PRIVILEGED AND CONFIDENTIAL ATTORNEY/CLIENT COMMUNICATION

September 19, 2000

Mr. Dave Rogers
Plant Manager
Reserve Silica
P.O. Box 95
Ravensdale, WA 98051

Dear Mr. Rogers:

Steve High of Tacoma Environmental Sciences has completed his Preliminary Investigation Report of the Ravensdale Site. We have enclosed a copy of the Report for your review. The Report is a confidential document and should be handled in accordance with the provision of the confidentiality agreement signed by Reserve Silica on August 8, 2000.

After you have had a chance to review the Report, we would like to schedule a meeting to discuss the result of the investigation, the Report's recommendations for interim actions and future actions that may be necessary to address they issues in the Report.

Please feel free to call me if you have any questions.

Very truly yours,

PRESTON GATES & ELLIS LLP

By William H. Chapman
Steve Rowe

WHC:mhs

cc: Ajay Kumar, Holnam
Frank Melfi, Reserve Silica

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HOLNAM

PRELIMINARY INVESTIGATION
RESERVE SILICA PROPERTY
RAVENSDALE, WASHINGTON

Prepared for:
Preston Gates & Ellis, LLP
Seattle, WA

August, 2000

Prepared By:
Tacoma Environmental Sciences, Inc.
Tacoma, WA

Preliminary Site Investigation
Final Report – Executive Summary

This report is prepared for Preston Gates & Ellis, LLP (PGE), Seattle, WA. PGE represents the interests of Holnam, Inc., Dundee, MI, a manufacturer of cement and related building products. The investigation and report of findings was prepared by Tacoma Environmental Sciences, Inc. (TESI), Tacoma, WA, an environmental and ecological consulting firm. The report presents the results of a preliminary investigation of property in the Ravensdale area of western Washington owned by Reserve Silica Corporation, Ravensdale, WA, at which cement kiln dust (CKD) from cement manufacturing facilities was landfilled from the late 1970s to early 1990s.

The objective of the preliminary investigation was to identify areas that have been disturbed by mining, grading and filling operations at the Reserve property that were of potential environmental interest to Holnam, Inc. Two areas of interest were identified during the investigation. CKD was landfilled in two former coal and sand strip mines from the late 1970's to the 1990's. Adjacent mining drainage areas are also identified as part of the two areas of interest.

The methods of investigation included review of historic aerial photographs, professional reports prepared for landfill proposals, groundwater studies, mining records, and title reports. Onsite investigations consisted of resistivity and ground penetrating radar studies, geologic and ecological investigation, including analysis of groundwater and surface water data. Land surveys were conducted at the two areas and detailed topographic maps were prepared.

The investigation determined that CKD was landfilled at the two former strip mining areas. The placement of fill was integrated with the mining reclamation plans for the site. In addition to CKD soils and rock, industrial waste from a bottle manufacturer were used as fill during mining reclamation. The level of investigation performed did not allow the determination of the presence or absence of other unspecified industrial wastes.

The Lower Disposal Area (LDA) is a former sand mine. The investigation found leachate seeping from the LDA in several locations. The seepage is due to a poorly constructed and maintained cap, failure to adequately divert and contain stormwater runoff, and the presence of mine water impounded upgradient from the LDA. High pH leachate seeping from the hillside below the LDA is likely formed when groundwater produced from stormwater and impounded mine water contact landfilled CKD.

The Dale Strip Pit (DSP) is a former coal mine. Coal was mined from subsurface tunnels and later from a surface strip mine. There is concern that groundwater quality at the site could be adversely impacted if it contacts landfilled CKD. Mine workings are located below the landfill and may be hydraulically connected to surface water at the mine portal. The investigation reviewed groundwater data, assessed the condition of the landfill cap and surface water drainage in the vicinity of the DSP. The investigation determined the landfill cap is constructed and maintained in a manner that facilitates ponding of surface water on the cap. Stormwater management at the DSP and on adjacent mining roads may exacerbate water infiltration problems at the landfill.

