signal, and a slight delay in the propagation of the signal. The second prominent observation is that all the wells show an increase in water levels corresponding to the wetter years of 1996 and 1997. The aquifer response to the increased precipitation varies across the site from +1 to +5.5 ft from Nov 1996 to Jan 1998. Note that this period only has three measurements, so seasonal signals are lost. The spatial variation in the seasonal pattern supports a local source for the recharge, rather than an upslope recharge where the sand units intersect the ground surface (related to the synclinal structure). For example, MW-9 and MW-10 are closely spaced with MW-9 upgradient from MW-10. These two wells show the largest and smallest increases over the 1996 to 1998 period; MW-9 increased by 1.0 ft and MW-10 increased by 5.5 ft.

Two points on the reliability of the data warrant discussion. The first point concerns the two reports contained data from 1991 to 1993 (Hecla 1998; Studious Solutions 1994). The first point is that the two data sources were not consistent; the differences are illustrated in Figures 8 and 9. Monitoring wells MW-9, MW-10, and MW-11 have noteworthy inconsistencies in early data. The second point is that the earlier report contained references to ground surface and borehole collar data elevation errors that required a new survey. MW-8 and MW-9 were resurveyed and found to have ground and casing heights off by as much as 3 feet. It was not clear from documentation if the data were revised to reflect the new survey information.

4.2.4.2. Possible Scenarios

There is uncertainty in describing the flow system associated with the uppermost aquifer because of a lack of subsurface information. Two plausible scenarios are discussed below.

The most reasonable scenario to explain the spatial and temporal variations water levels is for there to be preferential flow paths through the apparently fractured shales and claystones to the uppermost aquifer. This scenario is supported by the observation that the upgradient wells appear to respond differently to precipitation compared to the cross-gradient and downgradient wells. The sporadic presence of preferential flow pathways through the shales and claystones is consistent both with the spatial variation of temporal responses in water levels to changes in precipitation and with the indications of faulting and fracturing noted in Section 4.1.

Another possible scenario to explain the variations in water levels is for there to be upslope recharge to the sand horizons, and lateral flow towards the monitoring wells at the Durita site. However, it is more difficult to explain the spatial patterns of water levels as a result of recharge from north of the Site. Also, it would be difficult to explain how surface reclamation activities affected water levels if there were no direct hydraulic connection.

4.2.5. Dakota Formation Aquifer

The water supply well at the Coke Oven Ranch pumps water from the aquifer in the Dakota Sandstone from depths of 180 to 250 ft. No information is available to determine the extent of hydraulic connection between the uppermost aquifer at the Durita site and the Dakota aquifer tapped by the Coke Oven Ranch. Whereas a downward flow direction across stratigraphic horizons would be unlikely, it should be assumed the hydraulic connection exists and the migration of radionuclides modeled accordingly. It is acknowledged that dilution by mixing and dispersion will occur, and that concentrations of radionuclides also be reduced by sorption and affected by changes in chemical composition of the groundwater.

4.2.6. Geochemistry

The groundwater at the Site has relatively high concentrations of several dissolved anions, particularly sulfates (up to 5,400 mg/L historically and 3,300 mg/L in the 1998 sampling event) and carbonates, and total dissolved solids. The pH of the groundwater is mildly basic, ranging from 7.2 to 8.6 in the 1998 sampling event. Carbonate and bicarbonate values ranged from <2 to 40 mg/L and 369 to 1,530 mg/L, respectively.

Certain dissolved inorganic species indicate that the groundwater at the Site is under mildly oxidizing conditions, such as the sulfate concentrations. In shallow marine sediments, sulfides are present in the evaporative rocks deposited. In contact with less saline, oxygenated groundwater, the sulfides oxidize to sulfates. Over time, as the groundwater system evolves, the sulfates react with iron, organic matter, and carbon dioxide to form sulfides again and increase alkalinity. At the Durita site, both sulfate concentrations and alkalinity are present in relatively great concentrations. These generally oxidizing conditions implied by the presence anions affect the mobility of uranium in the subsurface environment. The pH and amount of calcium in the groundwater system also effect uranium mobility.

5. Groundwater monitoring

The State of Colorado defined shallow groundwater in the Mancos Formation as the uppermost aquifer to be protected and as the hydrostratigraphic unit of interest. Although this groundwater might not meet the conventional definition of an "aquifer," the groundwater monitoring program focused on this as the horizon to protect, and our comments and recommendations are predicated on this definition. The compliance boundary for the Site is the northern fence line as the northernmost controllable portion (i.e., the area in which exposure to groundwater can be restricted by the regulated party) of the land potentially affected by any contaminant releases to groundwater. Beyond the compliance boundary are BLM lands (currently undeveloped) and the Coke Oven Ranch.

Groundwater quality at the Site boundaries was monitored from 1977 (pre-development) to 1998 with a series of seven monitoring wells (Figure 7) screened in the shallow Mancos groundwater. Groundwater samples were analyzed for relevant radionuclides and selected wet chemistry parameters that might also indicated releases (e.g., pH excursions from released acids). These seven wells include three downgradient monitoring wells (MW-10, -11, and -12; although only MW-11 and -12 were designated as compliance wells), two cross-gradient wells (MW-9, -13) that could also intercept released contaminants depending on variations in flow direction and proximity to sources, and two upgradient monitoring wells along the southern Site boundary (MW-8, -14). No releases that adversely affected groundwater quality were evident from the available groundwater data.

The former plant operational features, particularly those in which liquids were handled, stored, transported, and disposed, are all potential sources for groundwater contamination. In particular, the raffinate and evaporation ponds are likely sources that might have leaked prior to their reclamation. Since the discrete point sources like the ponds and the diffuse sources like soil contamination have been reclaimed, future releases to groundwater are unlikely. Contaminated media are present on Site but isolated from the environment by appropriate barriers (liners and soil covers). However, the possibility of legacy groundwater contamination cannot be ruled out with the available data. Groundwater monitoring, which ceased in 1998, focused on the site perimeter. No groundwater quality data were available from the interior of the Site. Accordingly, releases from ponds could have occurred and remain undetected because any plumes, if present, might not have reached the perimeter monitoring network. Furthermore, the downgradient monitoring points (MW-11 and -12 by definition and including MW-10 and -13 by practical consideration) are very widely spaced, with a gap of approximately 1,400 feet between the two most critical monitoring wells (MW-11 and -12). Considering that the most prominent source, the evaporation pond footprint area, is within 50 feet of the perimeter and centered on the gap between wells MW-11 and -12, the likelihood of detection in the event of a release from this area is small.

The possibility of releases from the ponds (particularly the evaporation ponds) is supported by detection of contamination below the liner during reclamation. Confirmatory sampling below the engineered, low-permeability evaporation pond liner detected contamination by radionuclides. This contamination might have escaped through the liner as a consequence of mechanical damage to the liner from freeze-thaw cycles or desiccation after the effluent evaporated and precipitation re-wetted the solid residuum. No groundwater samples from below the liner were collected.

Receptors that could be adversely affected by potential releases include future users of the BLM land immediately north of the Site and the more distant Coke Oven Ranch. The Coke Oven Ranch reportedly operates one deep production well that is screened in the Dakota Sandstone. Although the Dakota Sandstone potentially is in hydraulic communication with the Mancos Shale, and therefore any potential plumes of contaminated groundwater, the lateral and vertical separation, hydraulic properties, and the resultant travel times of the screened interval (180 to 250 feet deep) from the shallow flow system suggest contamination of this well is unlikely. Of greater concern, however, are potential future users of the BLM land proximal to the compliance

boundary. We are aware of no institutional or land use controls that preclude BLM from releasing these lands for use or development, including groundwater extraction. Since compliance wells are located on the Site boundary, an off-site problem exists immediately upon detection in boundary wells.

6. Travel time calculations

The CDPHE calculated travel times for a released molecule of a contaminant to travel from its source to the Site boundary; note that these calculations are not mass- or concentration-based. In assessing and granting a 1998 Hecla request to terminate groundwater monitoring at the Site (CDPHE, 1998) and in its *Draft Completion Review Report* (CCR; CDPHE, 2005), the CDPHE assessed groundwater quality, geologic conditions, and contaminant travel times. The CDPHE calculated a travel time of 2.2 million years, then applied a safety factor of 100, reducing travel time to 22,000 years. We found that the CDPHE travel time estimates, used to justify their approval of cessation of groundwater monitoring, are unrealistic, non-conservative, and failed to include key hydrogeologic parameters and processes. Travel times were calculated using an algebraic expression based on the empirical Darcy's Law for groundwater flow. In this equation, time is calculated by dividing travel distance (**length**) by the velocity of the contaminant particle. This latter term is calculated by multiplying the **hydraulic gradient** (the slope of the water table) by the **hydraulic conductivity** (the ability of the geologic fluid to transmit a given fluid across a unit cross-sectional area) and dividing by the **effective porosity** (the fraction of the geologic medium formed by open, hydraulically connected pore spaces). The calculation of travel time can be made more realistic and representative by including a term for **retardation**, a multiplicative factor that accounts for a variety of physical and chemical processes that impede the transport of a solute dissolved in groundwater. Retardation is a common phenomenon for certain radionuclides, such as uranium, that sorb onto aquifer matrix materials, slowing their transport relative to the unretarded flow of groundwater and attenuating concentrations and mass. The CDPHE terms used in its travel time calculations that reflect unrealistically conservative characteristics are discussed in greater detail below.

