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SYNOPSIS: A major hazardous waste disposal facility near Arlington, Oregon serving the Pacific Northwest, Canada, and Alaska maintains numerous favorable environmental characteristics for siting of a hazardous waste disposal facility.

The risk of contamination as a result of potential leakage from a waste management unit via primary pathways to surface water, groundwater or by direct contact and/or ingestion is thus reasonably low. However, these same characteristics which make the site most suitable for hazardous waste disposal often conflict with: 1) the demonstration of the groundwater monitoring system's ability to adequately perform immediate leak detection monitoring as mandated under the Resource Conservation and Recovery Act (RCRA), 40 CFR Part 264, part F, and, 2) the level of demonstration required for the site to be "properly characterized."

INTRODUCTION

An extensive field investigative program to characterize existing site geologic and hydrogeologic conditions was conducted during the period from December, 1983 through November, 1986 in support of a Part B Application under RCRA (Dames & Moore, 1983). This program has included:

- Detailed geologic mapping including trenching to evaluate and characterize faults;
- Drilling of over 102 boreholes and installation of over 120 wells/piezometers to depths ranging to 363 feet below ground surface to evaluate subsurface hydrogeologic conditions and the groundwater flow regime;
- Collection of undisturbed samples for detailed laboratory evaluation and testing;
- Performance of both pumping/packer and slug tests to assess in-situ hydraulic characteristics and possible intercommunication between the uppermost aquifer and the underlying basalts;
- Performance of both surface and borehole geophysics;
- Performance of analytical testing of groundwater samples to evaluate general water chemistry and water quality, including the presence of tritium to assess recent recharge; and
- Development of a groundwater detection monitoring network.

The results of the site characterization, specfically, the site geology, and the existing groundwater recharge-discharge regime, and the implication to site suitability and groundwater detection monitoring are discussed herein.

SITE DESCRIPTION

The Arlington facility is located 6.5 miles south of the Columbia River and 7.5 miles southwest of the town of Arlington in Gilliam County, Oregon (Figure 1). The facility site is situated on a 640-acre parcel, of which 320 acres (eastern tract property) are currently used for waste management operations (Figure 2). The property is bounded on the south by the east-west trending Alkali Canyon at an elevation of approximately 700 feet (site datum). The upland plateau is at an elevation of approximately 850 to 995 feet. Waste management activities are limited to that area above 920 feet on the eastern tract property. In the southern portion of the property bounded by Alkali Canyon, the relief between the valley floor and the upland plateau is approximately 280 feet.

Adjacent tracts to the north, east, south and west of the site are owned by others. Portions of the tract to the east of the Chem-Security site are under cultivation and are irrigated. The facility is remote from any residential, commercial, or industrial developments. The nearest residence is approximately one mile by road west of the western site boundary.

FACILITY LAYOUT AND OPERATION

The Arlington facility was opened in 1976 and provides hazardous waste treatment, storage, and disposal services primarily to the Pacific Northwest, Alaska, and Hawaii, although it also receives hazardous wastes from other western states and Superfund-related activities. The Arlington facility presently operates under RCRA Part A Interim Status authorization, and a Hazardous Waste Disposal Site License from the Oregon State Department of Environmental Quality (DEQ License No. HW-1). PCB wastes regulated under the Toxic Substances Control Act (TSCA) are accepted at the site under authorization from EPA Region X and are stored, treated, and