The recommendations presented in this investigation consist of interim and long term engineering and management controls to establish and maintain cap integrity at the two sites. Cap integrity is important to control leachate production at the LDA and prevent seepage at the DSP. Stormwater control measures are proposed. Site security measures are proposed to lessen the likelihood that the public will come in contact with site hazards. Additional investigations are proposed to determine the best control

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Preliminary Site Investigation
Final Report – Section 1. Site History

1.0 Introduction & Scope of Work

This report is prepared for Preston Gates & Ellis, LLP (PGE), Seattle, WA. PGE represents the interests of Holnam, Inc., Dundee, MI, a manufacturer of cement and related building products. The investigation and report of findings was prepared by Tacoma Environmental Sciences, Inc. (TESI), Tacoma, WA, an environmental and ecological consulting firm. The report presents the results of a preliminary investigation of property in the Ravensdale area of western Washington owned by Reserve Silica Corporation, Ravensdale, WA, at which cement kiln dust from cement manufacturing facilities was landfilled from the late 1970s to early 1990s.

The objective of the preliminary investigation was to identify areas that have been disturbed by mining, grading and filling operations at the Reserve property that were of potential environmental interest to Holnam, Inc. The scope of the investigation required a phased study that began with the collection and assessment of historical site information to determine areas and features of potential environmental interest to Holnam, Inc.

Areas and features identified during the review of historic records were located on the ground and surveyed. The features and areas of interest were investigated further by non-intrusive geophysical methods performed on a random grid. Shallow areas of concern in the Dale Strip Pit area, east of the pit, were further investigated by shallow backhoe test pits. Additional geophysical resistivity points were evaluated following the initial survey to aid in locating the general area of the Lower Disposal Area. The data collected, together with observations made in the field, were used to provide a preliminary characterization of the site conditions. The characterization of the site presented in this report will be used to identify areas that may require remedial actions and ones that should receive additional investigation.

The investigation consisted of

- **Historical review of the site.** The review included historical and current mining records, maps and drawings; aerial photographs from 1960 to present that document the extent and, in some cases, the type of use; and interviews with mining and regulatory persons with knowledge of the site. In addition, regulatory databases and records, and former environmental reports, were reviewed in an attempt to identify areas and processes that caused problems and environmental hazards in the past and their geographic locations. Finally, title reports were reviewed to determine ownership and lease information about natural resource use on the property. The result of the historical review was identification of areas and features that warranted further, on-the-ground, investigation.
- **Onsite reconnaissance.** Onsite inspection of areas were made by environmental scientists, geologists and geophysicists to visually inspect facilities and operations. The initial onsite work consisted of interviewing Reserve Silica Corp. personnel to find out the location and extent of mining, filling and grading operations prior to, and concurrent with, their mining operations. A plan for further investigation was formulated using mining information and our initial assessment of which investigative techniques were likely to result in meaningful data. Some investigative techniques were eliminated from consideration for the preliminary investigation due cost, electromagnetic interference from the Bonneville Power transmission lines, or potential disruption to Reserve Silica's mining and filling operations.

- **Identification of areas and features of interest.** Historical and initial field investigation information were evaluated to select areas and features on potential environmental interest. Areas of interest were identified for more thorough inspection and evaluation. Criteria for selecting areas and features receiving additional attention included: areas where cement kiln dust may have been landfilled; areas where discolored seepage has, or is, occurring; areas exhibiting stressed vegetation; surface water drainages and impoundments that are near landfilled or reclaimed areas; and areas where ongoing mining-related processes are occurring that could potentially affect the integrity of landfill areas.

- **Land survey of areas and features of interest.** Areas and features of interest were surveyed to determine elevations, relative locations and the approximate area or volume of materials being investigated. Elevation and position data were tied in with the collection of geophysical data to maintain accurate geophysical and geological surveys and to formulate recommendations for interim actions to correct deficiencies in onsite conditions and processes.