- **Length**: The travel distance (2,400 feet) used by CDPHE represents a source (leach tanks) at furthest upgradient portion of site and, therefore, the longest potential travel distance. Sources were located within 50 feet or less of downgradient boundary (i.e., evaporation ponds), decreasing travel time by a factor of nearly 50.

- **Hydraulic conductivity:** The hydraulic conductivity value used by CDPHE (0.00007 ft/day) represents the least transmissive unit anticipated or value measured at the Site and likely represents only matrix conductivity. This assumption represents the hypothetical, slowest, most resistant flow path and is less than measured values (Fox, 1982) at the site by factors ranging from 10 to 10,000 (Table 3). In contrast:
  - Observed lithology and structural features indicate faster pathways are present – fractures and sand lenses (see photos in Appendix A).
  - Fox (1982) measured permeability (Table 3) values on discrete samples, representing matrix properties rather than more transmissive flow features such as fractures. Also, the temporary wells over short screened intervals used by Fox (1982) are unlikely to have intercepted the near-vertical fracture sets at the Site. In addition, Fox (1982) did not appear to develop the tested wells – a process in which preferentially-accumulated fine materials, which impede flow into the well screens as an artifact of drilling, are removed and well efficiency is improved and more representative of true hydraulic conditions, increasing the measured hydraulic conductivity.
  - Representative bulk conductivity values likely are between these extremes.
  - Actual flow likely is controlled by the smaller-scale features like fractures, making the controlling conductivity values likely closer to the faster end of the range.
- **Effective Porosity**: CDPHE neglected to include effective porosity in its calculations of travel time (or assumed an effective porosity of 1.0, by setting particle velocity equal to Darcy velocity). This parameters represents the actual flow path through which groundwater flows, following only connected pore spaces. Inclusion of this term increases the velocity at which groundwater, and therefore contaminants, travel and decreases travel time. Realistic estimates of effective porosity for this aquifer matrix likely range between 0.1 and 0.25 (Spitz and Moreno, 1996), increasing flow in the aquifer matrix by a factor of 4 to 10. The Naturita effective porosity values were estimated to be 0.2 (NRC, 2003).
- **Retardation**: CDPHE did not consider explicitly the process of retardation, by which solutes travel more slowly, relative to groundwater, because of interactions with geologic materials (e.g., sorption, ion exchange).   Adsorption to geologic media is a very significant process for attenuating dissolved uranium concentrations under certain geochemical conditions. When geochemical conditions are appropriate, travel times are slowed greatly; however, the pH, total carbonate values, and implied oxidizing

conditions in Site groundwater make retardation of more than one or two order of magnitude unlikely (USEPA, 1999; Fox, 2006). This phenomenon was studied extensively by the NRC and U.S. Geological Survey (USGS) at the nearby Naturita Uranium Mill Tailings Site, located in Naturita, Colorado, less than 3 miles from the Site (NRC, 2003; Curtis *et al.*, 2004; Curtis *et al.*, 2006; Davis *et al.*, 2006) and in a similar geologic environment[3]. Accordingly, retardation might slow uranium transport by up to a factor of 10 to 100, but likely not more than that.

Consequently, CDPHE's calculations represent unrealistically long travel times. Note also that by comparison, the conductivity values used by CDPHE are within an order of magnitude of those measured for the pond liners, which were engineered systems relatively unaffected by natural geologic-scale weathering (flow-enhancing processes). However, contamination escaped through the liner, as discussed in Section 5.0.

We calculated travel times using the same methodology but with more realistic and representative estimates of values for parameters, summarized in Table 4. These values include low, mid-point, and maximum values for **length** and **hydraulic conductivity** and a range of **retardation** values measured at the nearby Naturita site. The travel times calculated by NRC may still be too low, given the inability to estimate fracture hydraulic conductivity easily. The values used by CDPHE and mean measurements by Fox (1982) are included for comparison. The NRC travel time calculations represent a array of nine travel times (the product of the three hydraulic conductivity/effective porosity paired values and the three travel distances) for each tabulated retardation factor value. These travel times are tabulated in Table 5 and range from 1.1 years to nearly 200,000 years, depending on the combination of values used. This span of time values reflects the large variation in potential hydraulic conductivities at the Site. As shown in Table 5, for the minimum length (i.e., from the former evaporation ponds to the compliance boundary), travel times are less then about 1,000 years under conditions of average or greater expected hydraulic conductivity values effective porosity, irrespective of effective porosity and retardation. The more rapid travel times are supported by rapid hydrologic response to external events – for example, in the Site-wide synoptic response and correlation between precipitation and water level.

[3] Surface sediments at the Naturita site are predominantly unconsolidated flood plain deposits from the adjacent San Miguel River. However, the mineralogical composition of these sediments is anticipated to be sufficiently similar for

7. Conclusions and Recommendations

Based on our review of Site-related documents, Site observations, and independent calculations, we believe that groundwater monitoring at the Durita Site is necessary and appropriate to demonstrate reasonable assurance of the absence of potentially unacceptable risk to human health and the environment. This conclusion is based on a paucity of groundwater quality data from the interior of the Site close to potential source areas, detection of soil contamination below engineered systems designed to prevent the release of contamination, indicators for the potential presence of preferential pathways for more rapid contaminant migration through the subsurface, and the inadequate design of the perimeter groundwater monitoring network. Furthermore, the groundwater pathway in the sediments at the bedrock surface connected to surface water in Dry Creek should be evaluated.

We found that the implicit conclusion made by CDPHE about the absence of groundwater contamination is unsupported by the available data. This conclusion relied on (i) a presumption of low bulk bedrock permeability that cannot be supported by Site documentation or field observations and (ii) information from groundwater monitoring wells that were located too far apart to intercept potential plumes reliably and monitored for too short a period of time, given the range in travel times from source to boundary. The groundwater monitoring period, less than 20 years, is too short for contaminants to have traveled from their source to the wells, given the majority (94%) of travel times calculated. The CDPHE analysis of potential contaminant travel times (22,000 years) is also unsupported by the available data. Key parameters in travel time calculations were excluded from the CDPHE analysis and others used likely are not representative of Site conditions. Independent calculations of travel time suggest more realistic values might be as low as several decades, particularly for any contamination in the vicinity of the former evaporation pond, which would not have been detected by the monitoring wells, given their spacing.

We recommend that groundwater quality throughout the interior of the Site be investigated. The principal uncertainty at the Site is whether former Site features, such as the evaporation and raffinate ponds, caused groundwater contamination that has remained undetected. Alternatively, a hydrogeologic investigation focused on providing support for the assumption of no preferential pathways in the subsurface would address our concerns. If either of these investigations was to provide reasonable assurance that neither contamination or preferential

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comparison.

pathways are not present or likely, there is no compelling need for future groundwater monitoring at the Site boundary or an inner detection boundary. The residual contamination at the Site appears to have relatively low activity and is isolated from the environment adequately with engineering controls[4]. Absent a Site interior investigation, or if contamination were to be detected, a new compliance monitoring network at the boundary, and perhaps an inner detection monitoring network and program would be warranted. Either network would require more rigorous design than those used in the past, with more closely spaced monitoring wells and consideration of source locations. If travel times are calculated, further refinement of Site-specific characteristics is necessary, particularly with respect to the role and magnitude of fracture-controlled flow. Finally, mass- and concentration-based calculations should be used to support decisions rather than solely relying on travel time calculations; the former will require additional Site investigation and testing.

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[4] The adequacy of these engineering controls was outside the scope of our evaluation

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Table 3
Measured hydraulic conductivity values
Durita Site

Measured value (cm/sec)	Measured value (ft/day)	Ratio of measured value to CPHE value
3.27E-04	0.9269	13,242
6.95E-08	0.0002	3
4.80E-08	0.0001	2
8.21E-05	0.2327	3,325
1.44E-05	0.0408	583
1.57E-05	0.0445	636
6.03E-05	0.1709	2,442
1.15E-06	0.0033	47
6.53E-07	0.0019	26
4.02E-07	0.0011	16
8.18E-08	0.0002	3
9.11E-08	0.0003	4
1.22E-06	0.0035	49
1.30E-04	0.3685	5,264
3.65E-05	0.1035	1,478
3.30E-04	0.9354	13,363
3.42E-06	0.0097	138
1.53E-07	0.0004	6
3.88E-07	0.0011	16
2.18E-07	0.0006	9
2.74E-04	0.7767	11,096
3.53E-04	1.0006	14,295
4.09E-07	0.0012	17
7.06E-07	0.0020	29
3.30E-08	0.0001	1.34
Arithmetic mean	0.1851	2,644
Geometric mean	0.0080	115
CDPHE value	0.00007	

Notes:

1. Measured values taken from Tables 9 and 10 of Fox (1982)
2. CDPHE value from CDPHE (2005)

Table 4
Hydrogeologic values used by NRC
for travel time calculations
Durita Site

Parameter	**NRC** Min	**NRC** Average	**NRC** Maximum	**CDPHE** (2005)	**Fox** (1982)
Hydraulic conductivity (ft/day)	0.007	0.2	0.7	0.007	0.185
Effective porosity ( )	0.1	0.2	0.25	1.00	N.A.
Length (feet)	50	1,225	2,400	2,400	N.A.
Retardation ( )	1	46	91	1	N.A.
Hydraulic gradient ( )	0.0433	0.0433	0.0433	0.0433	N.A.

