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INFORMATION ONLY

CIVILIAN RADIOACTIVE WASTE MANAGEMENT SYSTEM

Management and Operating Contractor

Contract #: DE-AC01-91-RW00134
Document #: BAB000000-01717-2200-00062 Rev. 03

WASTE ISOLATION EVALUATION

TRACERS, FLUIDS AND MATERIALS FOR EXPLORATORY STUDIES FACILITY (ESF) PHASE 1A CONSTRUCTION

by

David C. Sassani

January 10, 1994

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January 10, 1994

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This waste isolation impact evaluation was prepared in accordance with M&O implementing line procedure NLP-3-17. The *Ground Support System for the Drill-and-Blast Section of the ESF Starter Tunnel* has been classified as "Important to Safety" (YMP, 1993d) and the *ESF Starter Tunnel Drill-and-Blast Section Concrete Invert, Segment Sloping Downward Toward the Portal* has been classified as "Important to Waste Isolation" (YMP, 1993d).

Waste Isolation Evaluation
Tracers, Fluids and Materials
for Exploratory Studies Facility (ESF)
Phase 1A Construction

1. INTRODUCTION

1.1 Purpose

This revision has been issued as a major modification and update to the previous version of this evaluation (Houseworth 1993d), and supersedes the recommendations made in the previous version and a number of related evaluations for both the Starter Tunnel (Statton, 1993; Younker, 1993a, 1993b) and Alcove #1 (Younker, 1993c). One purpose of this revision is to correct the values misstated in the previous version (Houseworth 1993d) both for the difference in elevation between the North Portal Pad and the ground water table and for the distance between the North Portal Pad and the eastern edge of a potential repository expansion area. In addition, this evaluation updates and consolidates a number of separate evaluations of tracers, fluids, and materials (TFM) for the Starter Tunnel (Statton, 1993; Houseworth 1993b, 1993c) and Alcove #1 (Houseworth, 1993a) with the evaluations contained in the previous version of this document which included the topsoil and rock storage areas, the North Portal Pad (NPP), some NPP surface facilities, and associated access roads and culverts (Houseworth, 1993d). Furthermore, newly incorporated in this revision are materials estimated to be used to construct the launch chamber for the tunnel boring machine (Naaf, 1993), updated estimates of TFM for starter tunnel construction (Kalia, 1993c, 1993d, 1993e), quantitative bounding calculations for impact of organic materials, and evaluation the NPP drain, per verbal request by the Determination of Importance Evaluation (DIE) group.

<u>History of Previous Evaluations</u>

ESF Phase 1A. This waste isolation evaluation supersedes the previous recommendations for Tracers, Fluids, and Materials for Phase 1A construction (Foust, 1992a, 1992b). The previous version of this evaluation (Houseworth, 1993d) was a revision to update the statement on quality assurance. The original waste isolation evaluation was performed in response to two memoranda from Los Alamos National Laboratory (LANL) to assess potential impacts of tracers, fluids and materials (TFM) for portions of Exploratory Studies Facility (ESF) Phase 1A construction (Kalia, 1992a, 1992b). That evaluation (Foust, 1992b, Houseworth, 1993d) made three recommendations: (1) that no new controls on TFM were needed in addition to those extant for water use, spill control, spill cleanup, and recording of actual TFM; (2) because of the distance from the potential repository it was unnecessary to evaluate individual TFM for the Phase 1A construction, but it was suggested that to improve future waste isolation evaluations that individual TFM be investigated, a TFM database be constructed, screen TFM by location, permanence, and quantities, and perform model calculations to better quantify potential impacts; and (3) that prior to licensing, the potential impact on waste isolation of materials remaining at the site be evaluated with bounding calculations. Some of these types of analyses (particularly for organic materials) are included in this evaluation and new recommendations for material usage are given below.

Starter Tunnel. The original evaluation of TFM in the North Ramp Starter Tunnel (Statton, 1993) was performed in response to three LANL memoranda (Kalia, 1993a, 1993b; Oliver, 1993a). No new recommendations for controls were made. The North Ramp Starter Tunnel, defined as the first 61 m (200 ft) of the North Ramp, was originally planned to be constructed using 424 m^3 (~112,000 gal) of water (Sandifer, 1993a; Foust, 1992b). However, after excavation of 34 m (~110 ft) of the top half of the Starter Tunnel, the water use was 429 m^3 (~113,400 gal) (Sandifer, 1993a). A revised estimate of water use to complete the Starter Tunnel found that an additional 723 m^3 (~191,000 gal) would be required, for a total of 1152 m^3 (~304,400 gal) (Sandifer, 1993a). A supplemental evaluation of water usage (Houseworth, 1993b) was performed in response to the request from Los Alamos National Laboratory (Kalia, 1993g) to assess the potential waste isolation impact of increased water use for construction of the North Ramp Starter Tunnel. A revised waste isolation water use limit of 12 m^3/m (~1,000 gal/ft), or 750 m^3 (~200,000 gal), not including water use for shotcrete and grout, was established in response to the increased need for water (Houseworth, 1993b). However, during completion of the bench cut, it again became apparent that the required amount of water to finish the Starter Tunnel would be greater than previously anticipated (Sandifer, 1993b). It was estimated that completion of the Starter Tunnel would require a total of 1650 m^3 (~436,400 gal) of water (Sandifer, 1993b). In response to the request for evaluation of impact to waste isolation (Kalia, 1993f), a second supplement (Houseworth, 1993c) was generated and superseded the previous supplement (Houseworth, 1993b) to the Starter Tunnel evaluation concerning increased water use. It was found that there was not expected to be any impact on waste isolation if water use was limited to 130 m^3 (~35,000 gal) over any 3 m (~10 ft) interval of the Starter Tunnel, exclusive of water used for grout, shotcrete, and concrete, and it was recommended that water not be allowed to pond to the extent practical (Houseworth, 1993c). These last recommendations are not changed in this evaluation, however they are cast in slightly different units.

Alcove #1. The original evaluation of TFM in Alcove #1 (Houseworth, 1993a) was performed in response to a request from Los Alamos National Laboratory (Oliver, 1993b) to assess the potential effects on waste isolation of construction, testing, and TFM for the Exploratory Studies Facility (ESF) Package 1A North Ramp Alcove #1. The Alcove #1 evaluation includes the logic and bounding calculation that are used to place constraints on water usage in Alcove #1 and that are adopted for water usage in the Starter Tunnel as discussed above. In addition, evaluation of cements, steel, organic materials, and tracers for use in Alcove #1 are also included. For Alcove #1 Houseworth (1993a) makes three recommendations: (1) that water usage is minimized to the extent practical and does not exceed 87 m^3 (~23,000. gal) over any 3 linear-meters (~10 linear-feet) of excavation (excluding water for cementitious materials); (2) to the extent practical, water is not allowed to pond; and (3) the total quantity of organic materials retained permanently does not exceed 140 kg (~310 lbs). This last recommendation was in addition to an assumed retained 19 kg (~42 lb) of organic material from diesel exhaust. This evaluation adopts the same logic and bounding calculation for water use in Alcove #1 and, as stated above for the Starter Tunnel, does not change the recommendations for water use. However, in an further effort to evaluate the potential impact of organic materials used in the ESF, additional bounding calculations are presented below, discussed, and used to develop some integrated recommendations for use of organics in the Starter Tunnel and Alcove #1.

1.2 Planned Activities

The planned activities covered in this evaluation are:

Construction of ESF Phase 1A which includes:
- the topsoil and rock storage area,
- the north portal pad,
- the drain for the pad,
- a drainage ditch uphill of the north portal pad,
- the access roads for the north portal pad and for the topsoil and rock storage area,
- culverts for the access roads,
- the starter tunnel,
- and the test Alcove #1.

Construction of the launch chamber for the tunnel boring machine.

The topsoil removed from all areas that are excavated or filled is hauled to the topsoil storage area. Rock from the starter tunnel excavation is stored separately in a rock storage area adjacent to the topsoil storage area. A plastic liner is placed on the base of the rock storage area (YMP, 1993c; Vol I, sec. 3).

The planned access road to the North Portal and Pad is paved with asphalt, and the road to the topsoil and rock storage area has a gravel surface. Water application is used for dust control at construction sites, and for road and pad fill compaction in conjunction with *Polyphos 44*. Blasting and associated materials are used to excavate the Starter Tunnel and Alcove #1. Concrete, reinforcing steel, and welding equipment and associated materials are used for the construction of drainage structures and retaining walls. Rockbolts for the headwall and Starter Tunnel are bonded to the rock with grouts and resins. Split sets with wood blocking and lagging are used for ground support in the Alcove #1, as are wire mesh and shotcrete/fibercrete for general permanent ground support. Concrete is used for the floor of the Starter Tunnel.

Normal construction equipment such as bulldozers, front-end loaders, trucks, dry screens, rock crushers, backhoes, and graders, use diesel fuels, lubricants, and coolants/antifreeze.

As shown in Figure 1, the North Portal Pad, the Package 1A North Ramp, or Starter Tunnel, and the Alcove #1 are located on the eastern flank of Yucca Mountain, inside the controlled area and about 1.4 km (0.9 mi) ENE outside the nearest point on the conceptual perimeter drift boundary (CPDB) (EG&G, 1992).

Alcove #1 is an excavation starting about 43 m (140 ft) from the entrance of the Starter Tunnel (Oliver, 1993b). The axis of the proposed Alcove is horizontal and approximately perpendicular to the axis of the Starter Tunnel (See Figure 2) (Oliver, 1993b). The Alcove #1 will be used for site characterization testing. The planned tests include the radial borehole and hydrochemistry tests.

The tracers, fluids, and materials (Kalia 1992a, 1992b; Kalia, 1993a, 1993b, 1993c, 1993d, 1993e, 1993f; Naaf, 1993; Oliver, 1993a, 1993b; Sandifer, 1993a, 1993b) proposed for use during construction (planned permanent items are bolded) are:

Tracers:

> 20 ppm **lithium bromide** in construction water, air traced with SF_6.

Fluids:

> water, oxygen, acetylene, thread cutting oil, cleaning solvents, diesel fuel, ethylene glycol, hydraulic fluid, engine lubricating oil, automatic transmission fluid, concrete form oil, gear case lubricant, emulsion explosive (*Magnafrac*), air compressor lubricating oil, brake fluid, battery acid, tire ballast materials, silicone sealant, **spray paint**, cable pull lubricant, polyphos 44.

Materials:

> **steel sets, wooden blocking, lagging** (steel), **rock bolts, wire mesh, shotcrete and/or fibercrete**, gravel and asphalt for roads, **cementitious grout, rockbolt resin/epoxy (Dupont Fasloc, Celtite Lokset, Williams Polygrout)**, ANFO explosive (ammonium nitrate and fuel oil), blasting caps (non-electric), explosive primer (emulsion cartridge), emulsion explosive (Atlas 7D, Powermax, Apex), weld rod (E70XX electrodes), explosive primer (40% dynamite), explosive powder, explosive trim powder, primacord, **wood, steel, concrete, concrete admixtures, galvanized steel**, fire caulking (ASTM E-815), glue (silicone), PVC cement (PVC), silicone caulking compound (ASTM C-920D), concrete joint sealant (elastomeric), expansion joint material (particle board), insulation (extruded polystyrene), pipe thread compound (teflon), fire sealant (ASTM E-815), bentonite clay, liner glue (PVC).