- **Geophysical and geotechnical survey.** We performed non-intrusive geophysical surveys to identify the location and position of subsurface landfilled material relative to native material. 1-D resistivity and ground penetrating radar were used to profile the subsurface environment, identify potential locations of landfill material and look for the presence of near-surface groundwater. Test pits were constructed to ground-true the ground penetrating radar survey and test near-surface materials to investigate the likely flow direction of subsurface stormwater and characterize bedrock material.

- **Report of findings and recommendations.** This report was prepared to present the results of our preliminary investigation. The results are in a format identifies and presents a preliminary characterization of areas and features that are, or may become, potential environmental problems for those responsible for site maintenance and operation. Finally, we present recommendations that it may be prudent to implement at this time to lessen the likelihood of existing problems worsening prior to conducting additional investigations or developing and implementing permanent mitigation measures.

1.1 Site History

The Ravensdale site has primarily been used for the production and processing of natural resources. These resources include timber, silica sand, clay and coal. The area was first clear-cut in the nineteenth century and second-growth timber was removed again in the 1970's. Coal mining began in ca. 1905 and continued into the 1950's. Timber was cut to provide mine shoring in the 1930's and 1940's. Sand mining and processing commenced in the mid-1960s and continues into the 21st century. Former strip mines have served as landfills for mineral waste products and this use continues to the present. The following sections summarize the ownership, mining, landfilling and industrial processing operations at the site.

1.2 Site Location

The Reserve Silica Mine is located about 4 miles east-southeast of the Four Corners (a.k.a. Summit) area of King County, Washington. The total acreage owned by Reserve Silica Corporation in the Ravensdale area is approximately 370 acres with 40 acres currently in active mining or reclamation. The mine processing plant is located at 26000 Black Diamond-Ravensdale

Road, about one-half mile west-southwest of the community of Ravensdale, see Figure 1. The mine area is east of the highway on the west flank of Ravensdale Hill, in the N1/2 of Section 1, Township 21N, Range 6E and the S1/2 of the SW1/4 of Section 36, Township 22N, Range 6E, Willamette Meridian, King County, Washington. The entrance to the mine area is across the road from the processing facilities. A locked rail gate (elevation approximately 600 feet) limits access to the site from Black Diamond-Ravensdale Road after mine work hours. The collapsed mine portal to the old Dale No. 1 underground workings is about 250 feet southeast of the entrance from Black Diamond-Ravensdale Road, just south of the intersection of the main haul road and the access road from the highway.

The primary mine road is designated as the "Haul Road." The haul road is a loop road that funnels onsite traffic in a one-way direction to-and-from the mining areas, see Figure 2. The haul road begins at the base of Ravensdale Hill near the Dale No. 1 mine portal (elev. Approximately 645 feet); goes south along the base of the hill; then east up the south end of the hill; back north along the top of the ridge; and finally back down the hill to the mine portal. For ease of discussion, this report defines two primary sections of the haul road: the Lower Haul Road (LHR), consisting of the section from the mine portal to the south end of the mining area; and the Upper Haul Road (UHR), consisting of the section of the haul road from the southeast parts of the mining area and the top of the ridge.

The LHR conveys onsite traffic from the mine portal area up the hill along the west side of the Lower Disposal Area (LDA). The LHR forks about 250 feet south of the mine portal. This fork is at the north end Lower Disposal Area (elevation 691 feet), and conveys traffic to the east edge of the LDA (elev. 790 feet) and then back down the hill, where it again joins the LHR under the BPA power lines (elev. 741 feet). The section of the LHR that traverses the area from the mine portal to the BPA power lines (elev. 645 feet to 741 feet) follows the west boundary of the LDA. Reserve Silica Corp. stockpiles mined sandstone along the west side of the LHR under the power lines.

Another road branches off the LHR under the power lines at the south end of the LDA. This latter road provides access to Reserve Silica Corporation's stormwater and mine dewatering infiltration ponds at the southwest corner of the mine site. Access to the storm water facilities is on the south end of the mine's stockpile area. The LHR continues south of the LDA past the entrance road to Reserve Silica's mine working on the east of the LHR. The road curves to the east and climbs to about elevation 917 feet in the vicinity of the south end of the Dale No. 4 Strip Pit (DSP). This section of the road is designated in this report as the Upper Haul Road (UHR). The UHR crosses under the BPA power lines and continues north approximately 1900 feet to the north end of the DSP. At the north end of the DSP is a paved area to the west which consists of a dumping ramp for placing fill material into a former sand strip mine that Reserve Silica Corp. is in the process of reclaiming. The UHR then traverses down the slope to the north, then curves to the west to intersect the access road north of the collapsed underground mine adit, as previously noted.