Notes:

1. CDPHE used hydraulic conductivty = 0.00007, multipled by a 'safety factor of 100 to account for uncertainties; this table subsumes the safety factor into the hydraulic conductivity value

2. CDPHE did not explicitly include effective porosity or retardation in its calculations; the values appearing in the table are the mathematical equivalent of their exclusion.

3. The Fox hydraulic conductivity value is the arithmeticmean of the measured values, converted to equivalent units.

Table 5

Range of potential travel times under various scenarios

Durita Site

RETARDATION		**TRAVEL TIMES (YEARS)**								
		Kmin			**Kave**			**Kmax**		
K_d (mL/g)	**R_f** ( )	**Length Min**	**Length Ave**	**Length Max**	**Length Min**	**Length Ave**	**Length Max**	**Length Min**	**Length Ave**	**Length Max**
0	1	**45**	1,107	2,168	**03**	**77**	**152**	**01**	**28**	**54**
0.1	1.9	**86**	2,102	4,119	**06**	**147**	**288**	**02**	**53**	**103**
0.5	5.5	**248**	6,086	11,923	**17**	**426**	**835**	**06**	**152**	**298**
1	10	**452**	11,065	21,679	**32**	**775**	1,518	**11**	**277**	**542**
2	19	**858**	21,024	41,190	**60**	1,472	2,883	**21**	**526**	**1,030**
2.5	23.5	**1,061**	26,003	50,945	**74**	1,820	3,566	**27**	**650**	1,274
3	28	1,265	30,983	60,701	**89**	2,169	4,249	**32**	**775**	1,518
4	37	1,671	40,941	80,212	**117**	2,866	5,615	**42**	**1,024**	2,005
5	46	2,078	50,900	99,722	**145**	3,563	6,981	**52**	1,272	2,493
6	55	2,484	60,859	119,233	**174**	4,260	8,346	**62**	1,521	2,981
7	64	2,891	70,817	138,744	**202**	4,957	9,712	**72**	1,770	3,469
8	73	3,297	80,776	158,255	**231**	5,654	11,078	**82**	2,019	3,956
10	91	4,110	100,693	197,277	**288**	7,049	13,809	**103**	2,517	4,932

Notes:

1. K(min, ave, max) refer to minimum, mid-point, and maximum values of hydraulic conductivity expected or measured at the Site
2. Length (min, ave, max) represents source to boundary distances from the southern, mid-point, and northern portions of the Site
3. K_ds are the range of possible and measured partitioning coe~~e~~fficients evalauted, calculated, or measured at the Naturita site
4. R_fs are the retardation factors, relative to unretarded groundwater flow calculated from the K_ds
5. Travel times highlighted ~~F9~~are those less than the threshold value of 1100 years

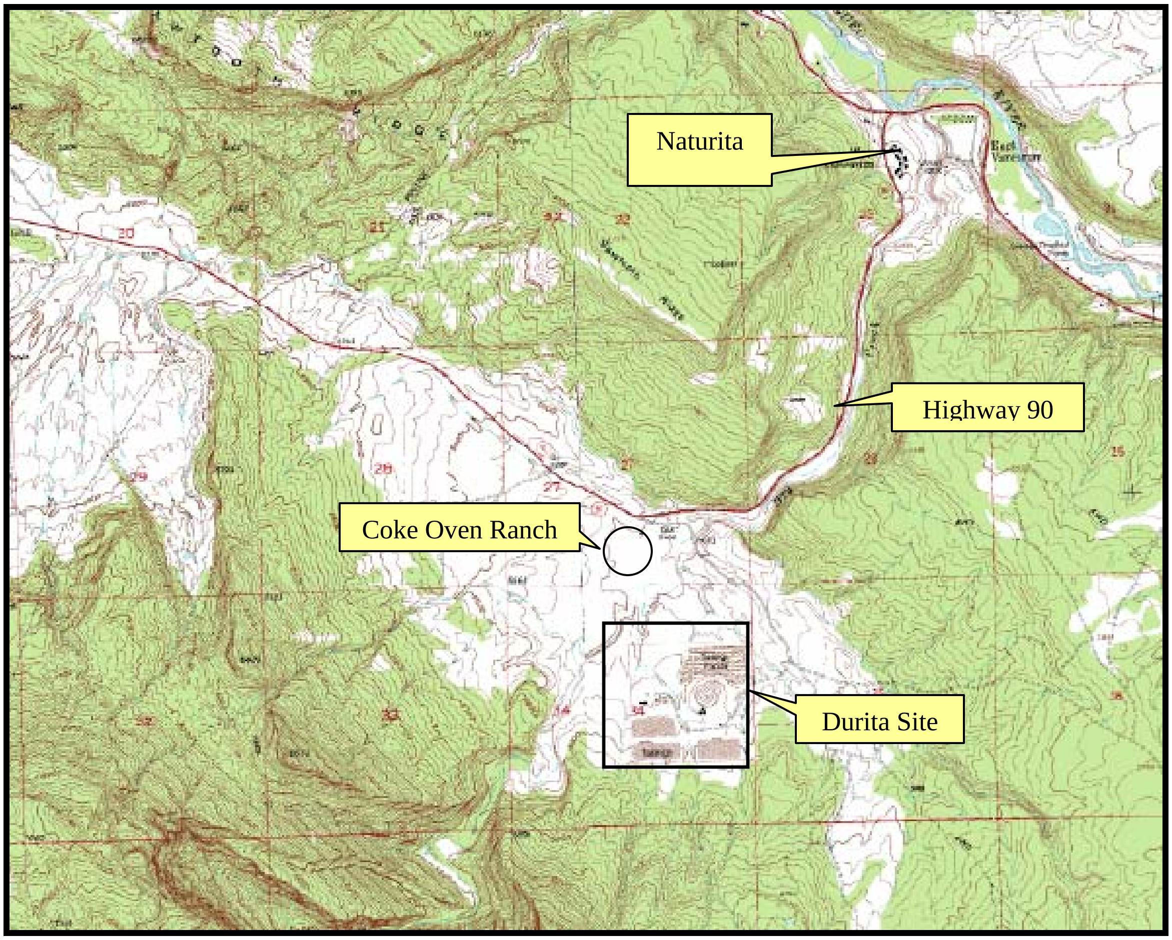


Figure 1. Annotated Topographic Map of Durita Site at 1:100,000 Scale. Modification of Downloaded File from Topozone™ on 07/17/2006.

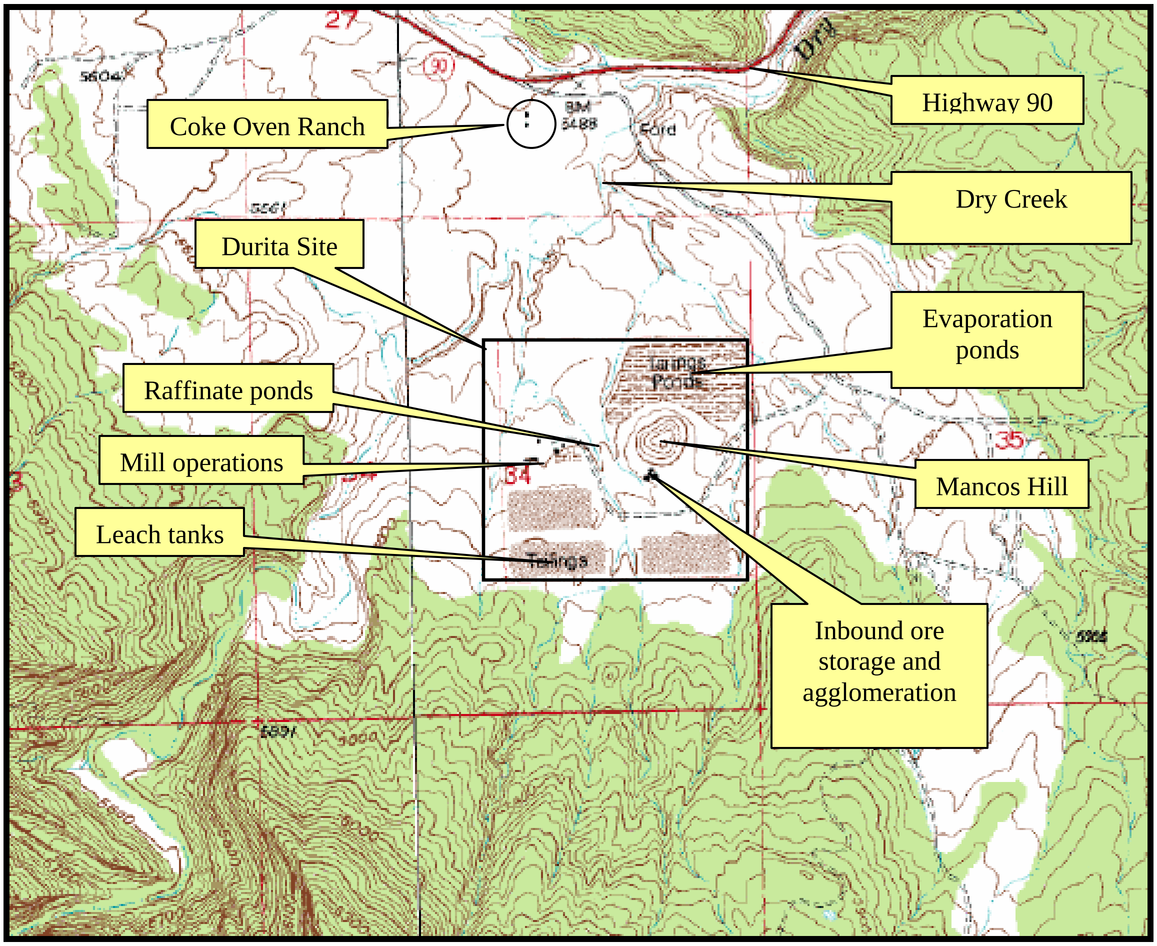


Figure 2 . Annotated Topographic Map of Durita Site at 1:50,000 Scale. Modification of Downloaded File Obtained from Topozone™ on 07/17/2006.