1.3 Quality Assurance

The planned activities at the ESF North Portal may affect natural barriers in the controlled area, which are in Section 2 of the Q-List (YMP, 1993d). Therefore, this report was prepared as a quality-affecting activity according to CRWMS M&O Implementing Line Procedure NLP-3-17. No computer coded calculations were performed specifically for this evaluation. Some of the referenced data may not have been approved for quality-affecting activities and the referenced analyses may not have been performed as quality-affecting activities or under software QA requirements. Based on the judgement of the author, the most appropriate data were used and all citations are given to provide traceability. The extent and possible effects of non-qualified data and analyses on the evaluations, conclusions, and recommendations of this report have not been specifically determined. However, the conservative assumptions, estimates and methods used in this evaluation were devised to address reasonable scenarios and are believed to bound the potential impacts on waste isolation.

A checklist (see Attachment I) was used as guidance to ensure no activities were overlooked. Guidance for the format and content of this waste isolation evaluation was provided by Houseworth (1993e) so that all potential impacts to waste isolation would be considered.

2. BACKGROUND INFORMATION

2.1 Evaluation Approach

This is a largely qualitative evaluation based on information in the referenced documents and supplemented by personal communications with Yucca Mountain Site Characterization Project Office (YMPO) and participant staff. Quantitative analyses include a hand calculation of water application rate for the Starter Tunnel and for Alcove #1, and calculation of the potential effects of organic materials permanently retained in the Starter Tunnel and Alcove #1. In the cases of these evaluations, it is currently not possible to evaluate the potential impacts at the level of consequence to radionuclide releases. Therefore, we have adopted perturbations to ambient site conditions (e.g., 10% increase in background dissolved organic carbon) as the criteria for indicating that an item/activity may impact waste isolation.

In these evaluations, the calculations represent scenarios that should conservatively bound the potential impacts to waste isolation. If these conservative calculations indicate that it is not likely that the items/activities would impact waste isolation, then it can be reasonably concluded that the items/activities can be used/performed with only those controls that are assumed in the calculation with minimal risk of impact to waste isolation from any reasonable scenario. Because these are bounding scenarios, in cases where these conservative calculations indicate some potential impacts to waste isolation it cannot be concluded that these impacts are assured. However, it can be reasonably assumed that for any plausible scenario the potential impacts represent upper bounds for impact. To provide a consistent approach to evaluating the potential impacts in all cases, an effort is made to choose a reasonable bounding scenario which, although not always the "most probable" case (the choice of such a scenario cannot be defended adequately in many cases because lack of appropriate information precludes quantifying the probability), encompasses the potential impacts from all reasonable scenarios. As such, this bounding scenario is not the worst-case scenario either (i.e., the bounding case for transport is not that of continuous, direct, disequilibrium fracture flow from the material to a waste package). In all cases, it will be necessary for a future evaluation of the consequences to radionuclide release resulting from the permanent items and configuration of any final constructed facility.

2.2 Relative Locations and Elevations

All of the planned construction is located inside the Test and Waste Isolation Evaluation Zone (TWIEZ; Dyer, 1993), within the conceptual controlled area boundary (CCAB; DOE, 1988), and outside of the conceptual perimeter drift boundary (CPDB). The topsoil and rock storage areas are located about 1.2 km (0.75 miles) east of the eastern CPDB (EG&G, 1991, YMP, 1992) and over a potential repository expansion area (DOE, 1988, v. III, pt. A, p. 6-226 & 6-228; YMP, 1990; EG&G, 1992). The north portal and pad are located about 1.4 km (~0.9 mile) east of the eastern CPDB and 250 m (~820 feet) east of the nearest eastern boundary of a potential repository expansion area (DOE, 1988, v. III, pt. A, p. 6-226 & 6-228; YMP, 1992; EG&G, 1992). The access roads connect these two areas from the "H" road. None of the construction is nearer than 1.2 km (0.75 miles) of the nearest point on the CPDB

The North Ramp Starter Tunnel and Alcove #1 (Figure 1) are located on the eastern flank of Yucca Mountain, about 1.4 km (0.9 mi) outside the nearest point on the conceptual perimeter drift boundary (CPDB) in an ENE direction; about 2 km (1.2 mi) inside the conceptual controlled area boundary (CCAB); and about 200 m (650 ft) east of the nearest conceptual repository expansion area boundary and the Bow Ridge Fault (EG&G, 1992; Scott and Bonk, 1984).

All construction will be at elevations higher than the conceptual repository horizon.

The North Ramp Alcove #1 (Figure 1) is located on the eastern flank of Yucca Mountain, about 1.4 km (0.9 mi) outside the nearest point on the conceptual perimeter drift boundary (CPDB) in an ENE direction; about 2 km (1.2 mi) inside the conceptual controlled area boundary (CCAB); and about 200 m (650 ft) east of the nearest conceptual repository expansion area boundary and the Bow Ridge Fault (EG&G, 1992; Scott and Bonk, 1984). Relevant elevations are as follows:

Location	Elevation	Source
Topsoil and rock storage areas, surface	~1170 m (~3850 ft)	EG&G, 1991
North ramp at surface	1124 m (3687 ft)	YMP, 1991a
South ramp at surface	1198 m (3930 ft)	YMP, 1991a
Calico Hills drift north end	824 m (2702 ft)	YMP, 1991a
Calico Hills drift south end	955 m (3134 ft)	YMP, 1991a
North Ramp Alcove #1	1120 m (3676 ft)	Oliver, 1993b
ground surface above Alcove #1	1158 m (3800 ft)	USGS, 1993
North Ramp, ground-water table	730 m (2395 ft)	Robison, 1988
Base of Tpp*, North Ramp Alcove #1	1073 m (3520 ft)	USGS, 1993
Base of Tpp*, West of Bow Ridge Fault	981 m (3220 ft)	USGS, 1993
ESF North ramp at Topopah Spring	988 m (3240 ft)	YMP, 1991a
ESF South ramp at Topopah Spring	1140 m (3740 ft)	YMP, 1991a

*Tpp is the Pah Canyon Member of the Paintbrush Tuff

2.3 Relevant Hydrogeology

Surface drainage is in an easterly direction toward branches of Drillhole Wash away from both the current conceptual repository block and potential repository expansion areas (EG&G, 1992). The geologic formations dip to the east from the conceptual repository to the planned construction sites (DOE, 1988, v. II, pt. A, p. 3-215). The topsoil and rock storage areas are located on top of the Bow Ridge Fault whose subsurface characteristics are not known.

The proposed position for the North Ramp Alcove #1 lies approximately 38 m (125 ft) beneath Exile Hill at the position shown in Figure 1. The unsaturated zone is approximately 430 m (1300 ft) thick at the North Ramp Alcove #1 (see section 2.2) and consists of the following members of the Paintbrush Tuff Formation: the Tiva Canyon welded tuff, the Pah Canyon nonwelded tuff, and the Topopah Spring welded tuff (USGS, 1993). The formations dip in an easterly direction, away from the conceptual repository and repository expansion areas. The Bow Ridge Fault, which dips steeply (~60-70°) to the west (Scott and Bonk, 1984), lies about 200 m (650 ft) west of the Alcove.

Relative to the Pah Canyon Member of the Paintbrush Tuff, the Tiva Canyon Member is highly fractured and has lower porosity and matrix permeability, but higher fracture permeability. The lower fracture density of the Pah Canyon Member has led to the conceptual model that fracture flow between the Tiva Canyon and Topopah Spring Members is interrupted by the Pah Canyon Member. Water movement in the Pah Canyon Member is believed to be primarily along the stratigraphy parallel to the dip because of enhanced permeability in this direction and the capillary barrier (see discussion below) to downward flow into fractures in the underlying Topopah Spring Member (Montazer and Wilson, 1984).

In the vicinity of the planned construction sites, the water table has been consistently at an elevation of about 730 m (2395 ft) (Robison, 1984; Robison et al., 1988), which is about 440 m (1450 feet) below the ground surface at the topsoil and rock storage areas and about 400 m (1310 ft) below the ground surface at the north portal. The water table in this area is fairly flat (DOE, 1988, v. II, pt. A, p. 3-3, 3-4, 3-59, 3-74 to 3-80). The saturated ground-water flow at this location is inferred to be in a southeasterly direction (Ervin et al., 1993), away from the current conceptual repository and repository expansion areas. The groundwater table lies in the Topopah Spring Member of the Paintbrush Tuff west of the Bow Ridge Fault and in the Calico Hills nonwelded unit east of the Bow Ridge Fault (Scott and Bonk, 1984).

2.4 Affected Natural Barriers/Engineered Items on the Q-List or MC-List

In the lists given below it is assumed that ESF surface facilities are not planned to become part of any potential repository (YMP, 1993c, Vol. I, Sec. 3) and that the only permanent ESF items that will be incorporated into the potential repository are (YMP, 1993c, Vol. I, Sec. 3): (1) underground openings; (2) ramp and shaft linings; (3) ground support; and (4) operational seals.

Natural barriers/engineered items on the Q-List (YMP, 1993d) or the MC-List (YMP, 1993e) which are directly affected by the activities discussed above include:

unconsolidated surface material (USM) (MC-List),
the Tiva Canyon Welded Hydrogeologic Unit (Q-List).

Engineered items on the Q-List (YMP, 1993d) or the MC-List (YMP, 1993e) which are directly affected by the activities discussed above include:

- waste ramp (Q-List),
- tuff ramp (Q-List),
- ground support system for the drill-and-blast section of the ESF Starter Tunnel (Q-List),
- ESF Starter Tunnel drill-and-blast section concrete invert, segment sloping downward toward the portal (Q-List),
- concrete invert, downslope into north ramp to end of drill-and-blast section of the Starter Tunnel (MC-List),
- test alcove, ESF Starter Tunnel, drill-and-blast section (MC-List),
- roadway (part of the Tuff Ramp) (MC-List).

3. SPECIFIC EVALUATIONS AND INTERPRETATIONS

3.1 Hydrology

Surface Facilities

Water is used for dust control on all roads and pads, and for fill compaction on fill areas only. The limit for dust control was established from very conservative calculations that showed that the moisture content at the repository horizon would not change in 10,000 years if this limit is observed (YMP, 1993c, Vol. II, App. I). This limit is given as 2 gal/sq.yd./day averaged over a five-year period of water application (YMP, 1993c, Vol. II, App. I). The period for averaging water application shall not exceed 6 months (YMP, 1993b).

Concerns were expressed by the YMP Assessment Team with regard to some assumptions and results in two Sandia National Laboratories (SNL) reports which form the basis for conclusions on water infiltration from the surface to the conceptual repository. SNL has provided evidence, however, that the conclusions are still valid due to the high conservatism in their assumptions and as indicated by new analyses (Shephard, 1992).

The rock storage area may represent an additional source of water because much of the water used in excavation should be removed in it (as noted below in the section on Alcove #1). However, most of the water will be trapped in pore spaces and the liner under the rock-storage area (YMP, 1993c, Vol. I, Sec. 3) should prevent any significant infiltration.