In addition to the main gate below the mine portal on the highway, there are other site access points. Plum Creek Timber Company and Reserve Silica maintain additional gates on the highway under the BPA power lines and at the northeast section of the haul road where it curves down the hill to the mine portal. The gate at the highway under the power lines was historically used by traffic bringing fill material to the LDA and DSP for disposal. BPA maintains a right-of-way under the power lines entering the property from the east.

1.3 Site Chronology

A variety of sources were consulted regarding the historical use of the subject property. These included historical mine permit records on file at the Washington State Department of Natural Resources and the Washington State Department of Ecology on-line facility information database.

1.3.1 Owners and Operators

Numerous individuals and corporations have had business interests in the property. Transnation Title Insurance Company prepared a chain of title, see attachment. The report indicates that the property was deeded to Reserve Silica by Glacier Park Company on December 19, 1997. Other parties having ownership, lease or other business interests in the property include.

Smith Brothers Silica Sand Co., Inc. (March 30, 1971)

Industrial Minerals Inc. (March 30, 1971)

Burlington Northern, Inc. (prior to January 2, 1974)

Union Oil Company of California (January 2, 1974)

Voyager Petroleums, Inc. (November 16, 1981)

Philbro Oil and Gas Corporation (January 17, 1983)

Lear Petroleum Exploration, Inc. (August 18, 1983)

BN Timberlands, Inc. (September 19, 1983)

North central Oil Corporation (April 24, 1984)

Texas Gas Exploration Corporation (September 17, 1984)

L. B. Petroleum, Inc. (November 13, 1985)

Larry Barnes (November 13, 1985)

L Bar Products, Incorporated (April 19, 1986)

Burlington Northern Railroad Company (October 13, 1986)

PCTC, Inc, (July 7, 1989)

Meridian Mineral Company (July 7, 1989)

PCYC, Inc. (July 7, 1989)

Meridian Oil, Inc. (July 7, 1989)

Reserve Silica Corporation (July 11, 1990)

Plum Creek Timber Company, L.P. (December 30, 1991)

Palo Petroleum, Inc. (October 27, 1992)

James J. Melfi as operator, replacing Arthur Miller (November 3, 1993)

Glacier Park Company (December 19, 1997)

1.3.2 Regulatory Records Review

The Washington State Department of Ecology identifies the Reserve Silica property as an active state clean up site. It is also subject to a waste discharge general permit that is administered by Seattle-King County Department of Public Health and monitored by the Washington State Department of Ecology, Northwest Regional Office, Hazardous Waste and Toxics Reduction Program. An informal on-line search of nearby properties was also conducted. No federal hazardous waste clean up sites were noted.

On June 15, 1999, the DNR Mining Permit file was reviewed. The materials contained in DNR's permit files reveal minor ongoing problems with timely payment of fees. Of greater interest is the long history of documented drainage problems and a notation concerning an investigation of illegal dumping. Pertinent portions of the file were copied and are attached. Below is a chronological summary gleaned from the materials contained in the permit files.

1967

Smith Bros. operated their sand mining and processing operations under several State and local permits including: Special Zoning Permit No. ZA 67-18 (to Burlington Northern Rail Road Co.); WA Department of Natural Resources (DNR) Water Permit No. 15096, Certificate No. 11039; WA Department of Ecology (Ecology) Waste Discharge Permit No. 2945; Puget Sound Air Pollution Control Agency (PSAPCA) Dust Control Operation Device permit; and King County Grading permit.

March 30, 1971

Smith Brothers Silica Sand Co., Inc. applied for a surface mining operating permit to mine 2 acres. Industrial Minerals Inc. was identified as the operating company for the applicant. The cover letter references an application for a King County Grading Permit. A.B. Berg signed the permit application. The application was denominated #10346.