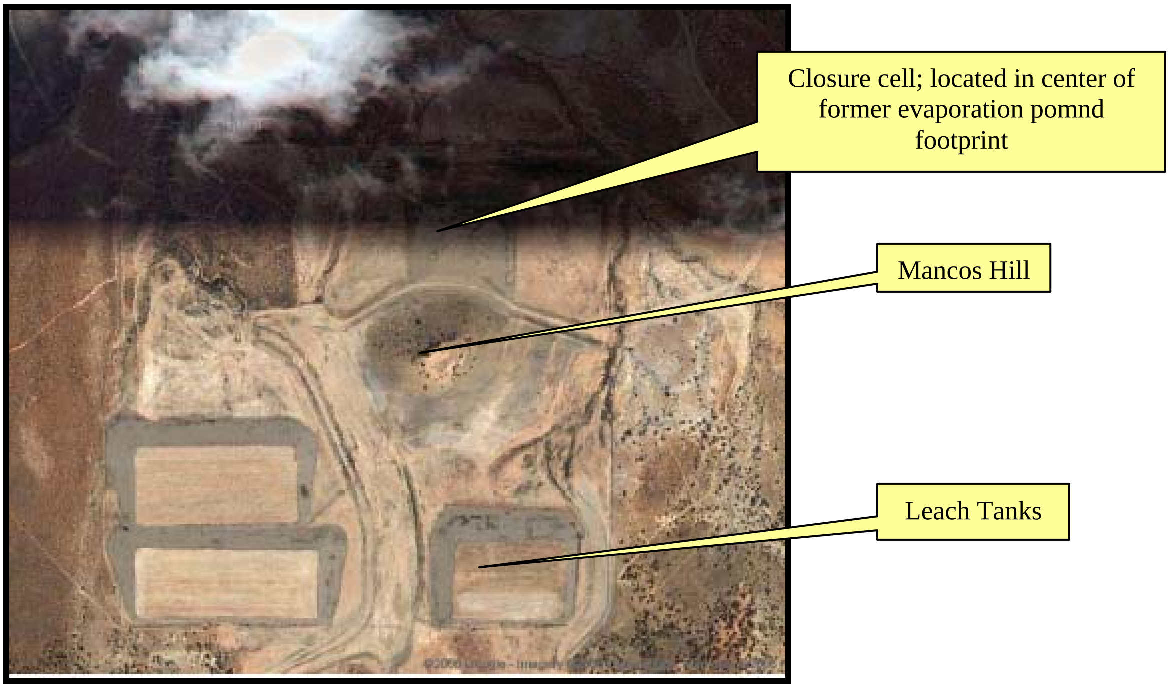


Figure 3. Annotated Aerial View of Durita Site. Northern-Most Portion of Site in Shadow. Downloaded Photograph from Google Earth™ on 07/17/2006

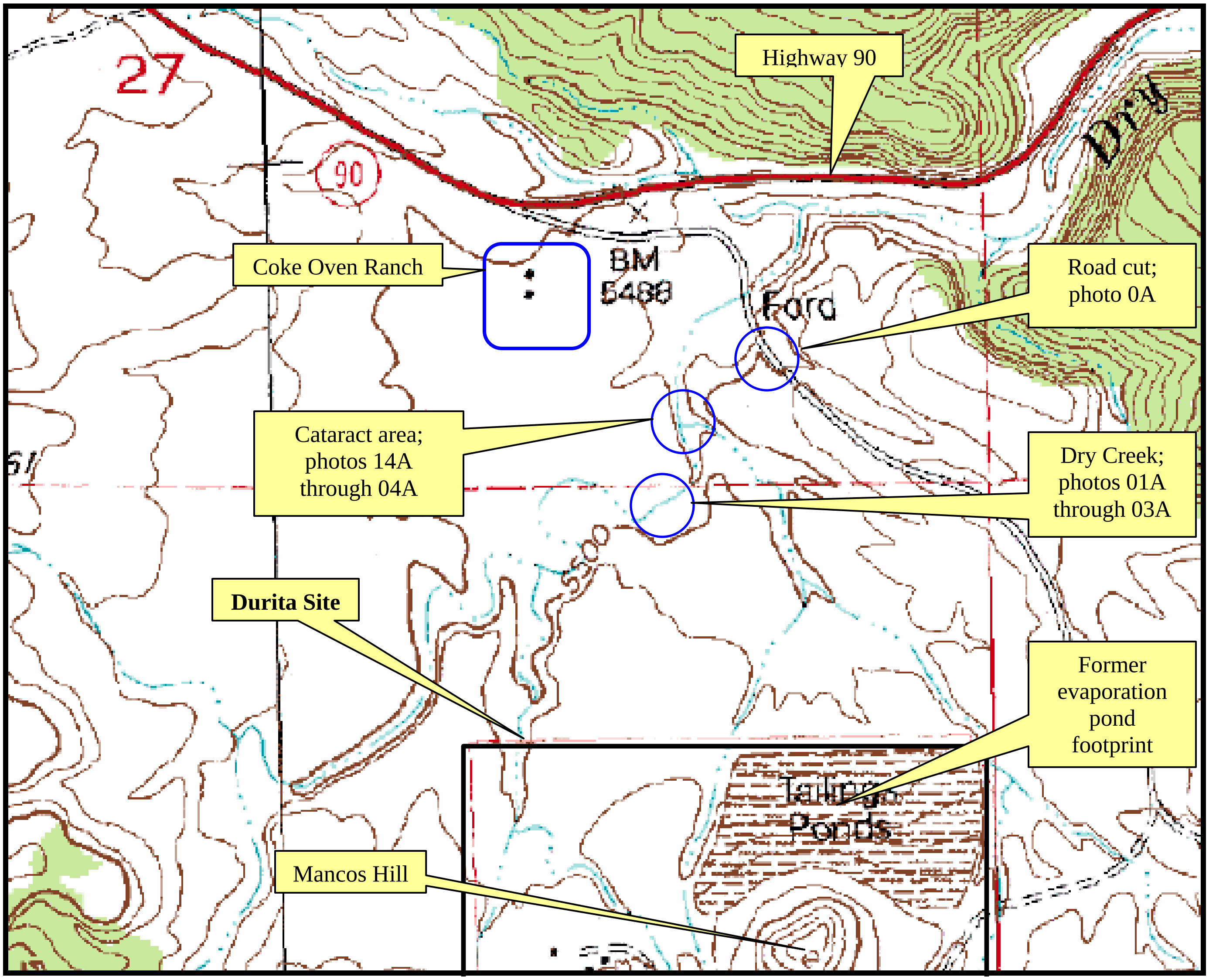


Figure 4. Annotated Topographic Map of Durita Site at c. 1:25,000 Scale. Modification of Downloaded File Obtained from Topozone™ on 07/17/2006.

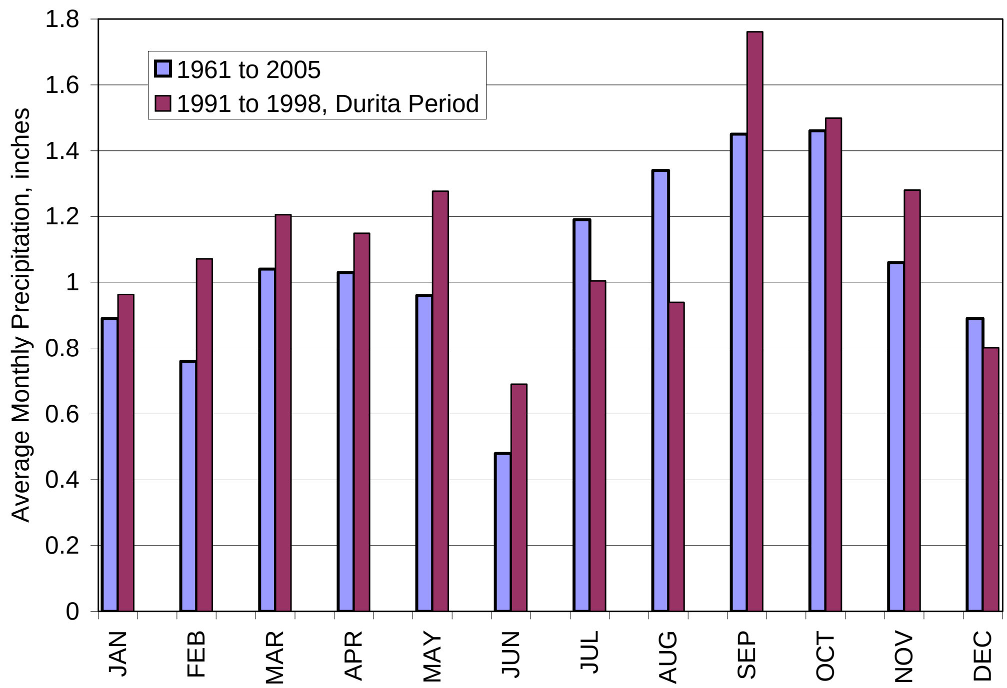


Figure 5. Average precipitation for entire period of record for Uravan and for period of water level monitoring at Durita (1991 to 1998)