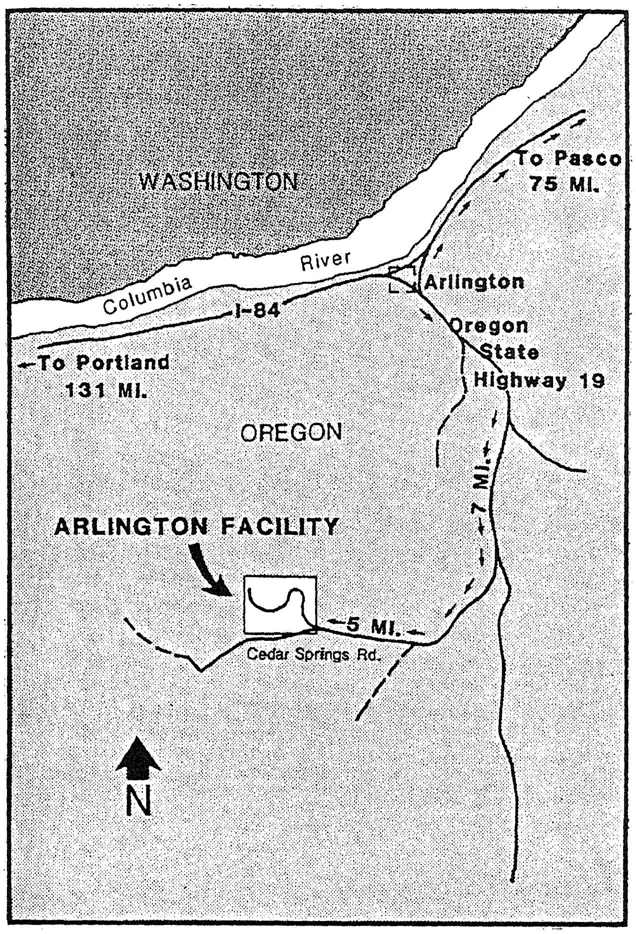

Figure 1 Site Location Map

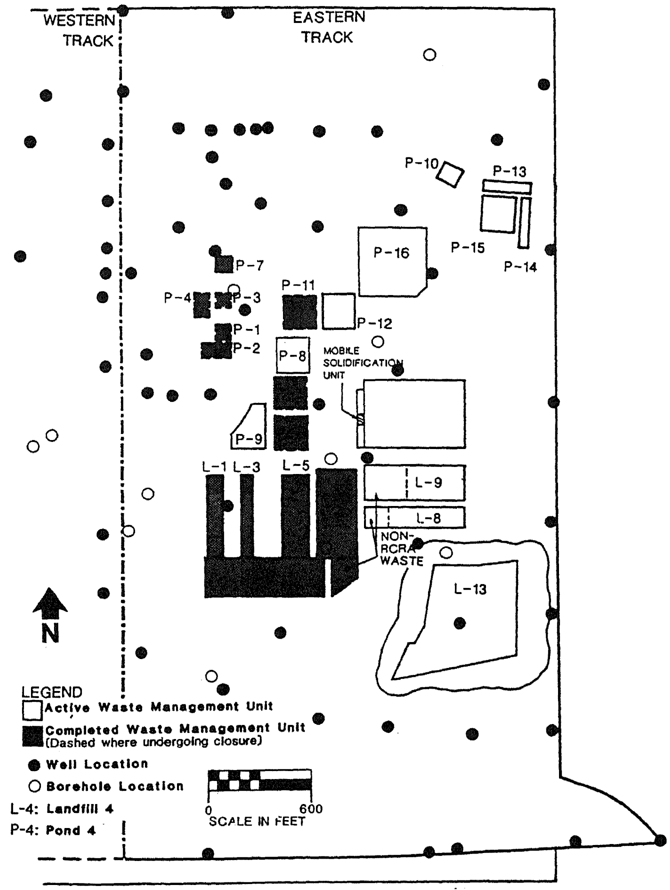

Figure 2 Facility Layout Map Showing Major Waste Management Units

disposed of separately from the RCRA-regulated wastes. The facility does not accept explosive, radioactive, or infectious wastes. Wastes that cannot be treated or disposed of at the facility, or that can be reused or recycled are temporarily stored at the facility and then shipped elsewhere for treatment, recycling, disposal, or beneficial use.

The existing waste management units that require groundwater monitoring under RCRA at the Arlington facility include surface impoundments, reactive solids hydrolysis, and landfills (of which four are complete), seven container storage areas and four storage tanks comprise the existing major RCRA waste management units at the site; although additional facilities are planned for the future. A liquid waste solidification system and a truck-wash operation are also in use. The layout of the existing waste management units of most importance at the facility shown in Figure 2.

GEOLOGIC SETTING

The Arlington facility is located in the south-central portion of the Columbia Plateau physiographic province within the Deschutes-Umatilla Plateau (Dicken, 1955). The area is characterized by upland areas of sandy deserts separated by relatively wide, deep to moderate ephemeral stream drainages such as the Alkali Canyon which borders the south side of the property. In addition to the semi-arid climate, several factors account for the physiography of the area and include the presence of extensive flood-basalt bedrock, subsurface geologic structure, and catastrophic floods of glacial meltwater.

The subsurface geology of the facility and surrounding areas consists of a thick, accordantly layered sequence of basalt flows and sedimentary interbeds, collectively known as the Columbia River Basalt Group. The basalt flows are part of the Columbia Plateau geological flood-basalt province (Fenneman, 1931) of Miocene to lower Pliocene age (8 to 17 million years old). This sequence is unconformably overlain by younger intercalated and suprabasalt sedimentary units of Miocene to Holocene age.

Within the site area the formations which comprise the Columbia River Basalt and the Ellensburg Formation include several members of regional extent. These are the Frenchman Springs and Priest Rapids Members of the Wanapum Basalt, the Pomona Member of the Saddle Mountains Basalt, and the Selah and Rattlesnake Ridge Members of the Ellensburg Formation. In addition to these formal stratigraphic units, several informal units useful to comprehension of site structure and stratigraphy are defined. These include several unnamed interbeds within the Priest Rapids Member, and an areally extensive vitric tuff which occurs at the top of the Selah Member. In addition to the informal units are several facies of local extent. These include three facies of different lithology within both the Selah Member of the Ellensburg Formatoin and the Dalles Formatoin. A generalized stratigraphic column is shown in Figure 3. A discussion of the underlying geologic units, oldest to youngest, is presented below:

Grand Ronde Basalt

The Grande Ronde Basalt is the oldest formation within the Columbia River Basalt group in the site area. In the site area, thickness of the Grande Ronde Basalt is not known although it is suggested to be probably 3,000 to 4,000 feet thick based on review of well records and regional outcrops (Rockwell Hanford Operations, 1979). Because these large flows advanced to the limits of the Plateau and then cooled while ponded, they form nearly continuous sheets of competent, black, glassy, fine-grained, columnar-jointed basalt, which are separated by vesicular to rubbly flow breccias which occur at the top of most of the flows. Only a few thin discontinuous sediments occur as interbeds within the Grande Ronde. This unit was not penetrated by on-site borings.

Vantage Member of the Ellensburg Formation

The Vantage Member of the Ellensburg Formation is an arkosic sandstone deposited by the ancestral Columbia River on top of the Grande Ronde Basalt. In most areas of the Plateau the Vantage sandstone is absent; however, a well developed saprolitic soil generally considered to be part of the member occurs at its stratigraphic position on top of the Grande Ronde. This unit was also not penetrated by on-site borings but is about 22 feet in thickness as noted in a boring drilled about six miles southeast of the facility (Foundation Sciences, Inc., 1980a).

Priest Rapids Member

The Priest Rapids Member of the Wanapum Basalt consists of two to six large and several smaller basalt flows. In the site area, the member is comprised of two flows which are laterally contiguous with the Priest Rapids Member north of the Columbia River (Schminke, 1964) and generally separated by an interbed. A thickness of 136 feet is inferred from a geophysical log of the onsite water supply well.