May 8, 1972

After returning the application for completion of several mandatory requirements, including a reclamation plan, Operating Permit #10346 was issued to A.B. Berg d.b.a. Smith Bros. Silica Sand Co., Inc.

May 26, 1972

George Prater, Vice-President of Smith Brothers requests A. B. Berg's name be removed from the permit and correspondence stating that "Mr. Berg is now simply an office manager". DNR agrees to do so, as long as Smith Brothers obtains a satisfactory bond in the Smith Brother's name.

October 17, 1972

The Annual Completion Report of Reclamation Activities indicates Smith Brothers Silica Sand Co., Inc. was considering opening an additional 10 acres.

February 8, 1973

Smith Brothers informs DNR that Smith Brothers Silica Sand Co., Inc. registered a change of corporate name with the State of Washington. The new corporate name is Industrial Minerals Products, Inc. (IMP).

November 29, 1973

The Industrial Minerals Products, Inc. annual report states that the production rate indicates the existing works (10 acres) is adequate through 1974.

December 20, 1973

Letter to George Prater outlining "gross deficiencies" discovered during annual inspection. These included a nearly vertical pit wall and a finding that drainage conditions "are totally inadequate". Water was being pumped form the bottom of the pit. The inspection revealed natural runoff was being channeled through the northwest corner of the pit access area and then allowed to run freely across the spoils pile and then into a natural watercourse. Suspended solids were entering the watercourse. The inspection report directed the construction of settling basins and spillways. The inspection also revealed the operation had expanded into the southeast permit area, again the inspection directed the construction of settling basins. The final area of concern was the expansion of the pit under the powerlines such that the area could not be reclaimed in accordance with the reclamation plan without undermining a power tower. Because of these problems, DNR determined the bond was inadequate and required submission of a 12 month mining plan. (Note neither the mining plan nor reclamation plans were in the file.)

March 9, 1977

IMP indicates reclamation of lower mine are likely to begin in 1977.

March 25, 1977

The annual inspection reveals additional deficiencies. Pumping continued to remove water from the bottom of the pit. Again the operators were admonished to construct settling basins to allow suspended materials to settle out of the discharge. A slump in the lower mine took out approximately 100 feet of the perimeter fence and displaced water in the mine floor "causing a tremendous surge of water to flow out, damaging the drainage ditch and eroding some of the stockpiled materials; at the present time the drainage system is non-functional." Additionally the drainage ditch in the southeast area under the powerlines was found to be inadequate. Finally, the inspector determined the operators had under-reported the acreage under mining. The bond was increased to cover 21.5 acres determined to be disturbed by mining. The operator was given the option of reclaiming 1.5 acres under the powerline in lieu of additional bonding.

January 1, 1978

Reclamation of the lower mine are begun. Progress dependent on availability of fill material.

December 10, 1979

Lower mine reclamation underway. IMP estimates completion in 12 to 18 months. Map attached to report showing reclamation activities. This reclamation was on-going as of January 6, 1981. Estimated to take another 6 months.

October 28, 1981

No field inspection of mine performed due to budget constraints. Operator again reports reclamation of the lower mine underway, now estimated 18 months to complete.

March 4, 1983

Glennda McLucas, mine geologist reports lower mine reclaimed by filling the mining pit to pre-mining topography. A clay cap was being installed and soils were to be placed within one year.

April 5, 1983

Field inspection reveals siltation from the IMP mine is flowing into a stream that feeds Ginder Lake. The report indicates King County Surface Water Management and

Mukleshoot Tribe are aware of the Ginder Lake siltation problem. DNR requests IMP submit a plan to address siltation issues.

April 14, 1983

Filed inspection confirms silt from IMP mine is reaching the bog above Upper Ginder Lake. DNR again directs remedial measures be undertaken.

January 19, 1984

Annual Inspection Report by DNR indicates silt trap constructed in the southwest corner of the pit is working and the reclaimed is satisfactory.