The drain for the North Portal Pad is designed to capture and channel pad runoff and then disperse it from two outlets onto riprap at the southeast edge of the pad at which point the water may disperse freely (YMP, 1993f). This does not represent a significant perturbation to the natural surface runoff and is not expected to effect significantly infiltration at the surface.

North Ramp Alcove #1

Water use during construction of Alcove #1 could introduce water into the surrounding Tiva Canyon Member. Water used for drilling of blast holes and rock bolt holes is in contact with the rock under positive pressure, resulting in a potential for mobilizing construction water into fractures. Construction of the Starter Tunnel has shown that low pressure grout injected into rock bolt holes requires on average 230 liters (60 gal) per hole, about 30 times the hole volume (Prichett, 1993). Presumably the grout is flowing into fractures surrounding the rock bolt holes. This evidence suggests that water may also enter the fracture system when drilling holes or from ponding of water.

The differences in movement of water in fractures and matrix are significant. Saturated fracture conductivities are not well characterized, but are believed to be at least on the order of 10^{-4} m/s (Barnard et al. 1992). Fracture porosities are on the order of 0.001 (Barnard et al. 1992). Matrix permeabilities in the welded tuffs are on the order of 10^{-11} m/s and porosities of about 0.1 (YMP, 1993a). These differences in properties are significant when considering the movement of water in a gravitational field. For example, under saturated conditions (assuming unit hydraulic gradient provides an upper limit), the calculated time for fracture-flow water to advance from the surface to the water table, or 400 m (~1300 ft), is about an hour. Under the same conditions, matrix flow, would only penetrate approximately 30 m in 10,000 years. Therefore, matrix water in the vicinity of the North Ramp Alcove #1 should be unavailable to interact with the conceptual repository or potential expansion areas. For a higher hydraulic gradient the calculated flow times would be reduced, but their ratios would be constant.

The stratigraphic cross-section along the North Ramp (Figure 3) may be used to construct different scenarios of what may happen to water entering fractures at the North Ramp Alcove #1. One possibility is that the highly fractured Tiva Canyon Member presents continuous fracture flow paths that connect fracture flow in the Tiva Canyon Member with the Bow Ridge Fault prior to encountering the Pah Canyon Member (Figure 3; note that the Yucca Mountain Member is absent from the stratigraphy at this location). In this scenario, continuous fracture flow is possible directly into the Topopah Spring Member. In Figure 3 it is shown that to the west of the Bow Ridge Fault zone the highest point of entry into the Topopah Spring Member is at an elevation of 975 m (~3200 ft), which is lower than nearly all of the conceptual repository (YMP, 1993a). In addition, this location is approximately 1.2 km (0.75 mi) from the conceptual perimeter drift boundary (EG&G, 1993), making any effect on the conceptual repository highly unlikely. If water does enter potential expansion area (PEA) 6 through this pathway, it will be confined to the lower levels of the Topopah Spring Member near the Bow Ridge Fault, where waste package placement is not considered probable. In addition, effects on PEA 6 are also unlikely given the circuitous route required for fracture flow to enter this horizon.

A more likely flow scenario, shown in Figure 4, indicates flow in a connected fracture path vertically down through the Tiva Canyon Member to the Pah Canyon Member. The nonwelded Pah Canyon Member is not believed to contain continuous fracture paths from the upper contact with the Tiva Canyon Member to the lower contact with the Topopah Spring Member (Montazer and Wilson, 1984). However, the rock matrix is much more porous and permeable than the matrix in either adjacent member, with a porosity of about 0.42 and a saturated conductivity of about 10^{-7} m/s (YMP, 1993a). In addition, the upper unit in the Topopah Spring Member (the Topopah Spring caprock) is a welded tuff which has a low-porosity, low-conductivity matrix, a high fracture density, and a fracture permeability that is large compared to the matrix permeability of the Pah Canyon Member. Because of the contrast between the matrix permeability of the Pah Canyon Member and the fracture permeability of the Topopah Spring caprock, water is prevented from entering the fractures in the underlying Topopah Spring caprock until the Pah Canyon Member nears saturation and the capillary pressures in the two systems are equalized. Therefore water migration through the Pah Canyon Member should encounter this *capillary barrier* to entry into fractures in the Topopah Spring caprock. As a result, water may tend to migrate along the stratigraphic contact between the Pah Canyon Member and the Topopah Spring Member. Such movement of water is away from the conceptual repository and potential expansion areas and therefore is not expected to affect waste isolation. If enough water enters the Pah Canyon Member to saturate the pore space, then the capillary barrier is eliminated and water entry into fractures in the Topopah Spring Member is possible. This open circuit of fracture flow is considered to be significant with respect to waste isolation, because there is a potential for rapid movement over large distances to virtually anywhere in the conceptual repository or potential expansion areas (see discussion above).

The capillary barrier concept suggests that the quantity of water lost to the geosphere during construction and testing in the North Ramp Alcove #1 should be restricted according to the quantity of water required to saturate the Pah Canyon Member. (This is a conservative assumption because the Pah Canyon Member is only a portion of the Paintbrush Nonwelded Hydrogeologic Unit). The thickness of the Pah Canyon Member may be estimated from Figure 3, where it is shown to be about 6 m (~20 ft). The natural saturation is estimated to be about 0.61 (YMP, 1993a). Therefore, given a porosity of 0.42 (YMP, 1993a), the amount of available unsaturated pore space is ~1 m^3/m^2 (~24.5 gal/ft^2). If we make the conservative assumption that the water migrates straight downward and does not disperse laterally, then the cross-sectional area of Pah Canyon Member affected by infiltration of water is the same as the cross-sectional area of water application in the North Ramp Alcove #1. Assuming practical use of water, it has been conservatively estimated that 80% of the water used during drill and blast operations (for drilling blast holes, rock bolt holes, and for dust suppression) will be removed from underground via muck removal, pumping of water ponded on the tunnel floor, and evaporation (personal communication to J. Houseworth from J. Peters, 12/93-see Attachment III). Therefore, the total quantity of water per unit floor area available for use in construction of the North Ramp Alcove #1 is 5 m^3/m^2 (~123.0 gal/ft^2). This constraint relies on the assumption that water use is evenly spread over the length of the Alcove. This value can be averaged over 20. m^2 (~215 ft^2) without affecting significantly the outcome of the calculation and leading to a practical limit of 100 m^3 over any 20 m^2 floor area (~26,500 gal over any 215 ft^2 floor area). Finally, the water used to make shotcrete or grout is not included in this limit, because that water is chemically bound and not directly available for movement in the surrounding environment.

North Ramp Starter Tunnel

The North Ramp Starter Tunnel, beneath Exile Hill, is approximately 1.4 km (0.9 mi) to the east of and outside the conceptual perimeter drift boundary and also lies outside any identified potential expansion areas (EG&G, 1992). The Starter Tunnel lies within the same geologic formation as the North Ramp Alcove #1. The reasoning used above for the North Ramp Alcove #1 is applied also to the Starter Tunnel, because the Starter Tunnel and Alcove #1 are physically adjacent and are approximately the same distance from the nearest significant geologic feature, the Bow Ridge Fault. Calculations given above indicate that water use for the Package 1A North Ramp Starter Tunnel is constrained to a **practical limit** of 100 m^3 over any 20 m^2 floor area (~26,500 gal over any 215 ft^2 floor area) of tunnel. Finally, the water used to make shotcrete or grout is not included in this limit, because that water is chemically bound and not directly available for movement in the surrounding environment.

It has been shown that perturbations to saturated-zone ground-water flow are bounded by the scenarios which address perturbations in the unsaturated zone (Houseworth, 1993f). Given the above limits on underground water usage, no impacts on the saturated-zone flow regime are expected. If the above limits are followed, the planned activities/items are not expected to have significant effect on the water movement/saturation near potential waste emplacement sites or along potential aqueous radionuclide pathways, and are not expected to have significant effect on the gas-phase movement/saturation along potential gaseous radionuclide pathways.

3.2 Geochemistry

Tracers

Sulfur hexafluoride and lithium bromide are proposed as tracers for gas-phase coring operations and construction water, respectively. Because of the low concentrations and limited quantities used, these tracers are not expected to have significant effects on the geochemistry near potential waste emplacement sites, nor along potential gaseous and aqueous radionuclide pathways.

Surface Fluids and Materials

A previous evaluation (Sassani, 1993) established a set of solid materials that are surficial, non-permanent, and not significantly soluble which should not contribute significant material to the environment and, therefore, are not expected to have significant effects on the geochemistry near potential waste emplacement sites, and along potential gaseous and aqueous radionuclide pathways. The materials listed in that evaluation are (Sassani, 1993):

> plastic, PVC, ABS plastic, rubber, solid metals, wood, concrete, iron, steel, aluminum, rubber, glass, sheet metal, graphite-based grounding material (*GEM*), copper wire or plates, explosives, asphalt, asphaltic concrete, concrete curing compound, soil containing *Road Oyl.*

A number of additional materials that are included in this evaluation for use at the North Portal Pad can be regarded similarly as surficial, non-permanent items such that they are not expected to have significant effects on the geochemistry near potential waste emplacement sites, and along potential gaseous and aqueous radionuclide pathways. These are:

> gravel for roads, weld rod (E70XX electrodes), glue (silicone), PVC cement (PVC), silicone caulking compound (ASTM C-920D), concrete joint sealant (elastomeric), expansion joint material (particle board), insulation (extruded polystyrene), pipe thread compound (teflon), fire sealant (ASTM E-815), bentonite clay, liner glue (PVC).

Because the solid materials discussed above are surficial, non-permanent, and not significantly soluble (see Sassani, 1993), the planned activities/items should not contribute significant material to the environment. In addition, establishment and operation of maintenance programs can only further insure that the solid items listed above are not expected to contribute noticeable residue to the environment. Therefore, non-permanent solid materials used/stored at the surface are not expected to have significant effects on the geochemistry near potential waste emplacement sites, and along potential gaseous and aqueous radionuclide pathways.

A set of fluids were listed in that previous evaluation (Sassani, 1993) that are not expected to have any significant impact provided that a plan for spill containment and clean-up exists. Such fluids are constrained to be those which are not *planned* for dispersal into the environment. Unlike solids, fluids may become part of the permanent environment through accidental breach of their container, even if the container is maintained. For example, mineral oil, used for transformer and circuit breaker insulation, may become an item permanently retained in the environment if spilled and not remediated. Given a plan for spill containment and clean-up, non-permanent fluids used/stored at the surface are not expected to have significant effects on the geochemistry near potential waste emplacement sites and along potential gaseous and aqueous radionuclide pathways. The fluids included in the Surface-based materials evaluation are (Sassani, 1993):

> propane, cylinders of gas standards for calibration of instruments, diesel fuel, ethylene glycol (antifreeze), lubricants for machines, insulating oils, fuel oil, gasoline, hydraulic fluid, battery acid, cleaning solvents, port-a-potty fluids (e.g., *potpouri*).

A number of additional fluids that are included in this evaluation for use at the North Portal Pad can be regarded similarly as surficial, non-permanent items such that they are not expected to have significant effects on the geochemistry near potential waste emplacement sites, and along potential gaseous and aqueous radionuclide pathways. These are:

> thread cutting oil, air compressor lubricating oil, tire ballast materials, silicone sealant, cable pull lubricant.