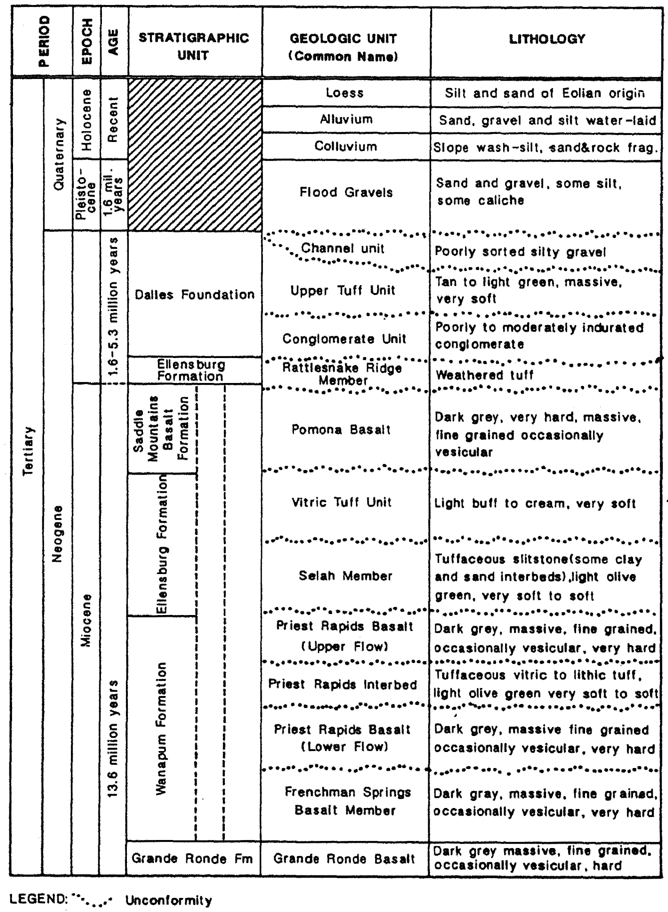

Figure 3 Generalized Stratigraphic Column

The upper part of the lower Priest Rapids flow and the Priest Rapids interbed are exposed in several outcrops in the vicinity of the site, and were reached in several onsite boreholes. The lower flow is approximately 45 feet thick. It is very similar to the upper flow with respect to petrography, jointing, and joint linings; however, in most of the boreholes the lower flow has a flow-top breccia. This breccia consists of ash to block-size fragments of scoria and vesicular basalt that is often loose; however, in some places it is slightly welded to form a relatively competent rock. Open voids are typical of this interval. In some boreholes, the voids are infilled with fine-grained sedimentary material which effectively reduces the permeability of the breccia.

The Priest Rapids interbed varies from two-to-twelve feet thick in boreholes at the site and is characterized as a tuffaceous siltstone; however, it is quite variable in lithology and includes clayey silt, silty clay, weathered hyaloclastite, and clayey silty sandstone.

The upper Priest Rapids flow at the site generally consists of hard,dark gray to greenish gray basalt. The upper few feet of the flow consist of vesicular basalt, flow breccia, or scoria that is moderately weathered or decomposed. The weathered basalt consists of soft to medium hard rock with the consistency of a clayey, sandy siltstone becuase of alteration.

The upper Priest Rapids flow varies from approximately 60 to 95 feet in thickness at the site. In outcrops in Alkali Canyon southwest of the site, the upper Priest Rapids flow is characterized by well developed columnar jointing ranging from four to eight feet in diameter and rise from the base of the flows for two-thirds to three-fourths the total thickness. Nearly vertical and roughly hexagonal in cross section, these columns are cut into sections by subhorizontal cross-joints with highly variable spacing (0.5 to 10 feet). Randomly oriented joints frequently extend through the upper part of the colonnade. These random joints increase in density upwards, creating a brickbat jointing pattern which forms the upper one-third to one-fourth of the flow. A generalized schematic diagram showing the stucture of a typical basalt flow is shown in Figure 4.

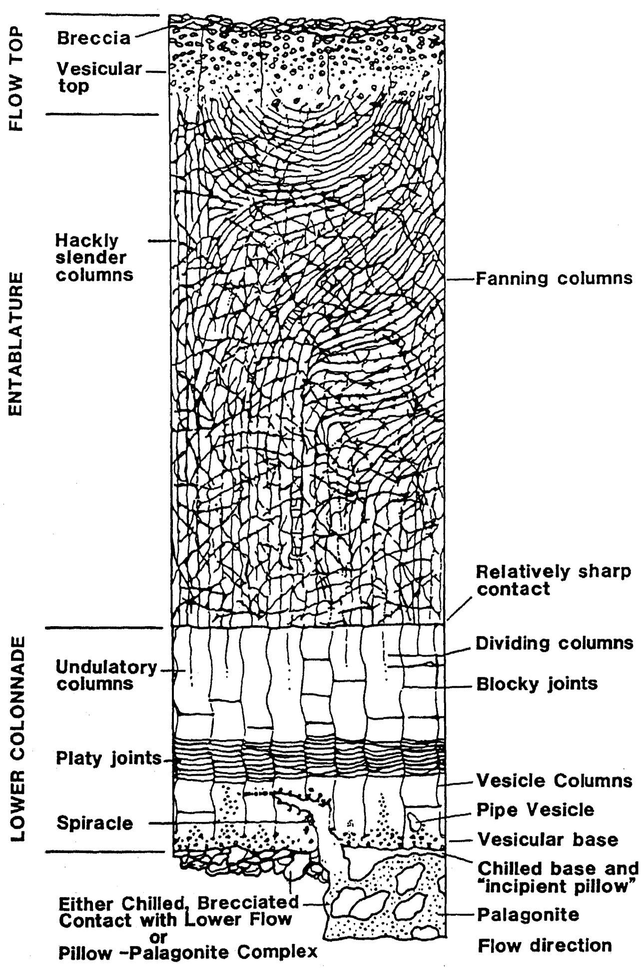

Figure 4 Generalized Schematic Diagram Showing Structure of a Basalt Flow

Selah Member

The Selah Member of the Ellensburg Formation (Schminke, 1967) occurs as an interbed between the Priest Rapids Member and the Saddle Mountains Member. Deposited directly on the underlying Priest Rapids Basalt, it is the most prominent interbed in the vicinity and is comprised of weathered tuffs and fluviolacustrine tuffaceous sediments that accumulated during the volcanic hiatus between extrusion of the Priest Rapids and Pomona Basalts. The thickness of the Selah varies from approximately 115 to 160 feet in boreholes at the site where the top has not been eroded in channels of Dalles or glaciofluvial gravel. The uneroded Selah averages approximately 138 feet in thickness.