April 29, 1985

Annual Inspection Report by DNR indicates silt trap still functional and reclaimed areas adequate.

December 4, 1985

Annual Inspection Report requiring new reclamation plan showing mine expansion and how to reclaim faces of the existing mine.

April 19, 1986

"The assets of Industrial Mineral Products, Inc. and its subsidiaries have been purchased by a wholly owned subsidiary of Reserve Oil and Minerals of Albuquerque, New Mexico. L Bar Products, Incorporated will be the new name of the facilities of Industrial Mineral Products, Inc. at Ravensdale, Washington." Frank Melfi indicates in a letter that 40 acres have been mined and a new reclamation plan covering the next 40 was in progress.

January 14, 1987

Annual DNR Inspection Report documents that new reclamation plan has not yet been received.

January 15, 1987

A. B. Berg reappears as the signatory on the annual operator's report.

November 18, 1987

DNR still not in receipt of new reclamation plan. Plan still not submitted as of September 1, 1988. Revised Mining and Reclamation Plan submitted may 17, 1989.

January 26, 1989

King County requiring clean up of illegal dumping and a permanent solution to water drainage problems.

July 11, 1990

Reserve Silica Corporation formed to assume the assets and operation of L-Bar Products related to Ravensdale silica sand operations. Arthur Miller is signatory for both companies.

September 11, 1990

Revised permit issued.

January 23, 1992

Letter from William Melfi describing financial difficulties hindering Reserve's ability to meet new bonding requirements. (Bond increased in March of 1991). Reserve explains the magnesium sludge supply problems experienced by its "sister company" L-Bar and Reserve's slow sales are to blame for its temporary inability to secure a bond. Reserve indicates Ball Incon and Holnam Ideal Cement are primary customers relying on Reserve's product.

February 25, 1992

DNR reiterates the need for a current bond.

August 18, 1992

Reserve secures a new bond.

November 3, 1993

Operator's Annual Report identifies James J. Melfi as operator, replacing Arthur Miller. Depth of mine is reported as 40 feet.

November 1, 1994

Operator's Annual Report indicates 23.5 acres are being mined at depth of 60 feet.

October 30, 1995

Transfer process initiated to transfer the property to Glacier Park.

October 22, 1996

Operator's Annual Report continues to report 23.5 acres disturbed and depth of mine as 60 feet.

October 14, 1997

Operator's Annual Report shows depth increased to 65 feet.

June 28, 1998

DNR has no opposition to request by Reserve Silica Corporation for authorization to import and place filter pressed clayey materials in mine for reclamation purposes, provided Reserve has a third party engineering firm monitor and report to DNR.

1.4 Mining History

The following summary of mining activities at the site closely follows information presented in two reports discussed in more detail in Section 2.0, the Metropolitan Engineers report (Metropolitan, 1972) see Appendix 1, and the Smith Bros. Report (ca. 1968), as well as personal interviews conducted by TESI during the course of the investigation.

Dale No. 4 coal seam and the Dale No. 7 coal seam (No. 7 lies approximately 200 ft. below No. 4, stratigraphically) were worked underground in the Dale No. 1 mine from 1924 into the 1930's. The entry tunnel was driven from the portal about 250 feet up the hill from the Ravensdale-Black Diamond Highway southeast approximately 1500 ft. along an unnamed seam overlying the No. 4 seam. From the main tunnel a crosscut was driven east to intercept the dipping No. 4 and No. 7 seams. Gangways were then driven south along both seams.

Ground water was encountered during mine construction. The mines were constructed so that ground water drained via gravity to the mine portal. Chutes on 50 foot centers were driven up into the seams within or to the surface with intervening pillars or blocks left until the end of the gallery was reached; then the pillars were removed upon retreat. The chutes completed to the surface provided ventilation and openings for transport of timbers down in to the mine. Mining at the Dale No. 1 was reported to have been completed in 1933. When mining was completed concrete bulkheads are reported to have been constructed to isolate the Dale No. 7 (mined first) from the Dale No. 4. No documentation confirming this was identified during this investigation.