As stated in the evaluation of surface-based fluids and materials (Sassani, 1993), any planned non-permanent fluids or materials that become retained unintentionally as part of the permanent environment require documentation of the amounts of substance retained in the environment and evaluation of the potential waste isolation impact of that specific retention.

A few fluids that are to be used at the surface do not fall into the above category and are evaluated here separately. *Polyphos 44* is added to surface-use water to prevent scaling. Because it is used in such small concentrations (9 ppm in water) as a surface application (Kalia, 1992a) such that dilution during transport to potential repository levels should produce negligible concentrations, it is expected to have negligible impact to waste isolation.

Vapors and residues from oxygen and acetylene used for welding can be reasonably assumed to disperse and have negligible impact on waste isolation.

Any leachates that may be produced by precipitation interaction with the rock storage materials, which should not be greatly different from ground water compositions, should be prevented from infiltrating by the liner under the rock storage area, and therefore are expected to have negligible impact on waste isolation.

Underground Fluids and Materials

The only ESF items that are planned to be permanent and incorporated into the potential repository are (YMP, 1993c, Vol. I, Sec. 3): (1) underground openings; (2) ramp and shaft linings; (3) ground support; and (4) operational seals. Applying the same reasoning presented above from the evaluation of surface-based materials (Sassani, 1993), non-permanent items are assumed to have negligible impact on waste isolation. Therefore only items that are planned to be permanently retained in the Starter Tunnel and Alcove #1 are evaluated here. These are: steel sets, wooden blocking, lagging (steel), rock bolts, rebar, wire mesh, shotcrete and/or fibercrete, cementitious grout, spray paint, rockbolt resin/epoxy (Dupont Fasloc, Celtite Lokset, Williams Polygrout), wood, steel, concrete, concrete admixtures, and galvanized steel. This includes materials for the launch chamber of the tunnel boring machine (Naaf, 1993).

Explosives are not considered permanent items because it is assumed that most of their residues will be removed either as volatiles or within the removed excavated materials. These materials include: ANFO explosive (ammonium nitrate and fuel oil), blasting caps (non-electric), explosive primer (emulsion cartridge), emulsion explosive (Atlas 7D, Powermax, Apex), explosive primer (40% dynamite), explosive powder, explosive trim powder, and primacord.

Fluids which are not *planned* for dispersal into the environment (e.g., diesel fuel, lubricants, coolants, battery acid, cleaning solvents, etc.) are not expected to have any significant impact provided that a plan for spill containment and clean-up exists. Unlike solids, fluids may become part of the permanent environment through accidental breach of their container, even if the container is maintained. Given a plan for spill containment and clean-up (e.g., Mattick, 1992; YMP, 1993c), non-permanent fluids used in equipment underground are not expected to have significant effects on the geochemistry near potential waste emplacement sites and along potential gaseous and aqueous radionuclide pathways. As stated above in the evaluation of surface-based non-permanent fluids and materials, any planned non-permanent fluids or materials that become retained unintentionally as part of the permanent environment require documentation of the amounts of substance retained in the environment and evaluation of the potential waste isolation impact of that specific retention.

Permanent Inorganic Substances. Items such as steel sets, rebar, lagging (steel), rock bolts, wire mesh, shotcrete and/or fibercrete, cementitious grout, and galvanized steel (in general steel, concrete, and shotcrete) are not expected to have any significant impact because their use near potential waste emplacement sites is expected to overshadow any effects resulting from their use in the Starter Tunnel or Alcove.

Permanent Organic Substances. Organic compounds may accelerate waste package corrosion through enhanced microbial activity and/or facilitate radionuclide transport in the geosphere via complexing of cations (INTERA, 1993). These effects require that the deposited organic materials can migrate to waste package locations or radionuclide pathways in sufficient concentration to have a significant impact. A bounding calculation was performed (Attachment II) to determine the potential influence of organic inputs. In this general analysis, the retained organic materials are assumed to be a point source that completely dissolves as organic carbon, and migrates toward potential waste package emplacement sites. All permanent organic fluids and materials are considered as indistinguishable.

The compounds included in this evaluation are wooden blocking, spray paint, rockbolt resin/epoxy (Dupont Fasloc, Celtite Lokset, Williams Polygrout), wood, any retained organic diesel exhaust components, and concrete admixtures. Although concrete admixtures have organic components, these may be chemically bound in the concrete and potentially may be excluded from this consideration, dependent upon further understanding of their behavior as a function of time and temperature. In any case, concrete admixtures may represent only a small percentage of the total organic material retained underground.

In addition, accidental loss of any organic fluids such as fuels, lubricants, or coolants for equipment necessitates evaluation of those specific unintentional releases and incorporation of those permanently retained amounts of organic fluids into the evaluation of the final configuration of any repository which may be constructed.

Although the total dissolved organic carbon content of the saturated-zone ground waters has been measured ranging from 0.14-0.58 ppm (Means et al., 1983; Choppin, 1992; Minai et al., 1992), to the best of our knowledge there has been no determination of the total dissolved organic content of the unsaturated-zone groundwater. The range of the total dissolved organic carbon (DOC) in many natural groundwaters is about 1-10 ppm (Drever, 1988). Therefore, the natural concentration of dissolved organic matter in the unsaturated zone of Yucca Mountain is estimated here to be on the order of 1 ppm. Peak dissolved organic carbon concentrations produced from the introduced organic materials are assumed to be negligible if they remain less than 0.1 ppm (10% of the ambient value).

The analysis in Attachment II allows limits to be placed on usage of organic materials in the Starter Tunnel and Alcove. In the analysis given below (Attachment II), it is assumed that:

1. the retained organic material represents a point source at the end of the Starter Tunnel,
2. the dissolution of the organic points source is complete and instantaneous,
3. dispersion of the organic source occurs via saturated flow, and
4. no reactions to degrade the concentration of total dissolved organic carbon occur.

The distance from end of the Starter Tunnel to the top of the repository horizon within the potential expansion area (taken as the top of the Tll unit excluding the small wedge adjacent to the western side of the Bow Ridge Fault) is 420 m (Figure 3, USGS, 1993). Given this distance, and flow directed along this path (the shortest distance to the expansion areas), the total mass of organic in the Starter Tunnel and the Alcove should be less than 420 kg (Attachment II, Table 1) to mitigate any potential impact to the expansion areas at the 0.1 ppm DOC. As the projected use of wooden blocking for ground support in the Alcove #1 is 1350. kg, this limit is not likely to be practical. As stated above in Section 2.1, this analysis (Attachment II) *does not indicate* that exceeding the 420. kg value for total retained organic material in the Starter Tunnel and Alcove #1 will produce an impact to waste isolation, but indicates only that there is a potential for some impact at the level of 10% perturbation to the ambient levels of total dissolved organic carbon.

In order to clarify the potential impact resulting from exceeding this 420. kg constraint, further analyses are given in Attachment II which address the migration of DOC plumes via flow directly to the closest point of the Conceptual Perimeter Drift Boundary (a distance of 1400 m and an attitude of 4 degrees below horizontal-USGS, 1993) as functions of the organic source mass (see Tables 2-6 and Figures 1 and 2 in Attachment II). In addition, the effect of flow orientation on the area affected by such plumes is also evaluated (as shown in Figure 1 of Attachment II). The eggs of perturbation shown on Figures 1 and 2 of Attachment II indicate the maximum extent of the Potential Expansion Areas 2, 3, and 6 which may be impacted by retained organic masses exceeding 420 kg. From the analysis in Attachment II it can be concluded that retained organic masses less than about 2500. kg are not expected to impact waste isolation within the potential repository.

It should be reiterated here that this analysis *does not indicate* that an impact to waste isolation will occur if these limits are exceeded, but only that the potential for impacts to waste isolation exist. Although there are insufficient data to quantify *probable* flow scenarios, shallow lateral flow along such a direct path to the repository is not likely to be the most probable case. However, mitigation of potential impacts from this case is expected to minimize impacts from any reasonable flow scenari_ (this excludes the worst-case of disequilibrium fracture-flow).

If the total retained organic materials in the Starter Tunnel and Alcove #1 is less than 420. kg it is expected that there should be negligible impact to the geochemistry of ground water within the Potential Expansion Areas Boundary. If the total retained organic materials in the Starter Tunnel and Alcove #1 is less than 2500. kg, it is expected that the impact to the geochemistry of ground water within the Conceptual Perimeter Drift Boundary should be negligible, although there is some potential for impact to the ground water geochemistry within the it is expected that the Potential Expansion Areas 2, 3, and 6. Given adherence to the 420. kg limit for total organic retained in the Starter Tunnel and Alcove #1, the organic substances are not expected to have significant effects on the geochemistry near potential waste emplacement sites, and along potential gaseous and aqueous radionuclide pathways. However, for total amounts of organic retained in the Starter Tunnel and Alcove #1 between 420. kg and 2500. kg, the organic substances are not expected to have significant effects on the geochemistry near potential waste emplacement sites within the Conceptual Perimeter Drift Boundary, nor along potential gaseous and aqueous radionuclide pathways directly below the potential repository, but may affect the geochemistry near potential waste emplacement sites within the Potential Expansion Areas 2, 3, and 6, and along potential gaseous and aqueous radionuclide pathways above or below them.

3.3 Thermal/Mechanical Characteristics

The potential effects on thermal/mechanical characteristics of rock surrounding a tunnel excavation can be assessed from a waste isolation evaluation (Tsai and Andrews, 1993) that was done to compare the mechanical effects of drill-and-blast excavation against those from mechanical excavation by using the peak particle velocities to evaluate the degree of damage surrounding an excavated volume. This analysis yields the result that a mechanically disturbed zone should extend about 10 m outward around a drill-and-blast operation to produce an 8 m diameter tunnel. In their evaluation, Tsai and Andrews (1993) conclude that because the thickness of this zone is negligible compared to the under- and overlying rock, there is expected to be insignificant impact on the overall waste isolation capability of the overall repository.

3.4 Interpretations

With only one exception, if the constraints discussed above and summarized below are followed, the activities and items considered in this report are not expected to affect significantly the hydrologic, geochemical, or thermal/mechanical characteristics for any portion of the site and, therefore, these activities/items associated with ESF Phase 1A construction are expected to result in negligible impacts on waste package corrosion, release of radionuclides from waste packages, and gaseous and aqueous radionuclide transport.

The single exception is the case of organic material permanently retained underground for which there are two limits given. If the first and lower limit is adhered to, then the retained organics considered in this report are not expected to affect significantly the geochemical characteristics for any portion of the site and, therefore, these substances associated with ESF Phase 1A construction are expected to result in negligible impacts on waste package corrosion, release of radionuclides from waste packages, and gaseous and aqueous radionuclide transport. However, this limit could be exceeded up to the second higher limit with an associated risk of perturbing the ambient concentration of dissolved organic carbon by greater than 10% in portions of Potential Expansion Areas 2, 3, and 6, and subsequently some unclear risk for impacting waste isolation in those areas, but not significantly affecting the geochemical characteristics within the Conceptual Perimeter Drift Boundary.

4. SUMMARY

4.1 Conclusions and Recommendations

Tracers

Tracers listed in section 3.2 are not expected to have significant effects on the geochemistry near potential waste emplacement sites, nor along potential gaseous and aqueous radionuclide pathways and are therefore not expected to significantly impact waste isolation.