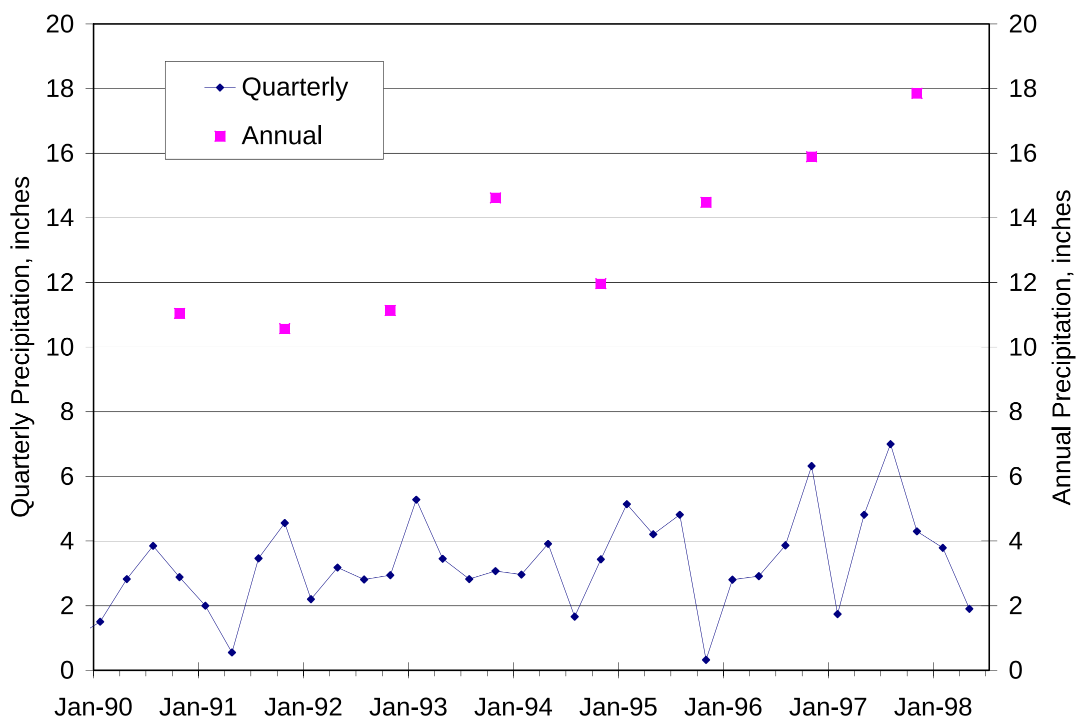


Figure 6. Quarterly and Annual Precipitation Data from Uravan NOAA Meteorological Station for the Period of Interest for Durita

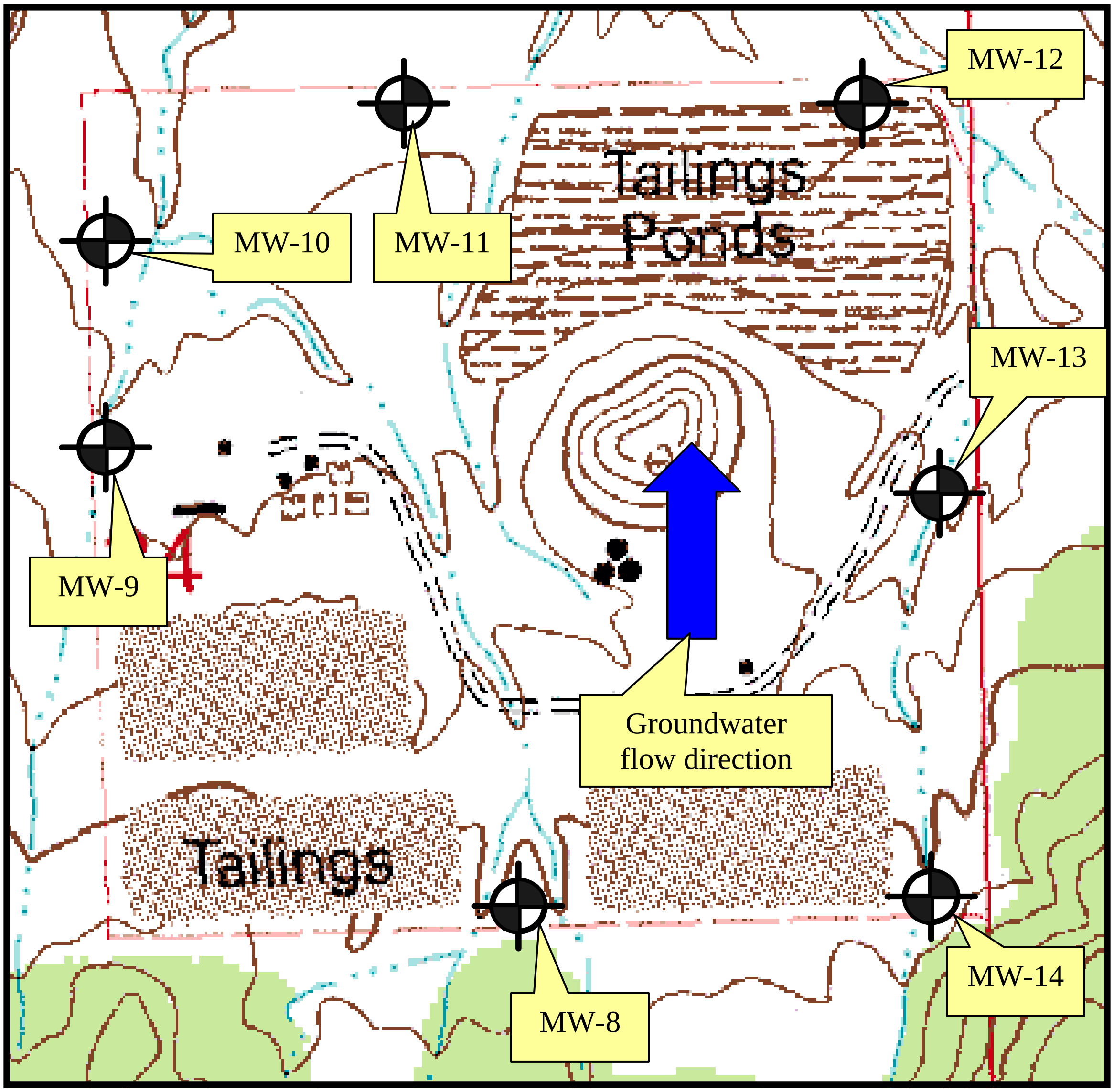


Figure 7. Topographic Map of Durita Site Showing Monitoring Wells. Modification of Downloaded File Obtained from Topozone™ on 07/17/2006.

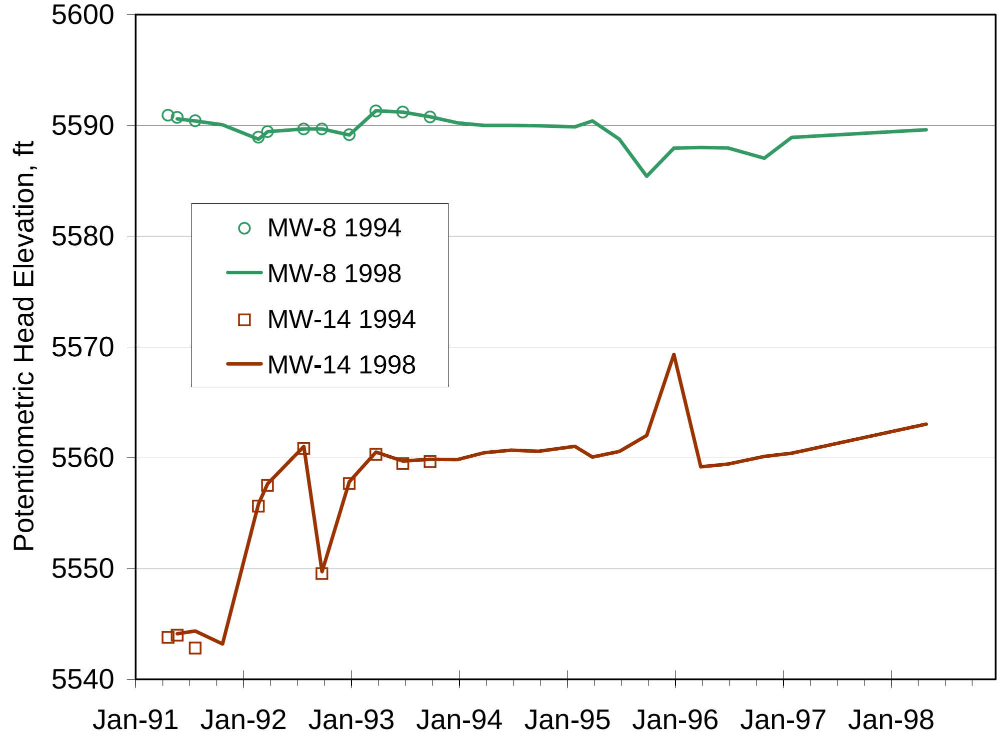


Figure 8. Potentiometric Heads for Upstream Boreholes From Two Data Sources, Hecla (1998) and Studious Solutions (1994)