From 1945 to 1948, Andersen Coal Co. mined the Dale No. 7 seam from a surface drift down to the old gangway level. The southerly end of the syncline (see Section 4.0, Geology) was mined at this time. The total coal production from 1924 through 1948 was reported to be approximately 240,00 cubic yards (263,000 tons). From 1946 to 1950 the Dale No. 4 seam was mined from the surface as a strip pit. The dimensions of the pit were reported to be 140 feet wide at the top (east-west) and at least 40 feet deep.(Bonneville Power Authority, BPA, cited in the Metropolitan report). The former galleries from the Dale No. 1 subsurface mining operations were reportedly encountered as cave-ins during strip mining at No. 4 seam. These former chutes were filled with surface mining debris as they were encountered to fill them to the bottom of the pit.

Mining at the McKay seam east of the Dale seams was conducted from subsurface mines from ca. 1905 to 1949 at depth of approximately 1,200 feet. The seam was strip mined between 1946 and 1954. Subsurface mining reportedly removed approximately 2,500,000 cubic yards of coal (2,700,000 tons); surface mining yield was approximately 300,000 cubic yards total. Ground water was also pumped out of the McKay mines, see Photo 1-1.

Sand mining at the Ravensdale site began in the mid 1960's. Smith Brothers Silica Sand Company's sand processing facility was relocated from Flaming Geyser to the Ravensdale-Black Diamond Highway location in 1967. The raw material mined for silica sand at the site occurs as a clay-rich cemented sandstone in the onsite formations (Site Geology is discussed in Section 4.0 of this report).

The area referred to in this report as the Lower Disposal Area (LDA) was mined in the late 1960's by Smith Bros. Mining consisted of stripping along the entire strike length from the BPA transmission lines north to the northwest-southeast trending fault line occurring near the Dale No. 1 mine portal. The sand mining at the LDA proceeded in "one continuous operation," (Smith Bros., 1968). The mining proceeded by forming benches along the north-south axis of the pit. Depth of mining was determined by the quality of the sand being mined. Smith Bros. mined approximately 60,000 to 70,000 cubic yards of sand per year.

Limitations in the processing of the raw product (siderite content) determined how much material at depth could be mined according to Smith Bros. However, Glennda McLucas, geologist, reported that the depth of mining operations at the LDA was limited by the presence of ground water in the strip pit (Ideal, 1984). It is likely that a combination of quality and environmental issues played roles in closing the LDA sand mine. However, future mining operations under Reserve Silica Corp. may involve extending the former LDA sand pit farther south than the BPA lines (Personal Communication with John Melfi, Reserve Silica Corp., 2000).