Surface Fluids and Materials

Surface water usage is not expected to impact waste isolation if the application rate does not exceed 2 gal/sq.yd./day averaged over a five-year period of water application (YMP, 1993c, Vol. II, App. I). The period for averaging water application shall not exceed 6 months (YMP, 1993b).

The solid materials listed in Section 3.2 are not expected to impact waste isolation because they are non-permanent, surface-based items of very limited solubility making permanent loss of large amounts of material to the environment unlikely. The impacts on waste isolation would need to be evaluated explicitly for any solid materials which become lost to the permanent environment. The other non-permanent, surface-based items listed in Section 3.2 are not expected to impact waste isolation provided the following controls are implemented:

1. Fluid spills are contained and removed in such a manner that fluids are not retained permanently in the subsurface environment. Therefore, as a precaution, it is recommended that spill-resistant barriers are placed between the ground and any components containing substantial fluids so that accidental losses are captured and removed rather than migrating into the underlying rock and becoming permanent items in the environment. In cases of small fluid volumes, the ground surface may represent a sufficient barrier; if a spill is retained in surface material it can be completely removed. In the unlikely event of a spill penetrating into the environment beyond which it can be removed, the amount retained in the environment shall be recorded and impacts to waste isolation shall be evaluated explicitly.

2. To the extent practicable, all non-permanent fluids and materials shall be removed at (or prior to) the time of potential repository closure, and;

3. If items are left in the permanent environment, the impacts to waste isolation shall be evaluated explicitly.

Underground Fluids and Materials

The items/activities discussed above are not expected to impact waste isolation provided the following controls are implemented:

1. Water use is minimized to the extent practical and does not exceed 100 m^3 over any 20 m^2 floor area (~26,500 gal over any 215 ft^2 floor area) of excavation. This does not include water used to make cementitious materials, such as shotcrete or grout.

2. Water is not allowed to pond to the extent practical using conventional mining techniques.

3. Unintentional fluid releases (spills) are contained and removed in such a manner that fluids retained permanently in the subsurface environment are minimized to the extent practical following existing procedures for spill control. In the event of a spill penetrating into the environment beyond which it can be removed, the amount retained in the environment shall be recorded and impacts to waste isolation shall be evaluated explicitly.

4. The total quantity of organic materials permanently retained in the Starter Tunnel and Alcove #1 does not exceed 420. kg (~926 lbs).

In addition, if the total mass of organic materials permanently retained in the Starter Tunnel and Alcove #1 exceeds 420. kg (~926 lbs) but does not exceed 2500. kg (~5510 lbs), it may affect the concentrations of total dissolved organic carbon at levels ≥ 10% of ambient within the Potential Expansion Areas 2, 3, and 6, but is not expected to significantly affect the area of the potential repository (within the CPDB). This higher limit results from the analysis in Attachment II and is provided as input for decisions required in cases where materials must be used for construction (i.e., no reasonable alternatives exist) in quantities higher than the limits set by very conservative scoping calculations which result in limits which, if followed, reasonably mitigate against any impact to conservative surrogate performance parameters (e.g., ambient conditions).

The above recommendations are based solely on the evaluation of potential impacts to waste isolation. Many of these recommendations are included in existing controls for spill containment and cleanup, spoils storage, land reclamation, and recording actual use of tracers, fluids and materials (YMP, 1991b; YMP 1993g; YMP, 1993c; YMP, 1993b; Mattick, 1992).

4.2 Critical Assumptions and Data

The Conclusions and Recommendations given above are directly dependent upon the following conditions/assumptions/data:

1. items planned as non-permanent are removed.
2. approximately 80% of the underground construction water used is removed via muck and/or pumping.
3. the Pah Canyon Member acts as a capillary barrier to water entry into the fractures of the underlying Topopah Springs Member,
4. organic materials instantaneously dissolve completely to organic carbon,
5. dissolved organic carbon does not react and degrade, and
6. flow directly toward the conceptual repository is possible

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Figure 1. Location of the North Portal Pad, Starter Tunnel, and Alcove #1 Relative to the CPDB and Potential Expansion Areas (EG&G, 1992).

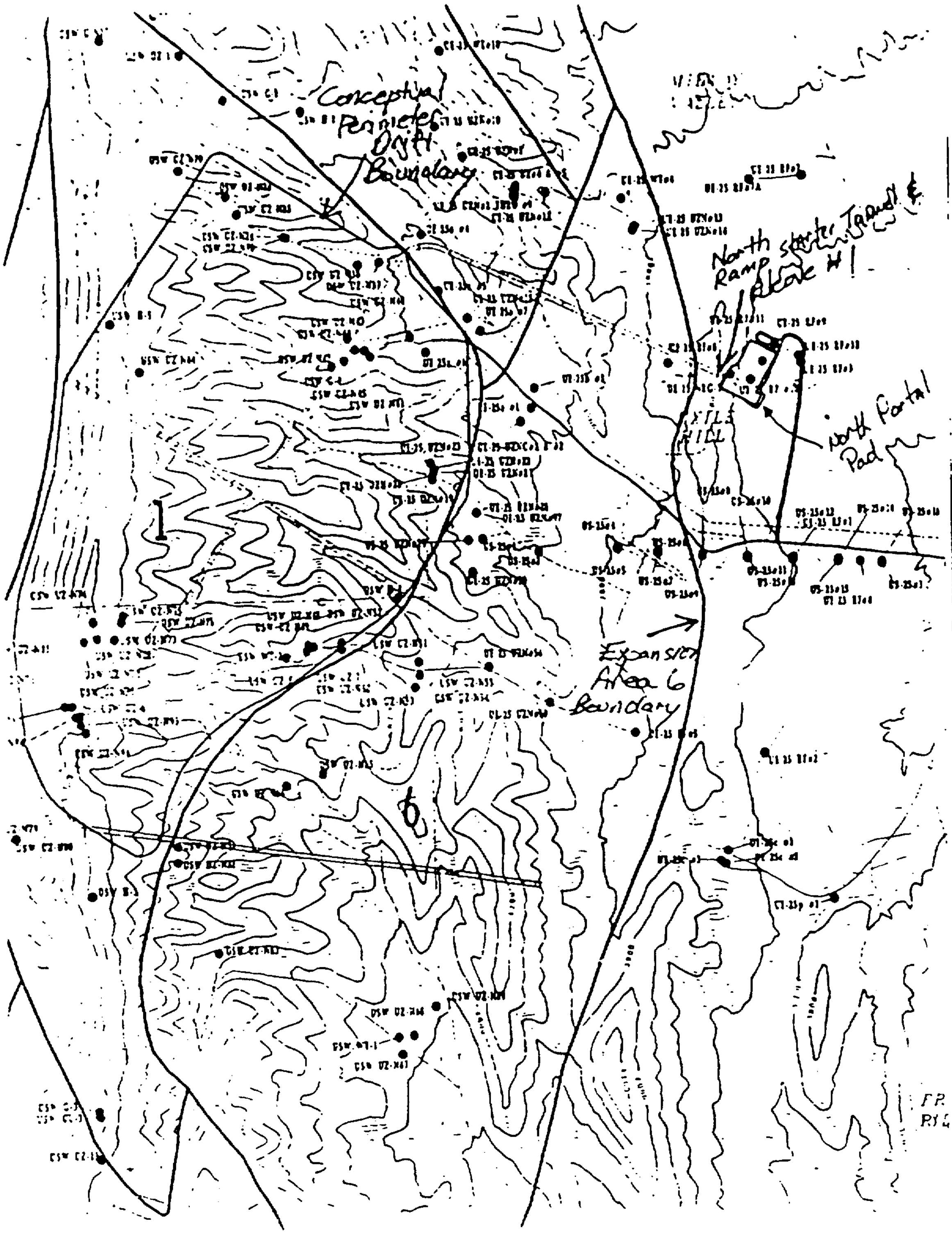

Figure 2. The North Ramp Alcove #1 Underground Configuration (Oliver, 1993b).

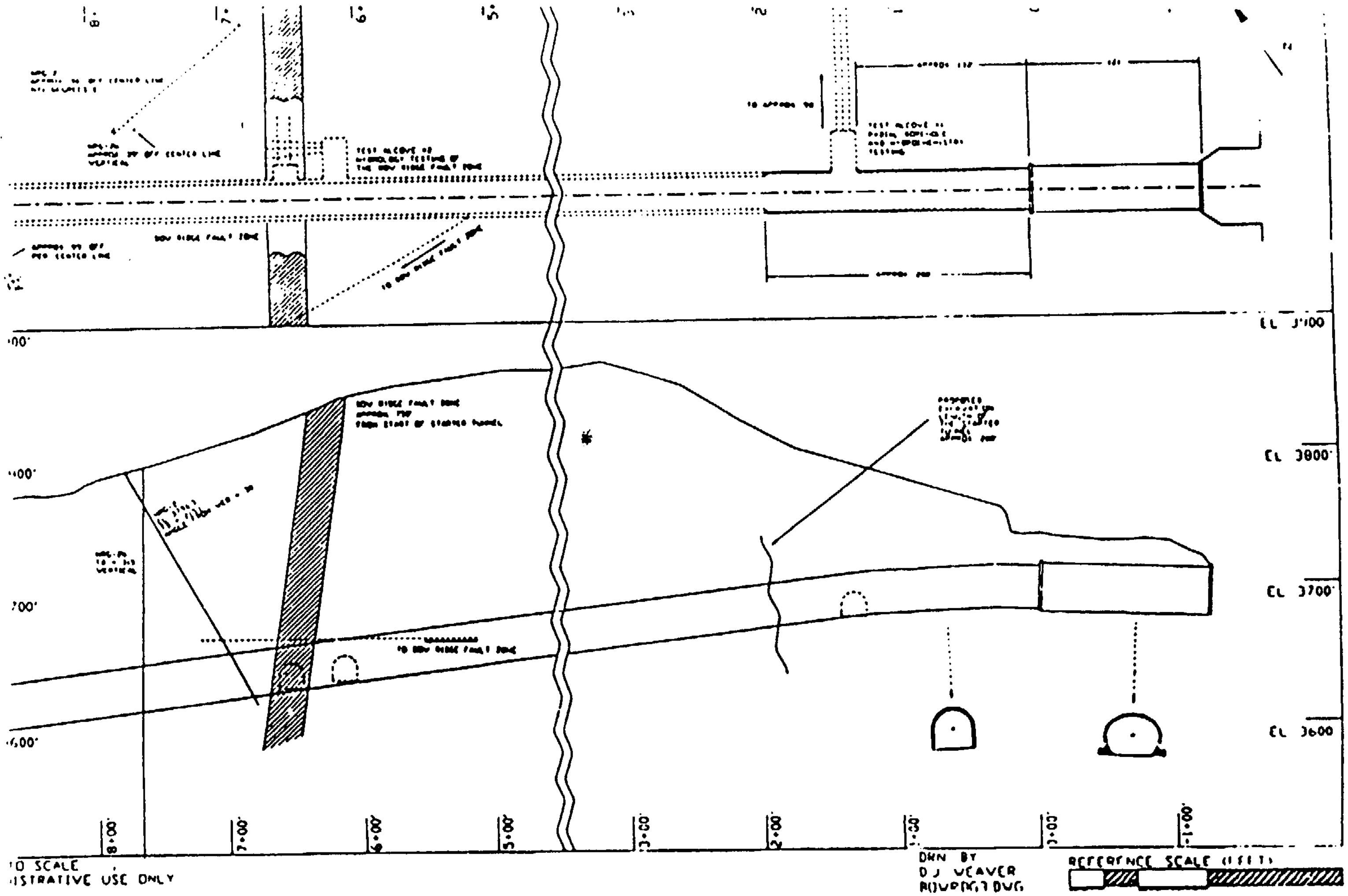

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Figure 3. Geologic Cross-section and Potential Flow Path Through the Bow Ridge Fault (USGS, 1993).