The Selah contains three facies which are readily distinguishable on geophysical logs. Due to severe weathering, and zeolitic and clayey alteration of the member, they are not as discernable in outcrop or borehole samples. The facies include: 1) a lower facies comprised primarily of flood plain deposits derived from the Columbia Plateau and adjacent areas, but also containing three to four airfall tuff units; 2) a middle facies similar to the lower, but containing large amounts of silicic-volcaniclastic material derived from volcanic areas; and, 3) an upper or channel facies which results, in part, from reworking of the lower two facies.

The lower facies of the Selah is distinguished from the overlying middle and upper channel facies by generally lower density and higher porosity, and from the middle facies by lower potassium content as indicated by the gamma gamma, neutron neutron, and natural gamma logs, respectively. Where the middle facies overlies the lower facies a marked decrease in natural gamma occurs at the boundary. Samples of the lower lithologies have textures which range from yellow-green massive clayey siltstone to laminated sandy siltstone, and yellow-brown to blue-green silty sandstone. Bedding is generally preserved in the sandy layers but obscured by weathering and possibly by bioturbation in silty claystone and clayey siltstone intervals. Tuff layers in the lower member are altered to massive silty claystone; their origin is indicated only by their high natural gamma and the presence of accretionary lapilli. In many of the boreholes, a blue-green, fine-grained sandstone occurs at the base of the Selah. The thickness and distribution of the sandstone are variable. Thickness variations of the lower facies suggest that the east-west trending anticline initiated development during deposition of the lower facies of the Selah. This is demonstrated by non-deposition of the lower facies in the north-central portion of the site at the approximate location of the axial trace of the structural high, and systematic thickening to the north and south. Variations of the lower facies of the Selah, therefore, appears to account for most of the variation in the total thickness of the Selah Member, except in localized areas where the Dalles Channel exist.

The middle facies of the Selah consists of soft to medium hard yellow green to brown, tuffaceous, silty claystone and clayey siltstone. It is characterized by higher natural gamma, higher density, and lower porosity than the lower facies. Samples of the middle facies from boreholes frequently contain finely laminated, weathered tuffs.

Locally, the middle or highly tuffaceous facies of the Selah Member appears to contain broad shallow channels filled with flood plain deposits range from clayey siltstone to fine sandy siltstone. These channel-fill sediments have low natural gamma similar to the lower facies. However, unlike the lower facies, they are dominantly weathered tuff that has the consistency of clayey siltstone.

Two of the test trenches excavated at the site exposed the top of the Selah member and provide excellent exposures of the middle facies. In both trenches the Selah consists of weathered tuffs that have the consistency of clayey siltstone and silty claystone. At natural moisture content they appear massive; however, upon drying fine laminations are locally visible.

Vitric Tuff Bed of the Selah Member

A gray, dacitic, vitric tuff attaining a maximum thickness of about 30 feet occurs at the top of the Selah Member of the Ellensburg Formation. Geologic mapping in the area indicates that the ash most likely originated from eruptions in the Cascades Range (Schminke, 1964). Texturally, the vitric tuff is soft to medium hard, gray, medium-grained sandstone (tuff) which is well-sorted and massive in the central 20 to 24 feet of the deposit. The lower one to five feet consist of soft to medium hard, gray to dark gray, laminated, silty sandstone (tuff) and sandy siltstone (tuff). The finer laminae are weathered to soft, clayey siltstone or silty claystone. The upper three to eight feet consist of silty, fine to medium, vitric sandstone that occurs as cross-laminated and/or thinly graded beds. These fine-grained layers consisted of weathered clayey silt/silty clay similar to the bottom laminated portion. Development of an open-pit pozzalana mine and explorations for its development have provided nearly continuous exposure of the vitric tuff in the southern part of the site.

Rattlesnake Ridge Member of the Ellensburg Formation

Overlying the vitric tuff in the north part of the site is a tan, fine-grained tuff which varies from zero to about eight feet thick. It averages four to six feet in thickness in areas where it was not scoured away prior to deposition of the overlying Dalles conglomerate. In the south part of the site, the tan tuff rests directly on the underlying vitric tuff and has a sharp, conformable contact with it. The tuff typically consists of weathered to decomposed fine volcanic ash and has the texture of a plastic, silty clay or clay which is largely montmorillonitic. The tuff is generally massive; however, locally the top and bottom few inches have thin laminae of carbonaceous material.

Pomona Member

The Pomona flow is restricted to the northern portion of the site and consists of very hard, black, fine-grained to glassy prophyritic basalt. Maximum thickness is about 40 feet while the average thickness is about 20 feet. The Pomona onsite exhibits its characteristic jointing habit of lower colonnade, entabulature and upper colonnade (Figure 4). However, where the flow is thin (25 feet thick) the flow top consists of three to five feet of platy jointed, vesicular basalt with little columnar development. Also, development of the distinctive fans of joints in the entablature is attenuated where the flow is thin.

Dalles Formation

The Dalles Formation overlies the Columbia River Basalt and Ellensburg Formation throughout the site area. It consists of fluvial gravel, conglomerate, sandstone, fluviolacustrine siltstone, tuffs, and loess. Many fossil soil horizons represented by zones of caliche are present in the Dalles, and local unconformities are common.

Two facies of different origin are present throughout most of the site area: a basal cemented sandstone and conglomerate facies, and an overlying tuffaceous siltstone facies. In addition to these two facies, a third facies consisting of poorly sorted silty, sandy gravel occupies a channel which meanders across the site and is cut to the top of the Selah Member.

Surficial Materials

Pleistocene glaciofluvial, slackwater, torrential flood, colluvial, alluvial and Holocene eolian deposits locally mantle the bedrock units.

Structural Geology

The geologic structure of the site is relatively simple. The site lies partially astride one of several samll east-west anticlinal folds that interrupt the floor of the required Dalles-Umatilla synclinorium. The overall trend of this small anticline is east-west; however, it is somewhat sinuous in detail. The strike of th anticline varies from about N 70 W in the north east part. North and south of the anticline, t bedrock units dip relatively uniformly to the north and south, respectively, toward adjacent synclines.