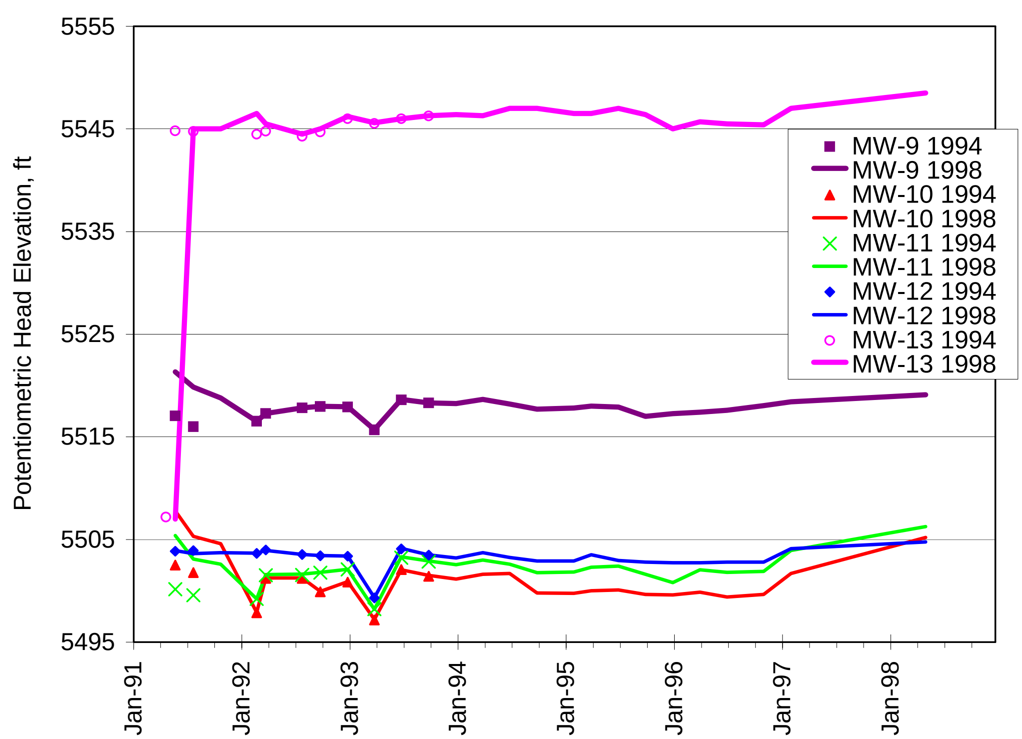


Figure 9. Potentiometric Heads for Downstream Boreholes From Two Data Sources, Hecla (1998) and Studious Solutions (1994)

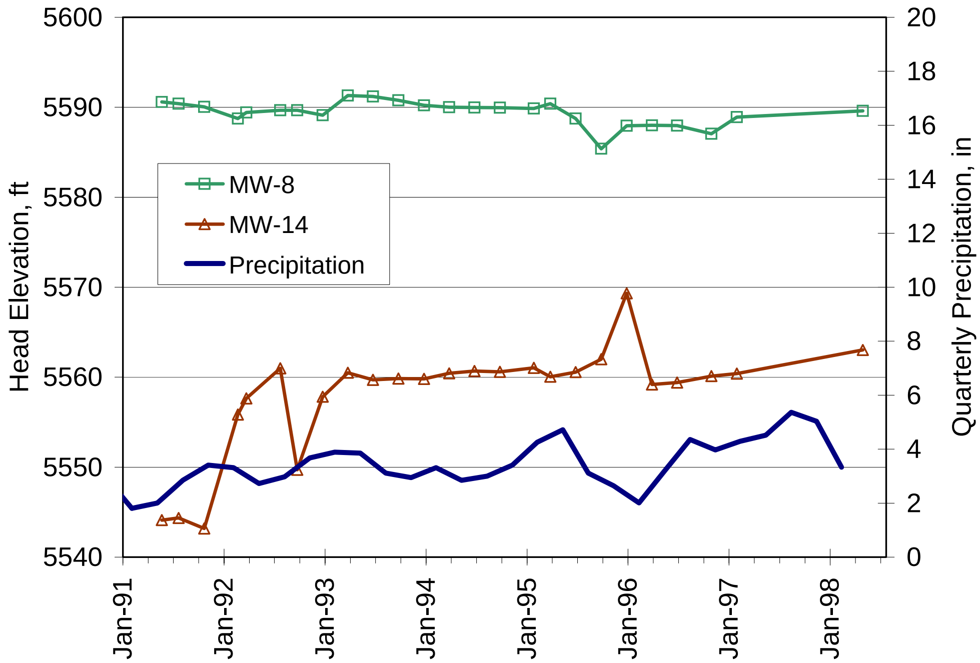


Figure 10. Smoothed Quarterly Precipitation Overlaid on Potentiometric Head Data for Upstream Wells

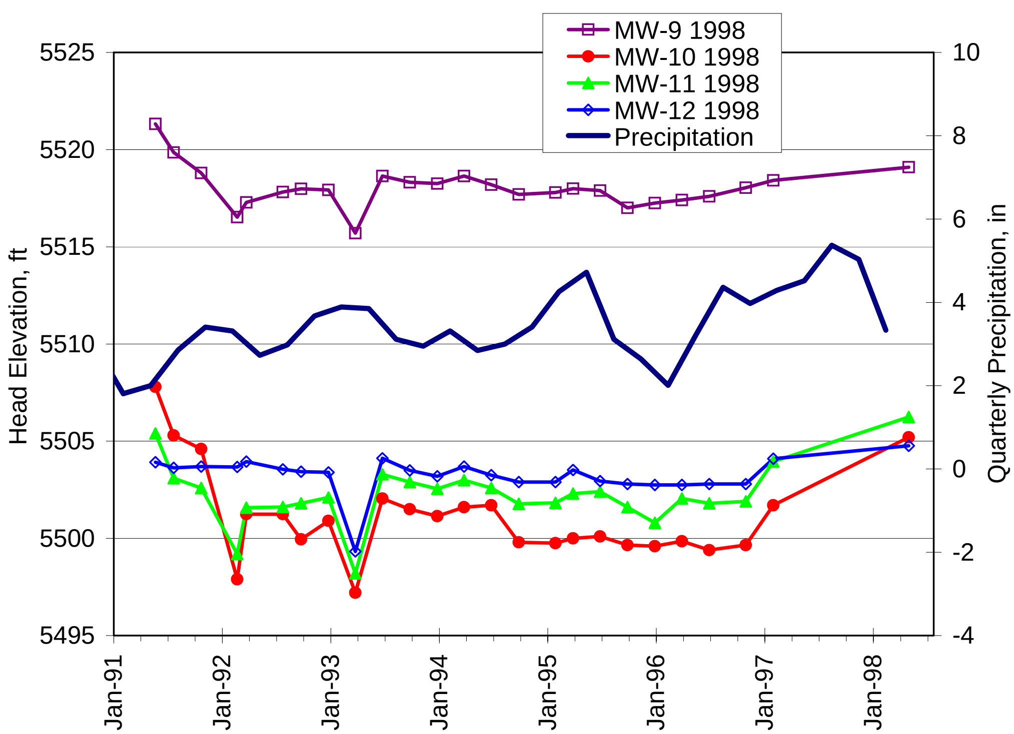


Figure 11. Smoothed Quarterly Precipitation Overlaid on Potentiometric Head Data for 4 of the 5 Downstream Wells boreholes

Appendix A

Site Photographs and Descriptive Log

Reconnaissance Visit to Hecla Mining Company Durita Uranium Mill Site
July 12, 2006
09:00-13:00

Participants:

U.S. Nuclear Regulatory Commission:	Gene Peters, Randy Fedors, Dennis Sollenberger
Colorado Dept. of Public Health & Environment:	Phil Stoffey
U.S. Department of Energy:	Tracy Plessinger (Office of Legacy Mmgt.)
USDOE Contractor:	
Reams Construction (representing Hecla):	Earl Reams II

Weather: Clear, occasional clouds, sunny and warm (>90F)