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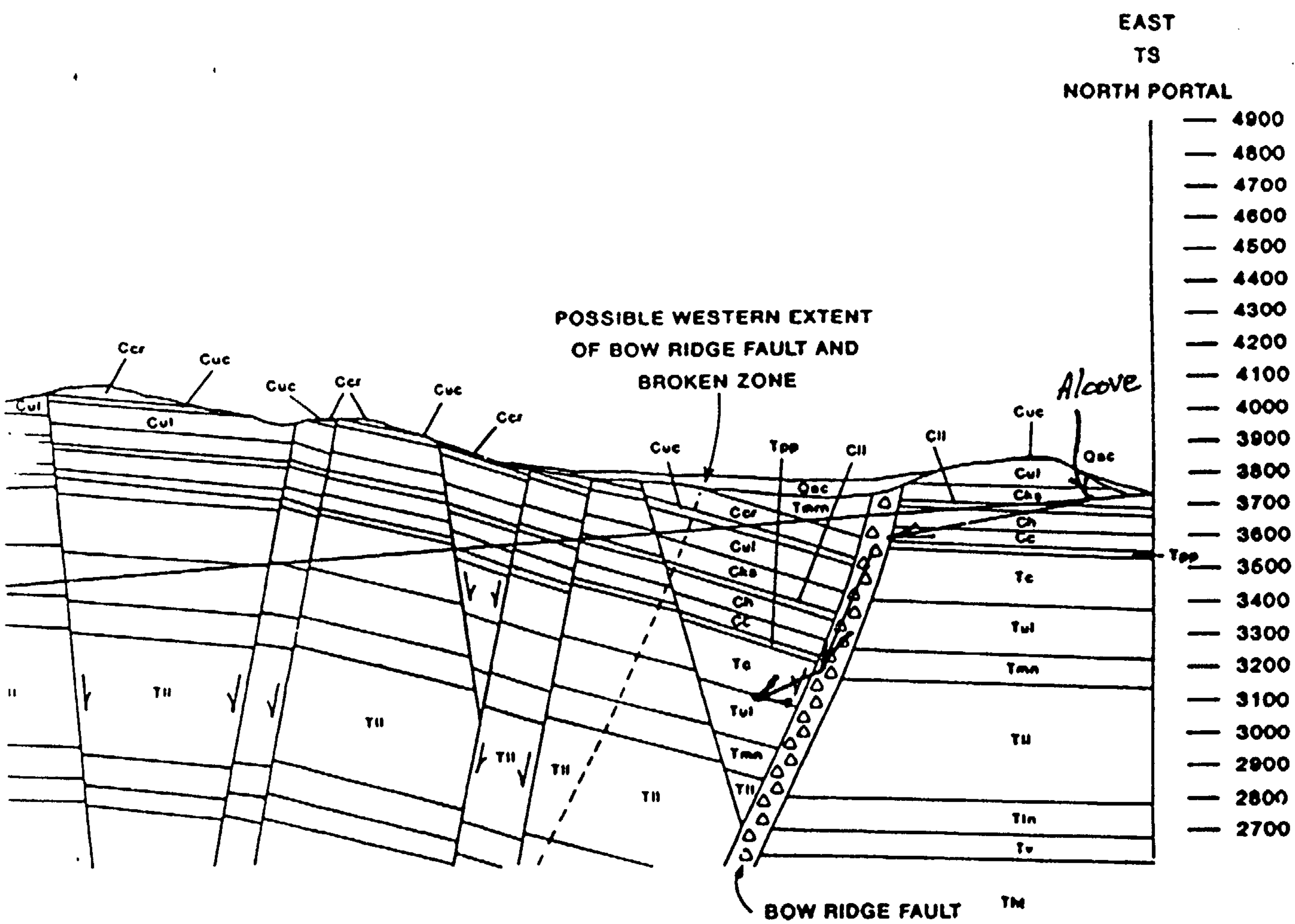

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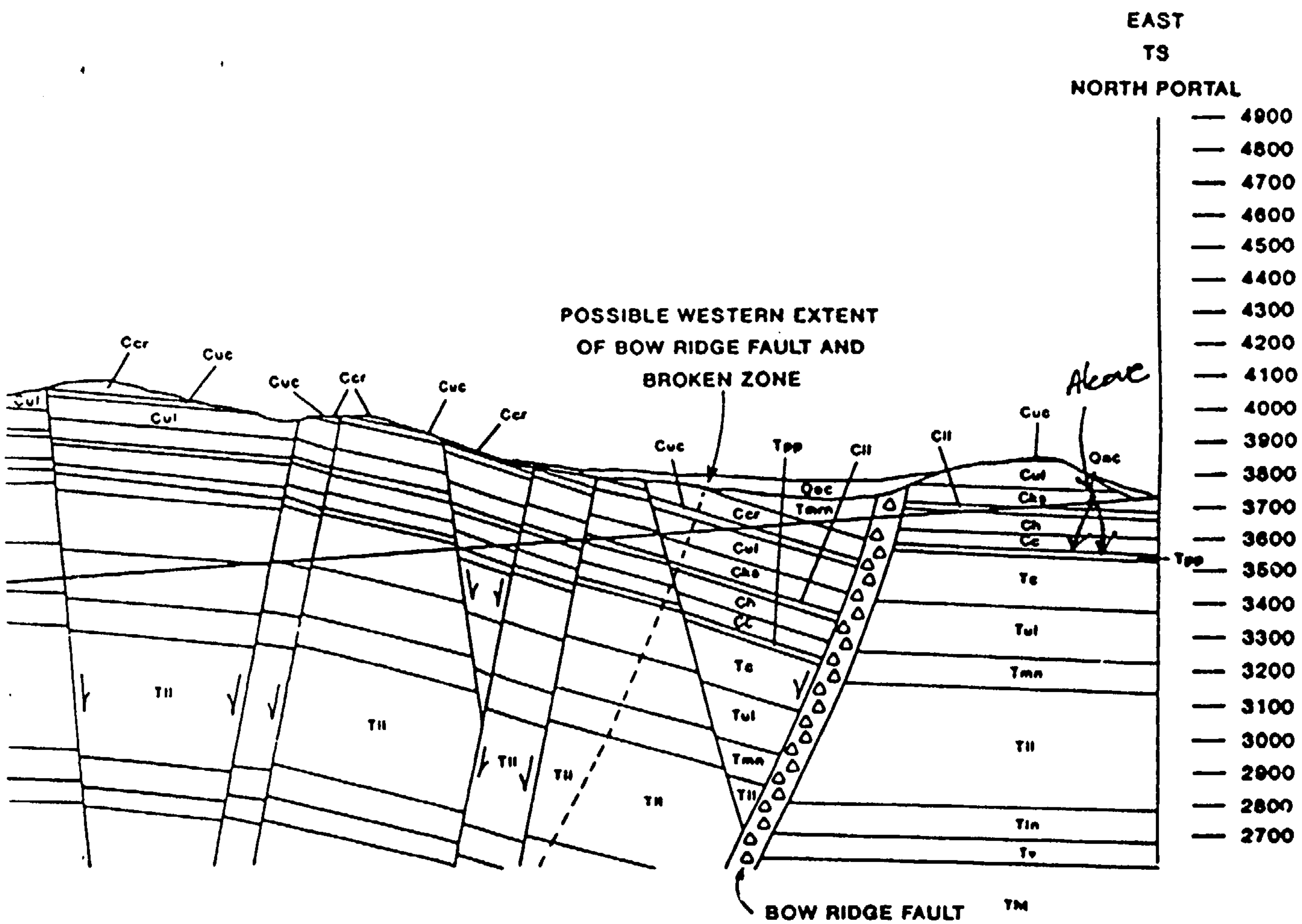
Figure 4. Geologic Cross-section and Potential Flow Path into the Pah Canyon Member (USGS, 1993).



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CHECKLIST OF ACTIVITIES AND TFM FOR WASTE ISOLATION EVALUATIONS	
ACTIVITIES / TFM	**COMMENTS**
I. Water	
A. Surface Sources	
1. Road watering for dust control	See Section 3.1
2. Drill pad dust control	See Section 3.1
3. Equipment washdown	See Section 3.1
4. Natural surface runoff	See Section 3.1
5. Accidental water spillage	See Section 3.1
6. Used in testing	NA
B. Underground	
1. Water loss during drilling	
a) Fishing	NA
b) Other	NA
2. Recovered or produced during drilling	
a) Perched water	NA
b) Water table	NA
3. Used in construction	
a) Drilling	See Section 3.1
b) Construction Materials	See Section 3.1
c) Dust Control	See Section 3.1
d) Equipment washdown	NA
4. Used in testing	NA

CHECKLIST OF ACTIVITIES AND TFM FOR WASTE ISOLATION EVALUATIONS (CONTINUED)				
ACTIVITIES / TFM				COMMENTS
II.	Materials (other than water)			
	A.	Used in surface and subsurface construction		
		1.	Building materials	See Section 3.2
		2.	Leachates from rock & muck piles	See Section 3.1 & 3.2
		3.	Fuels/lubricants/coolants	See Section 3.2
	B.	Used in borehole construction and/or sealing		
		1.	Grout for surface casings	NA
		2.	Drilling fluids	See Section 3.2
		3.	Other materials left in boreholes	See Section 3.2
	C.	Used in testing		NA
III.	Other considerations			
	A.	Physical and chemical characteristics of seals		NA
	B.	Cut-and-fill for roads, pads, trenches & pits		See Section 3.1 & 3.2
	C.	Blasting		See Section 3.2 & 3.3
	D.	Underground excavation		See Section 3.1, 3.2, & 3.3

ANALYSIS OF GEOCHEMICAL PERTURBATIONS FROM ORGANIC MATERIALS

Evaluation of 3-dimensional transport and dispersion from a point source is possible using the three dimensional dispersion equation given by Fischer et al. (1979; p. 49) as

$$C(x,y,z,t) = \left[\frac{M_{org}}{(4\pi t)^{3/2}(D_x D_y D_z)^{1/2}}\right]\exp\left\{-\frac{x^2}{4D_x t}-\frac{y^2}{4D_y t}-\frac{z^2}{4D_z t}\right\} \qquad (1)$$

where M_{org} represents the mass of the organic source term, x, y, and z indicate the distances in three orthogonal dimensions from the peak concentration of the plume, D_x, D_y, and D_z indicate the dispersion coefficients in each direction, and t refers to travel time. In addition, for flow in saturated porous media this relation is modified by the porosity (ϕ) such that

$$C(x,y,z,t,\phi) = \left[\frac{M_{org}}{\phi(4\pi t)^{3/2}(D_x D_y D_z)^{1/2}}\right]\exp\left\{-\frac{x^2}{4D_x t}-\frac{y^2}{4D_y t}-\frac{z^2}{4D_z t}\right\} \quad . \qquad (2)$$