Structure contours of the top of the Priest Rapids Member define the shape and amplitud folding that has occurred in the site area extrusion of the member approximately 15 mi years before present. Maximum amplitude of fold in the Priest Rapids Basalt is approxi 130 feet between the local culmination on t anticline in the northwest corner of the s synclinal axis south of the site in Alkali yon. Average dip of the Priest Rapids Bas about 1.5 degrees although higher dips occ along the anticlinal axis (1.5 to 5 degree lower dips occur in the south part of the (0.5 to 1 degrees). Folding of the east-we anticline is slightly disharmonic, in that folding of the Priest Rapids, Selah, and P was not perfectly concentric.

Folding of the anticline was accompanied by minor faulting along the fold axis. Faults and related shears on the Selah are typically characterized by gouge zones consisting of re-molded, plastic clay and clay and thus appear to be of relatively lower permeability than the small thrust faults are typically open or filled with loose glaciofluvial deposits and thus appear to be of relatively higher permeability than that of the Selah.

Evidence developed during investigations of the site and nearby areas indicates a lack of Holocene deformation (i.e., since the Spokane flood, 10,000 to 13,000 years ago). This evidence includes: 1) that developed by geologic mapping which shows that unfaulted glacial flood deposits cover the small faults onsite and in the western tract where no waste management activities presently exist and, 2) by relationships exposed in excavated trenches whereas the fault zones exposed are trunicated by unfaulted glacial flood deposits.

HYDROGEOLOGIC SETTING

Within the Columbia Plateau, groundwater recharge is derived mainly from incident precipitation and surface runoff; however, a small percentage may also be derived from irrigation and irrigation water diversions from the Columbia River (Pacific Northwest River Basins Commission, 1970). The climate of the Arlington area is arid to semi-arid; consequently, potential rates of groundwater recharge from precipitation are low in comparison with those for the more-humid areas such as the Blue Mountains south of the site. According to National Weather Bureau statistics, the mean annual precipitation at Arlington, Oregon is less than ten inches, mostly occurring between October and March. The low annual precipitation and high summer evapotranspiration (40 to 55 inches) is evidenced by the sparse vegatation consisting of prairie grasses, low flowering plants, sage brush and occasional junipers. Phreatophytes, including some deciduous trees, mostly brought in by early settlers, are found along the steam valleys, near springs, and in other areas where the groundwater table is at moderate to shallow depths (Dickens, 1955).

The principal aquifers within the Arlington area are associated with the interflow zones between basalt flows. The principal interflow aquifers in the site area are within and between the Priest Rapids, Frenchman Springs, and the upper part of the Grande Ronde Basalt. Of these, the Frenchman Springs is the principal aquifer developed locally for irrigational purposes. The use of this aquifer has decreased in recent years due to the reduction in yields as a result of overpumping.

Within the site area, the uppermost basalt aquifer of regional importance occurs within the interbed zone between the two Priest Rapids basalt flows at an elevation of 620 to 640 feet (site datum). The static water level in test wells completed within the Priest Rapids interflow zone is 100 feet or more above that reported for wells completed in the Frenchman Springs. The Priest Rapids has also been severly depleted in recent years because of overpumping. The Grande Ronde, which underlies the Priest Rapids and Frenchman Springs, is tapped by the city of Arlington for its water supply and by several irrigation wells south of the Arlington facility.

Recharge to the basalt interflow aquifers occurs maintly along outcrops and through fractures which provide hydraulic communication to the surface. The principal areas of groundwater recharge to the Priest Rapids, Frenchman Springs, and Grande Ronde aquifer systmes are south of the Arlington facility, where the edge of north dipping basalt flows is exposed and precipitation is comparatively higher. Additionally, the Priest Rapids and Frenchman Springs are exposed locally along the major drainages south of the sitewhich are local areas of groundwater flow within the Columbia River Basalts in the Arlington area is to the north toward the Columbia River.

The interflow aquifers within the Columbia River Basalts typically have high to very high permeability and low storativity because of the open nature, but limited volume, of joints and fractures. Furthermore, because of the generally impervious nature of the intervening tuffaceous sediments and dense basalt, stratigraphically adjacent interflow zones may be hydraulically isolated over large geographic areas. This physical and hydraulic separation is commonly reflected by differences in both piezometric levels and water quality between adjacent interflow aquifers.

Groundwater Occurrence

The hydrogeologic conditions at the Arlington facility were evaluated by installation of over 120 perimeter and interior wells and/or piezometers at the locations shown in Figure 2. These conditions encountered are complex, consisting of multiple zones of saturation with varying degrees of interconnection (Fiugre 5). The uppermost zone of saturation beneath the Arlington facility is at the base of the Selah, 100 to 200 feet beneath the existing ground surface. This zone of saturation at the base of the Selah is the first detectable zone encountered during drilling capable of yielding even small quantities of water to an open borehole and it is, therefore, the uppermost zone capable of being monitored. Because of stratification and marked permeability contrasts that exist within and between the overlying Dalles Formation, Pomona Basalt, Vitric Tuff, and the Selah, it is reasonble to expect that isolated, perched zones of saturation could exist above the base of the Selah. However, no such zones have been detected. Furthermore, no perched zones of saturation were identified from the downhole geophysical logs although variation in soil moisture content with depth is evident.

Groundwater occurs under water table conditions at the base of the Selah. It also occurs under both water table and partially confined conditions within the upper Priest Rapids flow above the interbed between upper and lower flows, and within the interflow zone between the two Priest Rapids basalt flows. Barometric efficiency tests were performed to assess whether there were measurable fluctuations in water levels as a result of changes in atmospheric pressure. The test indicated that water level fluctuations in the uppermost aquifer within the lower portion of the Selah on the order of 0.25 foot, and that these fluctuations are in part of a function of varia-