Photo	Description
22A	View from top of Mancos Hill, facing north to northwest. Closure cell and former evaporation ponds located in foreground. Coke Oven Ranch located in left mid-ground of photo. The northern site boundary can be seen running left to right through the mid-ground of the photo, marked by vegetation change.
21A	View from top of Mancos Hill, facing northeast. Eastern boundary of site runs left to right in mid-ground of photo, just beyond vehicles, which are located near the entrance to site.
23A	View from top of Mancos Hill, facing northwest to west-northwest. Coke Oven Ranch is observed in center of photo. The disturbed topography and vegetation located in left-center of photo is northern portion of former mill area and raffinate pond complex. Right-center portion of photo is western extent of former evaporation pond complex. Entrance road from highway is visible in the right-center portion of photo (N.B., this is site of later 'road cut' photos). Trees in mid-ground mark Dry Creek alignment. Linear feature from left dipping slightly to right, marked by vegetation change, is fenced northern site boundary.
24A	View from top of Mancos Hill, facing west. The northern edge of Leach Tank 201 visible in left mid-ground. The former mill area and raffinate pond complex are present in the center of the photo. The central diversion (run-off) channel runs from lower left through the center of the photo.
25A	View from top of Mancos Hill, facing south to southeast. Northern edge of Leach Tank 203 visible in center. Barren area in center of photo likely is former ore processing area, in which tailings from Naturita site (located c. 2.5 miles northeast of Durita site) were agglomerated with H_2SO_4 before placement in leach tanks.
20A	Shallow bench excavated into lower one-third, south side, of Mancos Hill. Pen for scale, pen cap oriented upward. Excavation depth approximately 1.5 feet below grade. Salt-related, friable induration visible at ground surface (note absence of vegetation) in upper portion of photo. Surficial material is heavily weathered, small (<1.0-in) shale fragments; original texture absent. At base of excavation, original structure and texture preserved, but rock friable and easily disaggregated. Vertical and subvertical joints are prominent and frequent. Iron staining and calcite present on bedding planes in joints. White material is crystalline $CaCO_3$ present in friable veins and lenses, oriented from vertical to horizontal. Calcite crystals exhibited long, slightly curved acicular form; where present as vein filling, exhibited crystal growth from both sides, meeting in center.
19A	Surface excavation (2 feet by 2 feet) at base of Mancos Hill, on south side. Total depth of excavation approximately 6 inches. Pen for scale; cap oriented approximately north. Surficial

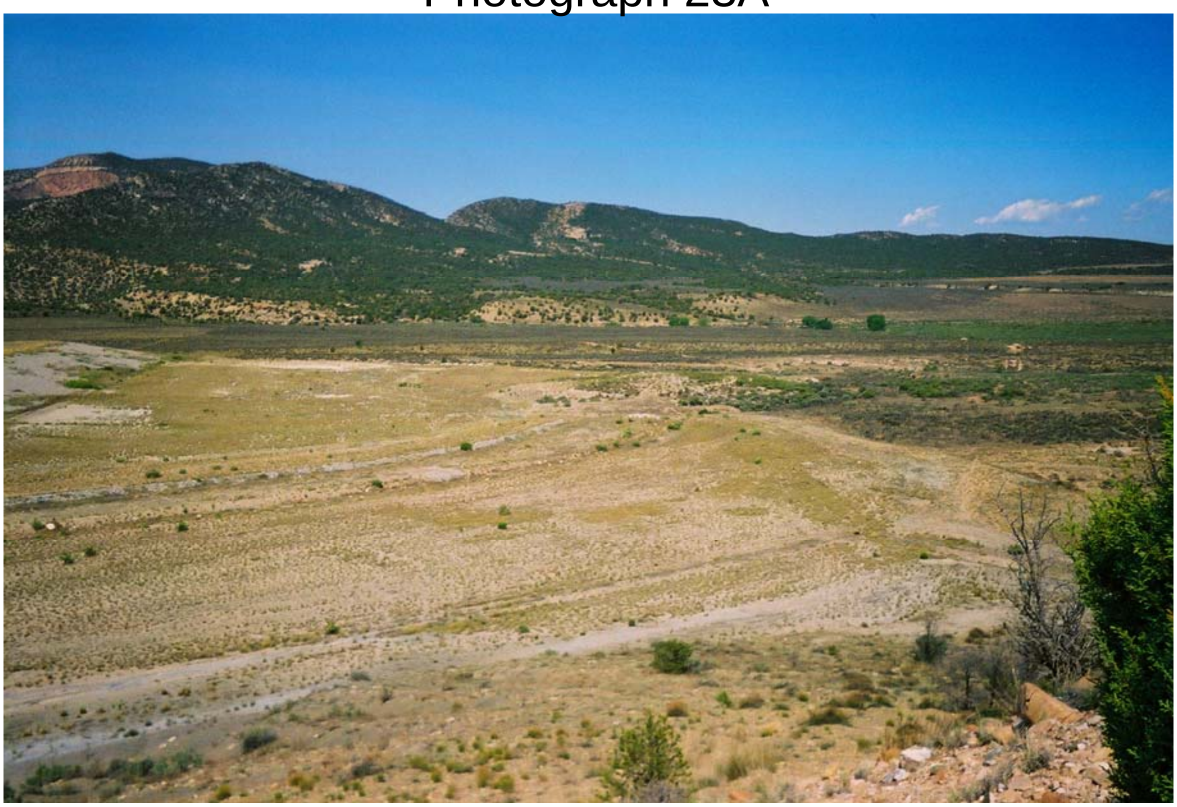
Photo	Description
	material same as in Photo 20A – heavily weathered, small shale fragments. Material at 6 inches in center pf photo is more competent and hard. Note prominent ¼-inch, northeast-southwest oriented joint, partially filled with unconsolidated sediment ranging in size from silt- to sand-sized particles. Bedding planes nearly horizontal.
18A	Photo taken at base of Mancos Hill, west side, facing north. Absence of vegetation on slope side may be related to reclamation activities, though no processes are reported to have occurred in this immediate area. Note horizontal to subhorizontal, more weathering-resistant layers approximately 3 feet up slope. These layers are laterally extensive and continuous. Note absence of rills or other surface run-off geomorphic features.
17A	Photo of shallow excavation at base of Mancos Hill, west side, facing northeast. Clipboard for scale. Excavation was of more resistant layer visible in Photo 17A. Note rapid change from heavily weathered surficial material to more competent claystone/shale. Note north-south and east-west intersecting joint sets.
16A	Photo of base of Mancos Hill, north and northwest sides. Absence of vegetation may be related to reclamation activities, though no processes are reported to have occurred in this immediate area. Note prominent drainage rills, which are absent on other sides of Mancos Hill, exposing several layers of more competent, resistant claystone/shale. Visible in upper portion of photo, near top of Mancos Hill re much larger rock fragments of sandstone, ranging up to cobble-sized. Ground surface, in foreground of photo, more clay-rich; note desiccation cracks. Visible in photo are Earl Reams (left, of Ream Construction, representing Hecla) and Ed ???, DOE contractor.
15A	View of Mancos Hill from southeast side, facing northwest. The inclined linear feature dropping to right in photo, marked by vegetation change is related to reclamation activities, according to Earl Reams.
14A	Photo of dry tributary channel to Dry Creek, north of site boundary, off northeast corner of site. This channel leads to the cataract area depicted in subsequent photos. Channel may be fracture-controlled, based on several long (10-meter scale) vertical to subvertical fractures evident in channel bed, with orientation parallel to channel trace. Note fine-grained material present in channel bed, exhibiting very prominent desiccation cracks and fragment curling.
12A	View of upper cataract area facing east-northeast, approximately 1,660 feet north of site, close to centerline of site. Dry Creek not flowing, but with large pools several feet deep in areas. Note resistant sandstone caprock layer controlling cataract, underlain by easily eroded shale layers, suffering extensive block failure and headward erosion. Likely represents the general interbedded contact between the Mancos and Dakota units. Standing water on left represents principal channel for Dry Creek. Individual in lower left standing in area of dry tributary channel in which photo 12 A was taken. Several large joints visible at ground surface.
13A	View of lower cataract area facing east-northeast, approximately 1,660 feet north of site, close to centerline of site. Dry Creek not flowing, but with large pools several feet deep in areas. Note alternating layers of more resistant claystone material with layers of less resistant shale. Both interbedded with sandstone. Likely represents the general interbedded contact between the Mancos and Dakota units.
11A	View of cross section exposed in upper cataract area, facing approximately southwest. Clipboard for scale. Note extensive weathering in layers below sandstone caprock layer, with extensive vertical joints and fractures.
10A	View of cross section exposed at upper cataract area, facing approximately southeast. Note large, vertical fracture extending into plane of photo.