The travel time (t) can be written as

$$t = L_x / V_x \qquad (3)$$

where V_x refers to the average linear flow velocity in the direction of advective transport, and L_x represents the distance traveled by the concentration peak along the flow direction. The dispersion coefficients in each orthogonal direction can be represented as (de Marsily, 1986)

$$D_x = a_x V_x \quad , \qquad (4)$$

$$D_y = a_y V_x \quad , \qquad (5)$$

and

$$D_z = a_z V_x \quad , \qquad (6)$$

where a_x, a_y, and a_z signify the dispersivities in the orthogonal coordinate system around the peak concentration in the plume. Substituting Equations 3-6 into Equation 2 and cancelling like terms leads to

$$C(x,y,z,L_x) = \left[\frac{M_{org}}{\phi\,(4\pi L_x)^{3/2}(a_x a_y a_z)^{1/2}}\right]\exp\left\{-\frac{x^2}{4a_x L_x}-\frac{y^2}{4a_y L_x}-\frac{z^2}{4a_z L_x}\right\} \quad . \qquad (7)$$

This equation can be used to solve for the farthest migration distance (L_{max}) of a specified concentration (C_{limit}) by noting that this value corresponds to that of the peak concentration in the plume at L_{max}. Because the peak concentration lies at the center of the orthogonal coordinate system (x=0, y=0, z=0) Equation 7 reduces to

$$C_{limit} = \left[\frac{M_{org}}{\phi\,(4\pi L_{max})^{3/2}(a_x a_y a_z)^{1/2}}\right] \quad . \qquad (8)$$

Assuming a porosity of 10% (ϕ=0.1), setting the perturbation value (C_{limit}) to 0.1 ppm, and using minimum values of dispersivities (which would give maximum distances) that apply to field-scale transport in fractured lithologies taken from de Marsily (1986) (a_x=30.0 m; a_y=20.0 m; and a_z=20.0 m) allows solution of Equation 8 for the maximum transport distance of C_{limit} along the flow direction (L_{max}) as a function of the mass (M_{org}) of the source (Table 1).

Table 1. **Maximum transport distance for 0.1 ppm dissolved organic carbon perturbation as a function of source mass.**

M_{org} (kilograms)	M_{org} (pounds)	L_{max} (meters)
420.	926.	420.
500.	1102.	472.
1000.	2205.	749.
2000.	4409.	1189.
3000.	6614	1558.
4000.	8818.	1887.
5000.	11023.	2190.

It should be noted that for greater porosity and/or larger values of the dispersivities the calculated maximum transport distances for a 0.1 ppm total dissolved organic carbon perturbation would be reduced relative to those shown in Table 1. In addition, this calculation assumes saturated pore spaces and equilibrium between fracture fluids and matrix pore fluids. If actual values of saturation are lower, a larger volume would be required to achieve the same dilution. This calculation is not directly applicable to the case of disequilibrium fracture flow. For that scenario, transport may be efficient enough such that no substantial dilution would occur and, as such, even minor amounts of organic material would be prohibitive. However, because this type of flow may be episodic, the total amount of organic mass transported may be small. The requisite information to address this scenario even semi-quantitatively has not been amassed at this time. The scenario addressed here, three-dimensional dispersion in a saturated porous medium with flow oriented toward the closest point of the CPDB, is viewed as a reasonable bounding calculation.

In addition to calculation of the maximum transport distance along the flow direction, the maximum lateral extent of a perturbation concentration (y_{max}) can be evaluated for transport distances from $L_x = 0$ to L_{max} by noting that its location corresponds spatially to the point in the plume where $x = 0$ and $z = 0$. Substituting these constraints into Equation 7, rearranging, and solving for y_{max} results in

$$y_{max} = \sqrt{4 a_y L_x \left\{ \ln\left[\frac{M_{org}}{\phi (4\pi L_x)^{3/2} (a_x a_y a_z)^{1/2}} \right] - \ln(C_{limit}) \right\}} \quad . \qquad (9)$$

Using the same values for ϕ, C_{limir} and a_x, a_y, and a_z given above, this expression reduces to

$$y_{max} = \sqrt{80 L_x \left\{ \ln\left[\frac{M_{org}}{487.98 (L_x)^{3/2}} \right] + 2.3026 \right\}} \quad . \qquad (10)$$

Note that $y_{max} = 0$ in the limit as $L_x = L_{max}$, consistent with the above calculation of L_{max} as a function of M_{org}. Tables 2, 3, 4, and 5 contain the calculated value of y_{max} as a function of L_x for values of M_{org} of 420. kg, 1000. kg, 2000. kg, and 3000. kg, respectively.

Table 2. Maximum lateral distance for 0.1 ppm dissolved organic carbon perturbation as a function of distance along the flow path for 420. kg of organic material.

L_x (meters)	y_{max} (meters)
1.	27.
50.	113.
100.	131.
200.	133.
300.	110.
350.	87.5
400.	48.4
410.	34.4
415.	24.4
420.	0

Table 3. **Maximum lateral distance for 0.1 ppm dissolved organic carbon perturbation as a function of distance along the flow path for 1000. kg of organic material.**

L_x (meters)	y_{max} (meters)
1.	28.
50.	127.
100.	155.
200.	178.
300.	181.
400.	173.
500.	156.
600.	126.
700.	75.
720.	58.
730.	47.
740.	32.
745.	21.
749.	0

Table 4. Maximum lateral distance for 0.1 ppm dissolved organic carbon perturbation as a function of distance along the flow path for 2000. kg of organic material.

L_x (meters)	y_{max} (meters)
1.	29.
50.	138.
100.	172.
200.	207.
300.	223.
400.	229.
500.	228.
600.	222.
700.	211.
800.	195.
900.	173.
1000.	144.
1100.	101.
1150.	68.
1170.	47.
1180.	32.
1185.	21.
1189.	0

Table 5. **Maximum lateral distance for 0.1 ppm dissolved organic carbon perturbation as a function of distance along the flow path for 3000. kg of organic material.**

L_x (meters)	y_{max} (meters)
1.	30.
50.	144.
100.	182.
200.	222.
300.	244.
400.	255.
600.	262.
800.	252.
1000.	231.
1200.	194.
1400.	134.
1500.	82.4
1525.	62.
1540.	46.
1550.	30.
1555.	18.
1558.	0

The loci of y_{max} values define 2-dimensional ovoids, or "eggs", of 0.1 ppm dissolved-organic-carbon perturbation limits for a given source mass of organic material. These eggs of perturbation are oriented lengthwise along the flow direction, have their broader ends pinned at the point source (L_x = 0), and taper toward L_{max}. The surface projections for 0.1 ppm eggs of perturbation from source masses of 420. kg, 1000. kg, 2000. kg, and 3000. kg, are shown in Figure 1 for a flow direction oriented *from* the end of the starter tunnel *to* the closest point of the Conceptual Perimeter Drift Boundary (CPDB) at the depth of the potential repository (top of the Tll unit-USGS, 1993). Because this flow orientation is relatively shallow (~4° from horizontal), the projections are essentially identical to the unprojected shapes. The tip of any perturbation egg represents the furthest extent of the 0.1 ppm concentration limitation for that given source mass. Lateral rotation of any egg of perturbation as a function of flow orientation allows demarcation of its concentration limitation. These boundaries are also shown on Figure 1 as long dashed arcs.

Because the dispersivities in the y-direction and z-direction are the same, these eggs are symmetric in the third dimension and, therefore, the flow direction represents an axis of rotational symmetry. A generalized cross section along the approximate flow path is shown in Figure 2 where the vertical eggs of perturbation for the 420 kg and the 3000 kg source masses are shown.

A problem in applying this simple three-dimensional calculation of these perturbation eggs to such a shallowly dipping flow orientation can be seen by examination of Figure 2. Because the volume in which dispersion would occur is calculated to extend above the ground surface, these perturbation eggs can only be used as approximate guides unless explicit account is taken of the material "deflected off" of the ground surface boundary. The effect of this boundary can be accounted for by adding a fictive image source which is offset above the ground surface by an amount equivalent to the depth of the actual source. The flow path of the image source is constrained to be oriented identically to the lateral direction of the actual source, but diverges in the vertical direction at an angle *above the ground surface* equivalent to the *angle below the ground surface* made by the flow path of the actual source. This situation corresponds to the ground surface functioning as a mirror plane.

In order to solve the dispersion transport equation, these two sources need to be put into an equivalent coordinate system, the equations for the concentrations combined, and then algebraically manipulated in the manner used above for the single equation. The algebraic manipulation and solution for y_{max} is more complex than the simple hand calculations presented above so that a simplified alternative approach was used that adds the contribution of the image source to the 0.1 ppm levels at the calculated y_{max} locations for the actual source. This calculation allows an evaluation of the relative sensitivity of the shape of the eggs of perturbation to the breaching of the ground surface by the dispersion plume and only requires the development of a coordinate transformation, in addition to the algebra presented above

For the actual source, a stationary orthogonal coordinate system is defined with the origin at the source point X_1 increasing along the flow path, Y_1 is in the horizontal orientation, and Z_1 increases upward. The identically oriented orthogonal coordinate system that is moving with the concentration peak is given by

$$x_1 = X_1 - V_1 t_1 = X_1 - L_x \quad , \qquad (11)$$

$$y_1 = Y_1 \quad , \qquad (12)$$

and

$$z_1 = Z_1 \quad . \qquad (13)$$

For the image source, a stationary orthogonal coordinate system is defined with the origin offset by 60 m (K_{off}) from the actual source origin and with the image source axes in the x-z plane rotated through an angle (θ) of 16 degrees upward (such that the x-axis of the image source slants at 8 degrees above the average surface line, mirroring the x-axis of the actual source which dips 8 degrees below the average surface line). In this case, X_2 is along the flow path of the image source, Y_2 is oriented identically to Y_1, and Z_2 is increasing upward. The relation between these two stationary coordinate systems is given by

$$X_2 = X_1 \cos\theta + Z_1 \sin\theta \quad , \tag{14}$$

$$Y_2 = Y_1 \quad , \tag{15}$$

and

$$Z_2 = -X_1 \sin\theta + Z_1 \cos\theta - K_{off} \quad . \tag{16}$$

For the moving coordinate system travelling with the concentration peak from the image source we then have (noting that $V_2 = V_1$ and $t_2 = t_1$)

$$x_2 = X_2 - V_2 t_2 = (X_1 \cos\theta + Z_1 \sin\theta) - L_x \quad , \tag{17}$$

$$y_2 = Y_2 = Y_1 = y_1 \quad , \tag{18}$$

and

$$z_2 = Z_2 = -X_1 \sin\theta + Z_1 \cos\theta - K_{off} \quad . \tag{19}$$

Along the traces of $y_{1,max}$ for the actual source, $x_1 = 0$ and $z_1 = 0$, therefore $X_1 = L_x$ and $Z_1 = 0$. Substituting these constraints into Equations 17-19 results in