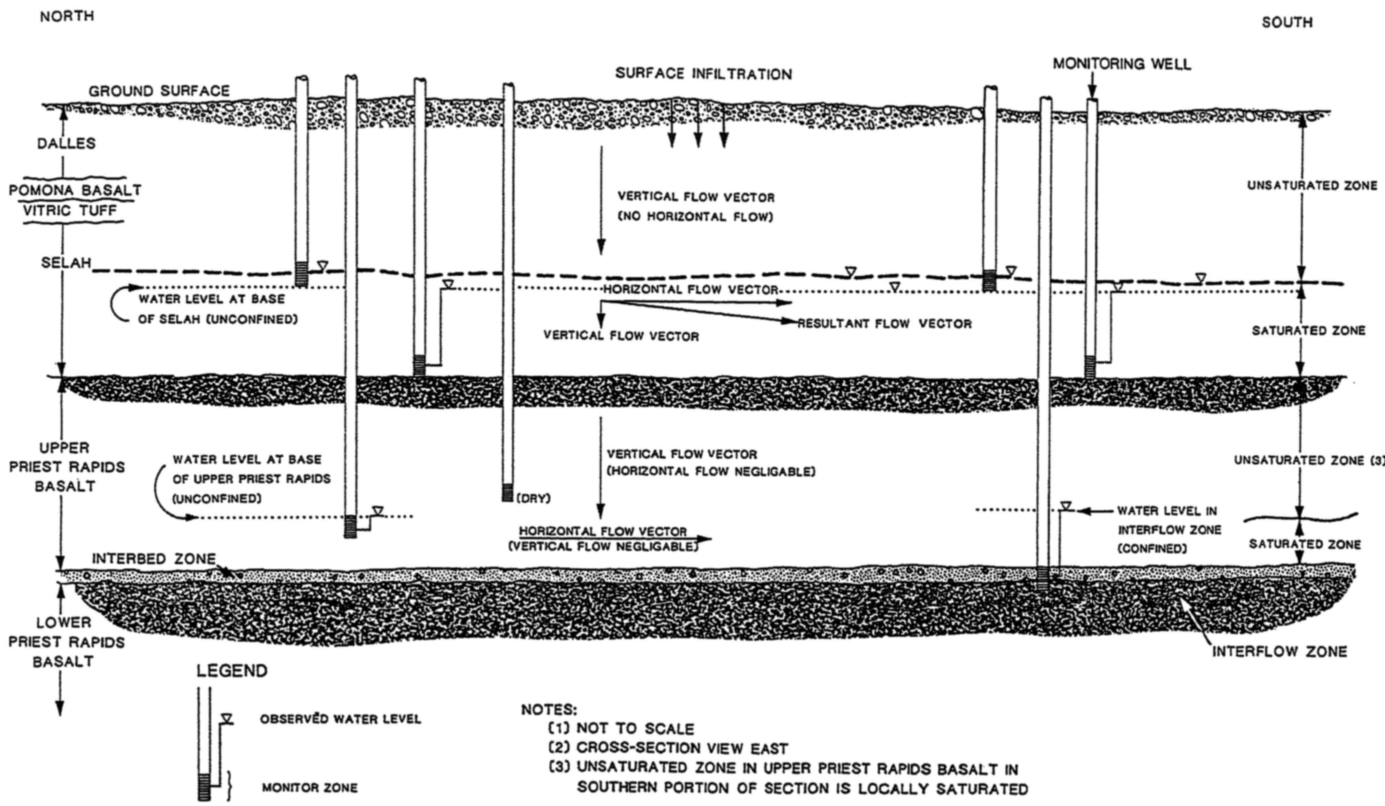

Figure 5 Conceptual Flow Model Showing Flow Vectors in Relationship to Observed Water Levels

tions in atmospheric pressure. Thus, the uppermost aquifer is partially confined and therefore responds to changes in atmospheric pressure; although these fluctuations are minimal.

The uppermost zone of saturation is located physically within the Selah and above the top of the Priest Rapids Basalt. This saturated zone is continuous across the southern two-thirds of the site (north of Alkali Canyon) where waste management activities occur. It is either thin or absent beneath the northwestern corner and in the north-central part of the site. Groundwater that would otherwise be present in these areas is believed to flow downward from the Selah into the Priest Rapids, in contrast to other areas of the site where groundwater is perched on top of the Priest Rapids and forms a continuous saturated zone.

Beneath the northern two-thirds of the site and along its southern margin, an unsaturated zone exists within the upper part of the upper Priest Rapids basalt flow. The thickness of this unsaturated zone ranges from a few feet near the southern boundary of the property to greater than 80 feet in the northern portion of the site. The lower portion of the upper Priest Rapids basalt flow is saturated. In the southeastern portion of the site, continuous saturation appears to exist from the base of the Selah downward to the top of the interbed. The existence of the saturated zone within the Selah is thus a manifestation of the anisotrophic nature of the Selah as well as the existence of a low permeability zone(s) at the Selah/Priest Rapids interface.

Groundwater also occurs under both confined and water table conditions within the interflow zone at the top of the lower Priest Rapids basalt flow. Groundwater within the interflow zone beneath the south-central portion of the site, in general, is confined or partially confined. In the northern portion of the site where the interbed rises toward the anticline, groundwater within it exists under water table or unconfined conditions.

Groundwater Regime

The groundwater regime within the uppermost zone of saturation within the lower portion of the Selah was evaluated by installation of wells which discretely screened the top of the zone of saturation (on the water table), at or near the base of the Selah and occassionally intermediate between the water table and the base of the Selah. Groundwater flow is predominantly lateral from the groundwater divide in the northwest corner of the site to the south and southeast, and toward Alkali Canyon (Figures 6 and 7). Groundwater movement appears to be principally horizontal, although available piezometric data indicate that there is also a vertical (downward) hydraulic gradient within the zone of saturation. This indicates recharge from the Selah to the Priest Rapids, albeit at a slow rate. The observed pressure head distribution within the Selah suggests the existence of a low hydraulic conductivity zone at the base of the Selah/top of the Priest Rapids. Evidence of the presence of such a layer was found in rock oore samples from the Selah/Priest Rapids interface. In these core samples, the fractures and