Photo	Description
09A	Closer view of sandstone caprock layer at upper cataract area. Pen for scale; cap oriented upward. Note horizontal to subhorizontal joints and bedding planes, cross-stratification, and considerable bioturbation in sandstone. Iron staining and calcite present.
08A	Cross section exposed at southeast portion of upper cataract. Note subvertical continuous, iron-stained joint in center of photo. Clipboard for scale.
07A	View of small hillside descending to cataract area from northeast. Surficial materials very clay-rich.
06A	Large boulder northeast but proximal to the upper cataract area. Notebook for scale. Near side and upper surface appear to be joint-controlled with extensive slickensiding.
05A	View of lower cataract layer, facing west-northwest.
04A	View of Dry Creek main channel, facing approximately south, towards site. Mancos Hill visible in right-center portion of photo. Surficial and channel bed material unconsolidated sediment, predominantly clay and silt, with fine-grained sand.
03A	View of incised Dry Creek channel upstream and southwest of cataract area. Photo facing northeast, with Dry Creek off photo to left (north). Note near-vertical scarps of alluvial material penetrated by root systems, underlain by bench of more resistant horizontally bedded claystone and shale layers. This area representative of transition from Quaternary alluvium to Mancos Unit. Surficial materials below bench fine-grained sand with silt and clay. Near vertical, north to northwest-trending joint sets present in bench exposure, spaced at approximately 6- to 12-inch intervals (visible in near-ground of photo).
02A	Closer view of claystone/shale bench in Photo 03A; same features evident.
01A	View of alluvium in upper portion of section exposed in Photo 03A. Note root penetration and prominent horizontal soil change center of photo. Possible paleo-surface. Calcite present and increasing in proportion towards bottom of upper soil horizon. Pen for scale; cap oriented upward.
0A	View of road cut on west side of access road, facing west-northwest, approximately 2,000 feet north of site. Coke Oven Ranch buildings visible in right-center portion of photo. Upper portion of cut exposes Mancos/Dakota interbeds. Note prominent fractures oriented northwest into plane of photo, some with apertures of several inches. Darker layer near base of section is near-anthracite coal layer, diagnostic of Dakota Formation.
00A	View of site from Highway 90, facing southeast. Mancos Hill visible slightly right of center of photo.

Photograph 22A

Photograph 21A

Photograph 23A



Photograph 24A

Photograph 25A

Photograph 20A

Photograph 19A

Photograph 18A

Photograph 17A

Photograph 16A

Photograph 15A

Photograph 14A

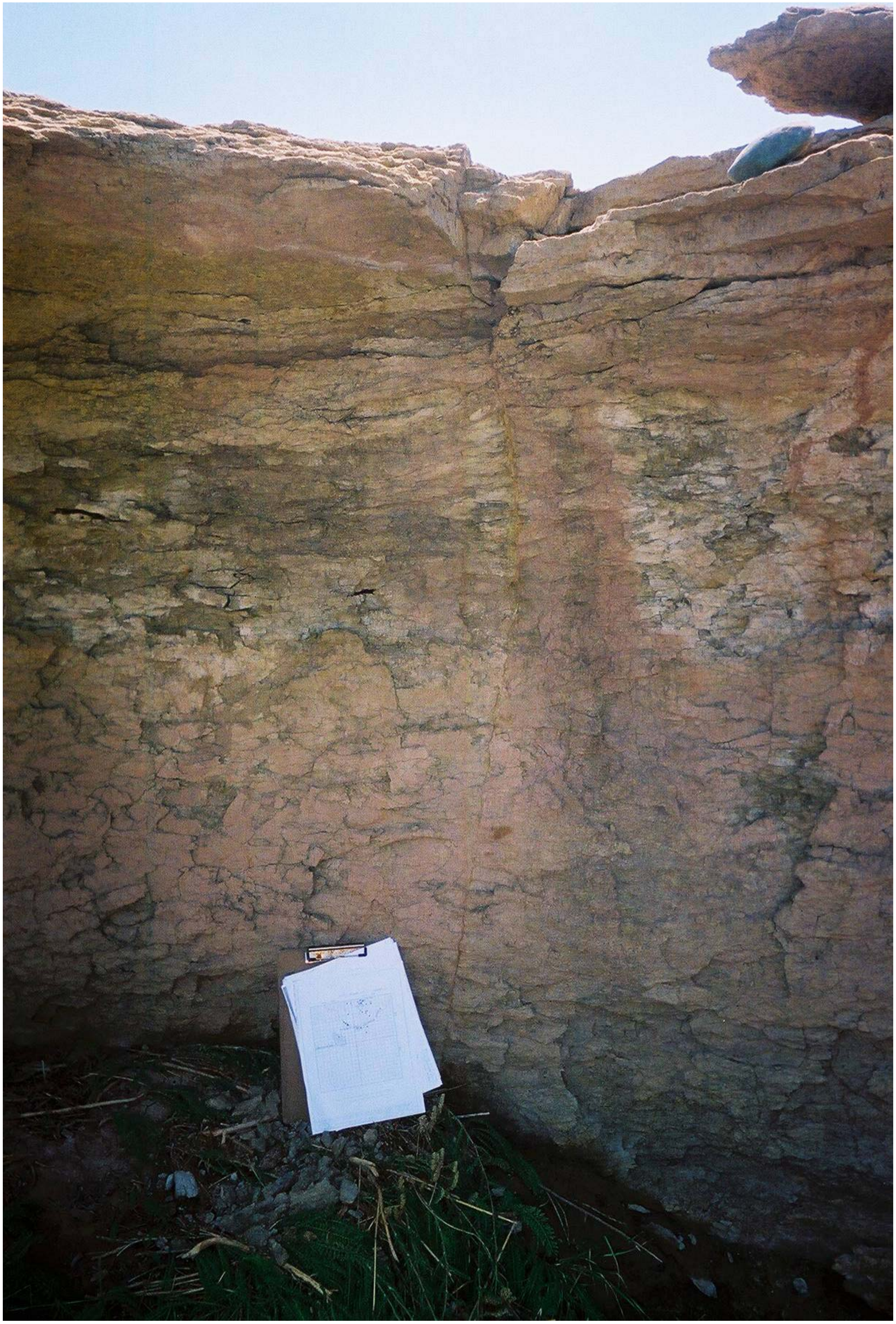
Photograph 12A

Photograph 13A

Photograph 11A

Photograph 10A

Photograph 09A



Photograph 08A

Photograph 07A

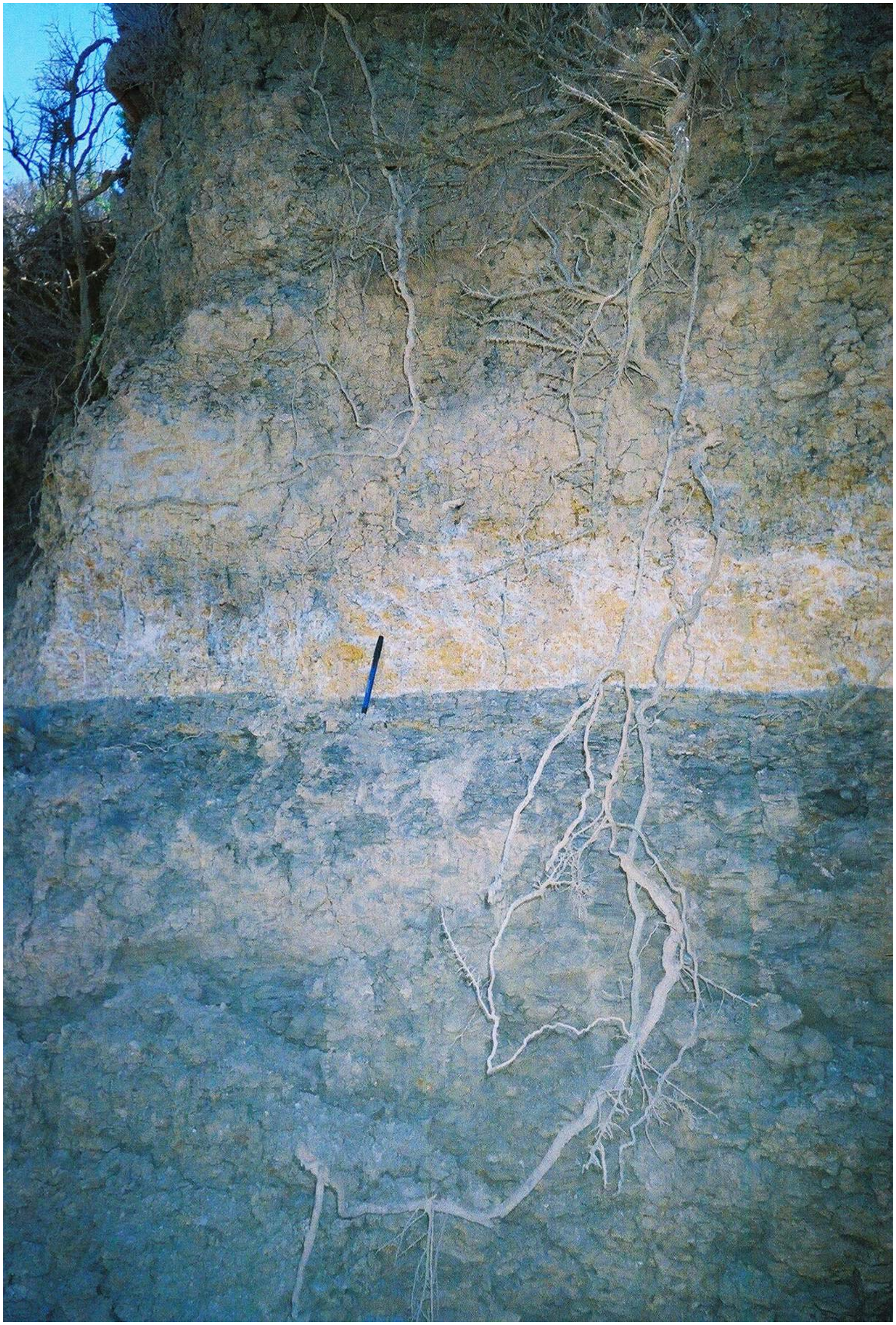
Photograph 06A

Photograph 05A

Photograph 04A

Photograph 03A

Photograph 02A



Photograph 01A


Photograph 0A


Photograph 00A