$$x_2 = L_x \cos\theta - L_x \quad , \tag{20}$$

$$y_2 = Y_2 = Y_1 = y_1 \quad , \tag{21}$$

and

$$z_2 = -L_x \sin\theta - K_{off} \quad . \tag{22}$$

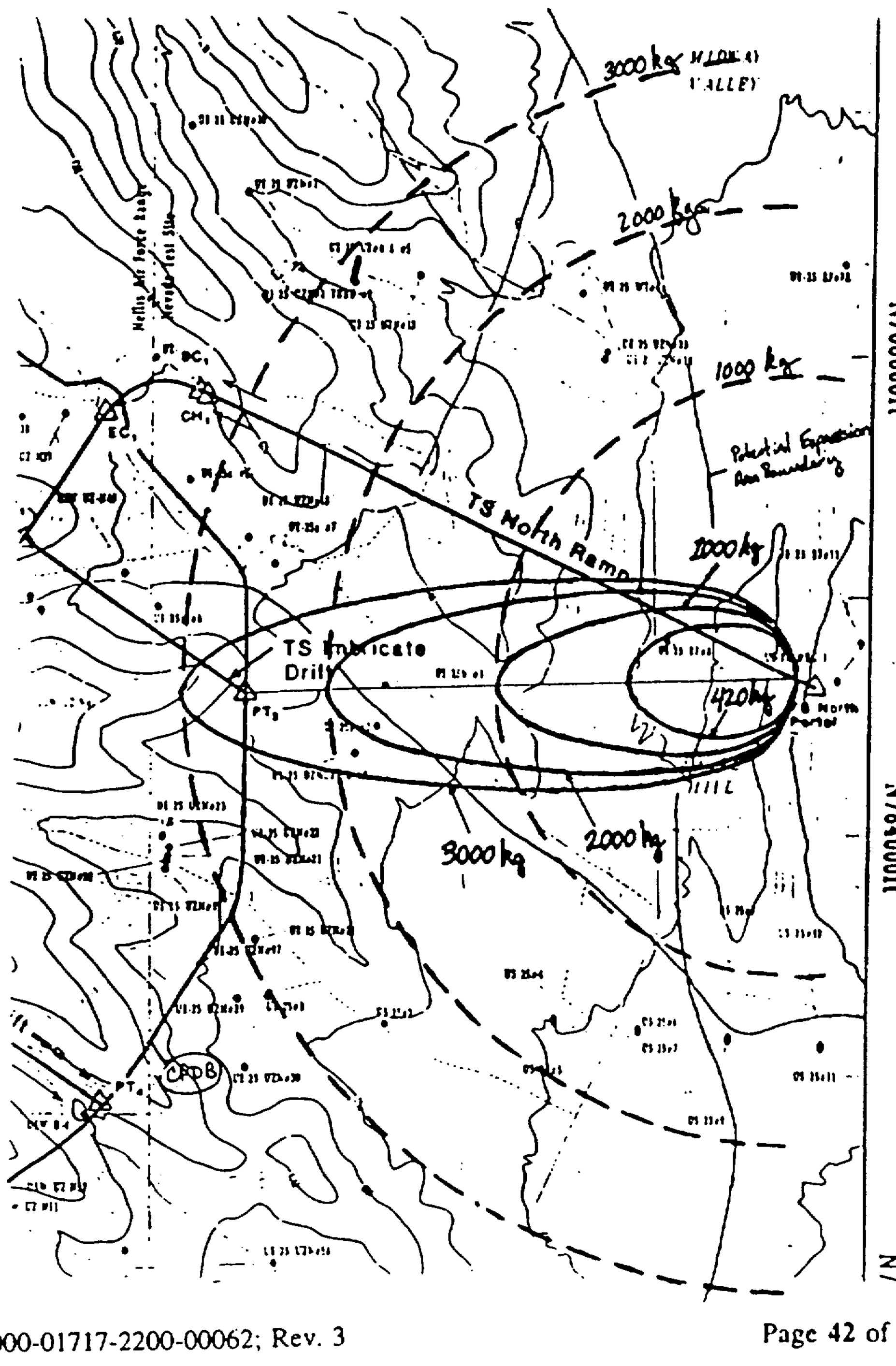
Using this coordinate transformation and Equation 7, the additional contribution (C_{add}) to the dissolved organic carbon from the image source to the 0.1 ppm at $y_{1,max}$ can be calculated and combined as a function of L_x and x_2, y_2, and z_2. The values calculated for a 3000. kg source term (the largest effect) are shown in Table 6.

Table 6. **Additional contribution to 0.1 ppm dissolved organic carbon perturbation egg resulting from image source for 3000. kg of organic material.**

L_r (m)	$y_2 = y_{1,max}$ (m)	x_2 (m)	z_2 (m)	C_{add} (ppm)
1.	30.	-0.039	-60.28	1.5×10^{-21}
50.	144.	-1.937	-73.78	0.025
100.	182.	-3.874	-87.56	0.037
200.	222.	-7.748	-115.13	0.044
300.	244.	-11.622	-142.69	0.042
400.	255.	-15.495	-170.26	0.041
600.	262.	-23.243	-225.38	0.034
800.	252.	-30.991	-280.51	0.029
1000.	231.	-38.738	-335.64	0.024
1200.	194.	-46.486	-390.77	0.020
1400.	134.	-54.234	-445.89	0.017
1500.	82.4	-58.1075	-473.46	0.015
1525.	62.	-59.076	-480.35	0.015
1540.	46.	-59.657	-484.48	0.015
1550.	30.	-60.044	-487.24	0.014
1555.	18.	-60.2381	-488.62	0.014
1558.	0	-60.354	-489.44	0.014

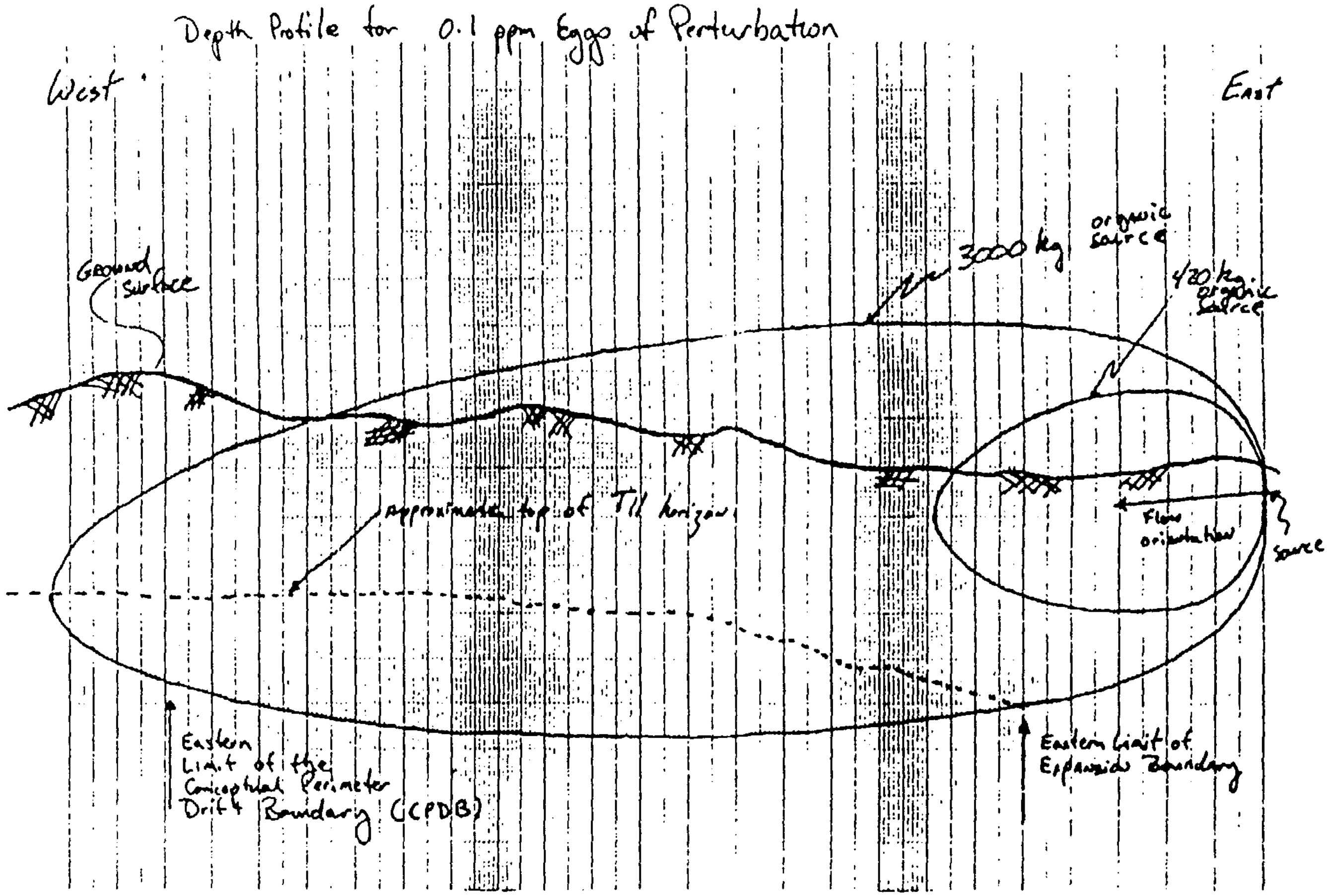
Examination of Table 6 reveals that, although the 0.1 ppm boundary may be affected by up to 44% relatively near the source (at 200 m), the farthest extent of this egg is only affected by 14%. This addition corresponds approximately to an increase of 10% in the length of the 0.1 ppm egg. For the smallest source mass of 420. kg (Table 2), the egg of perturbation would be extended by about 30% by this type of interaction. These effects are well within the uncertainties of this calculation (particularly fc the assumed porosity of 0.1, and the choice of constant values for the dispersivities), and the eggs of perturbation shown in Figure 1 can be used as guides to the potential impacts of various masses of organic materials in the Starter Tunnel and Alcove #1.

Attachment II: Figure 1. Surface projections for 0.1 ppm eggs of perturbation from source masses of 420. kg, 1000. kg, 2000. kg, and 3000. kg for a flow direction oriented *from* the end of the starter tunnel *to* the closest point of the Conceptual Perimeter Drift Boundary (CPDB) at the depth of the potential repositry (top of the Tll unit-USGS, 1993). Also shown, as long dashed arcs, are the 0.1 ppm concentration limitation boundaries as a function of Lateral rotation of flow orientation.



DIE for ESF Starter Tunnel Drill-and-Blast Section, BAB000000-01717-2200-00003-07, Attachment 6 , Page 45 of 46

Attachment II: Figure 2. A generalized cross section along the approximate flow path showing the vertical dimension of the eggs of perturbation for the 420 kg and the 3000 kg source masses.



CRWMS M&O

Personal Communication Record

WBS 1.2.5.4.7
QA: QA
Page 1 of 1

Content of Personal Communication:

During drill and blast operations, water is used to drill blast holes, drill rock bolt holes, and suppress dust from the muck pile. It is conservatively estimated that 80% of this water will be removed from the underground environment through muck removal, pumping of ponded water on the tunnel floor, and evaporation. This estimate assumes that the use of water is minimized, to the extent practical, for drilling holes and controlling dust

Information Source
Name: JOHN D. PETERS
Organization: ESF DESIGN
Signature: [signature] Date: 12/10/93

Information Recipient
Name: [illegible handwriting]
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