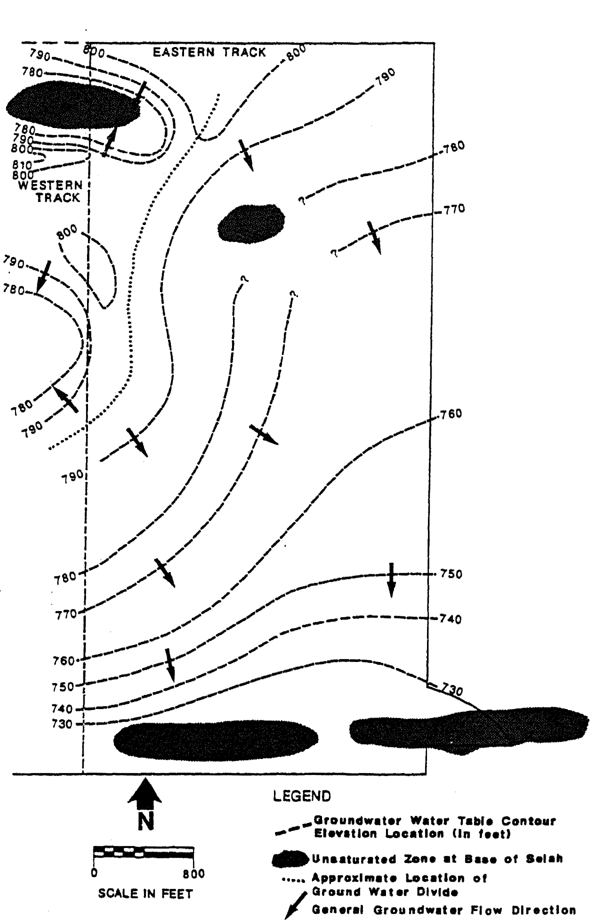

Figure 6 Generalized Groundwater Table Contour Map of Uppermost Aquifer at Base of Selah

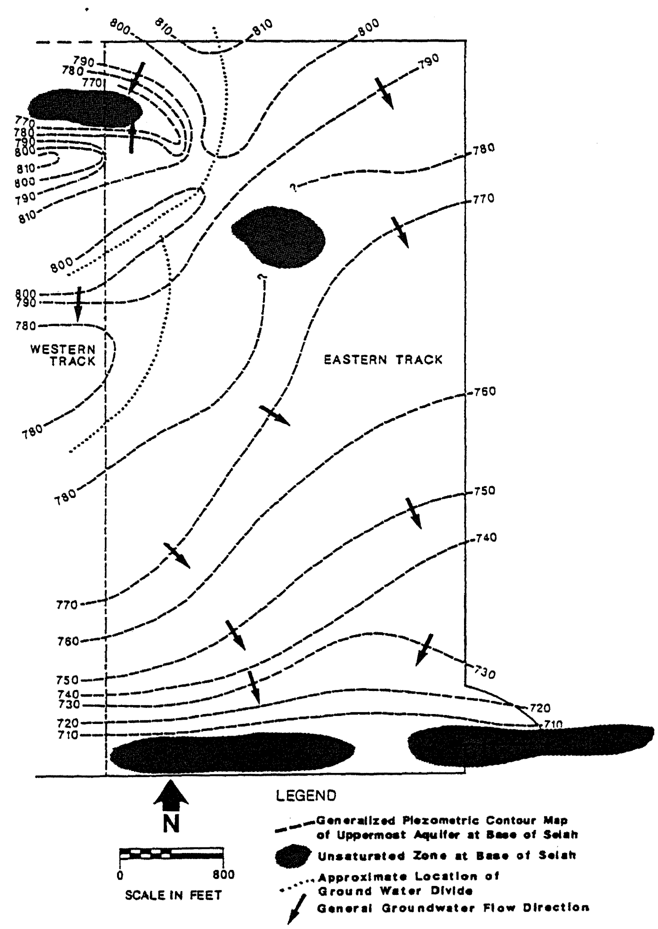

Figure 7 Generalized Piezometric Contour Map of Uppermost Aquifer at Base of Selah

vesicles within the top several inches of Priest Rapids were infilled with secondary weathering products (clay and silt).

Comparison of the water table contour map and the piezometric contour map for the base of the Selah compares favorably although the piezometric contours at the base of the Selah more closely reflects the configuration of the top of the Priest Rapids than do the water table contours (Figures 6 and 7). The piezometric head at the base of the Selah is also lower than that of the water table. This reflects the geologic control on groundwater occurrence and the flow regime within the Selah.

Kriging analysis, a statistical technique for estimating quantitative values for spatial (geographic) variables based on the results of sampling at discrete points, was perfomred to assess the degree of confidence in relation to predicted groundwater flow directions at the site (Wolf and Testa, 1985). The Kriging analysis perfomred was consistent with and support the regularity and predictability of the groundwater contours (i.e., low variance from a reasonable model) within the active portion of the site. Kriging is limited in that it does not account for geologic and hydrogeologic factors which could reduce the level of uncertainty (i.i., underlying erosional surfaces which may substantially alter the occurrence and movement of groundwater, or vertical gradients). However, Kriging was used to assess whether the level of uncertainty or variability within the site area is small compared to the overall hydrogeological constraints -- specifically, the boundary condition of the saturated zone and the configuration of the potentiometric surface (Wolf and Testa, 1985).

Recharge to the saturated zone at the base of the Selah is believed to be from direct infiltration of incident precipitation across the site and ponded surface runoff. In this regard, the closed depressions in the northern portion of the site and the silty gravel-filled Dalles channel are believed to be preferential areas for groundwater recharge. Groundwater discharge is to Alkali Canyon as evapotranspiration, as lateral inflow to the glaciofluvial deposits in the canyon and by vertical recharge to the underlying Priest Rapids Basalt. The water table at the base of the Selah is depressed below the top of the Priest Rapids Basalt along the extreme southern boundary of the site. This depression of the water table coincides with a groundwater mound within the upper Priest Rapids basalt indicating recharge from the Selah to the Priest Rapids. Tritium analysis indicates that groundwater within the lower portion of the Selah predates 1953.

Aquifer Characteristics

The existence of a zone of saturation at the base of the Selah directly overlying an unsaturated zone within upper Priest Rapids Basalt suggests either a permeability contrast between the Selah and the Priest Rapids or the presence of a lower hydraulic conductivity layer or zone. The latter hypothesis is consistent with the observed pressure head distribution within the Selah.

In-situ falling head permeability (slug) tests in open boreholes terminated at the base of the Selah/ top of the Priest Rapids indicate that the horizontal hydraulic conductivities at the base of the Selah range over two order of magnitude from about 1 x 10-6 to 1 x 10-4 cm/sec. Laboratory tests on undisturbed cores from the saturated zone at the base of the Selah indicate that the vertical hydraulic conductivity, which ranges from 1×10^{-8} to 1×10^{-5} cm/sec, is one to several orders of magnitude less than the horizontal hydraulic conductivity as determined from slug tests. The apparent difference between field horizontal hydraulic conductivity may be attribued in part to the difference in measurement techniques.

Packer tests conducted within the Priest Rapids Basalt indicate wide variations in hydraulic conductivity of the Priest Rapids Basalt is generally of the same order of magnitude as that within the basal portion of the Selah.

To assess their hydraulic characteristics and degree of hydraulic connection, pumping tests were conducted in the Selah and the Priest Rapids. The Selah pump tests entailed pumping from the base of the Selah and monitoring the response to pumping at the base of the Selah, at an intermediate depth between the base and the water table, and at the water table. Two locations were selected and pumped at rates 0.25 and 0.167 gpm, respectively, which resulted in full drawdown in the pumping wells. The Selah pump tests were, however, of limited duration because of the low permeability of the Selah.

The calculated horizontal hydraulic conductivity of the Selah for the Jacobs nonequilibrium (Lohman, 1972), and the Theis (Lohman, 1972) analytical methods ranges from 1×10^{-6} to 1×10^{-4} cm/sec. These values are based on the time-drawdown responses, which closely follow the Theis curve predictions. Because of the limited duration of the tests, the calculated results were considered order-of-magnitude estimated only.

The Priest Rapids pump test had dual objectives: 1) the assessment of the aquifer characteristics within the Priest Rapids interflow zone and 2) the assessment of possible interaquifer communication between the Priest Rapids interflow zone, the upper Priest Rapids basalt flow, and the saturated zone at the base of the Selah. Observation wells/piezometers were installed at three levels: within the saturated zone at the base of the Selah, within the upper Priest Rapids basalt flow and within the Priest Rapids interflow zone. The Priest Rapids interflow zone was pumped at a constant rate of 0.5 to 1 gpm, which was the maximum sustainable pumping rate over the planned duration of the tests.

The Theis and Jacobs analyses were applied on the assumption that the observation wells partially penetrate an anisotropic, unconfined aquifer composed of the Selah, the upper Priest Rapids basalts, and the interflow zone. These analyses, however, would not be applicable if an unsaturated zone existed between the base of the Selah and the interflow zone. An unsaturated zone would provide an effective discontinuity between the saturated zone at the base of the Selah and the pumping zone within the Priest Rapids, and hence mask any response. The area in which the Priest Rapids pump test was conducted is the only known area on the site that is fully saturated from the base of the Selah to the interflow zone. The drawdown response of several of the observation wells indicates that the interflow zone in this area is hydraulically connected with the saturated zone at the base of the Selah.

The transmissivity calculated on the basis of the Priest Rapids pump test ranges from 0.3 to 19.1 ft^2/day. Assuming an average saturated thickness of approximately 7.5 feet for the interflow zone, the horizontal hydraulic conductivity of the interflow zone is estimated to be 1×10^{-5} to 9×10^{-4} cm/sec. Due to the limited duration of the test, and the mathematical limitation of the Theis and Jacobs analyses, the calculated pump tests results are considered order-of-magnitude estimates.

An analysis by Witherspoon (et al, 1967) for aquitard response to pumping in an aquifer has also been applied on the assumption that the Selah, the upper Priest Rapids basalt, and the interbed zone are an aquitard and the interflow zone is an aquifer. In this analysis, the observed drawdown responses in the aquitard are used to estimate the vertical hydraulic conductivity of the aquitard. The estimated vertical hydraulic conductivity of the aquitard estimated on this basis ranges from 1×10^{-7} to 2×10^{-7} cm/sec, although these values may be an underestimate due to the time lag response to the piezometers.

DISCUSSIONS AND CONCLUSIONS

Geologic and hydrogeologic characterization of the Arlington facility to the extent necessary to proceed with development of a detection groundwater monitoring system was approved by the Environmental Protection Agency Region 10 in November, 1986. The studies performed addressed criteria established under 40 CFR 264, Subpart F and included identification of the uppermost aquifer and aquifers hydraulically interconnected thereto beneath the waste management area, evaluation of their respective groundwater flow rates and direction, and the basis for such identification. These studies have also demonstrated that the geologic and hydrogeologic conditions at the Arlington facility make it environmentally favorable for hazardous waste disposal. The favorable environmental characteristics includ

- o Semi-arid climate;
- o Low precipitation;
- o High evapotranspiration;
- o Low rate of infiltation;
- o Deep water table (uppermost zone of saturation);

- o Thick vadose zone;
- o Abundant low permeability and moisture deficient soils;
- o Low population density; and
- o Lack of nearby surface water bodies.

These favorable conditions at the site; however, have been very difficult to demonstrate in an unequivocal manner due to tenuous reliability of testing methods available for use under the site conditions described herein.

For the purpose of designing a detection monitoring network, each regulated waste management unit at the facility was considered to be a discrete entity with its own point of compliance. Thus, a primary monitoring network within the saturated zone at the base of the Selah was prepared for each unit. However, in designing a groundwater monitoring system to detect the "immediate" potential release of contaminants from a particular waste management unit, such favorable environmental characteristics warrant consideration of and conflicts with site-specific factors such as:

- o Heterogeneous mixture of waste types;
- o Complex stratigraphic depositional environments;
- o Identification of hydrostratigraphic units;
- o Complex groundwater movement regimes within the vadose and saturated zones;
- o Infeasibility to use conventional unsaturated zone monitoring techniques which reflect low permeable and moisture deficient soils, and
- o Level of demonstation versus level of risk to site integrity.

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