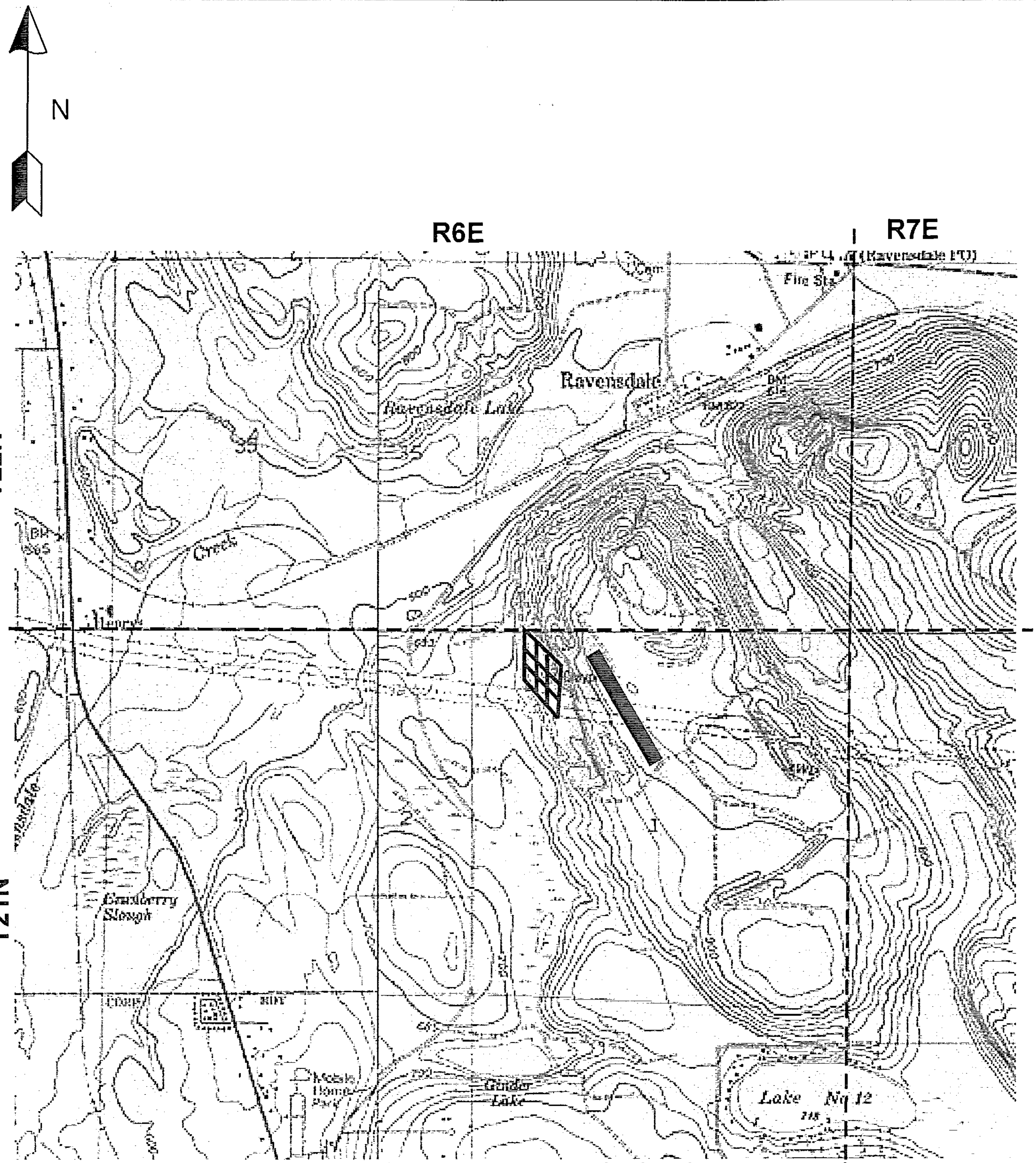
The reclamation plan for Smith Bros. operations consisted of filling mined areas with material from intervening (non-sandstone) beds and overburden from expanded sand mining operations. No vertical slopes were to be left. The Smith Bros. report states that erosion was a problem from the start at this site due to the tendency of the sandstone formations to gully. Road building in the area was impeded by the washing down of debris on to road surfaces. The early solution the erosion and drainage problem was to construct ditches perpendicular to the slope to convey runoff away from the roads as quickly as possible.

Industrial Mineral Products (IMP) was formed in 1972 with the purchase of Smith Bros. Silica Sand, Inc. IMP was engaged in natural resource ventures in Washington, California, Hawaii, Arizona, Philippines, and Guam, ands processed slag from the ASARCO smelting facility in Tacoma, WA. The IMP operations at Ravensdale appeared to be limited to sand mining. In 1972, sand mining was located approximately 1,000 feet west of the Dale Strip Pit, in the Lower

Disposal Area (DSP). Mining in the LDA was a side-hill excavation with a 70 to 80 foot high vertical face (high-wall), see Photos 1-2, 1-3 and 1-4.

IMP produced approximately 100,000 cubic yards of sand per year from the Ravensdale site (IMP, 1985). While no documentation was found by TESI that ASARCO material was landfilled at the Ravensdale site, onsite investigations by TESI did note slag material, possibly from ASARCO, in the road base and eroded slopes in the vicinity of the LDA.

Reserve Silica Corp., successor to IMP, continues mining and resource recovery operations at the Ravensdale site. Current operations include mining, processing and marketing of high quality silica sand used in glass making, cement manufacture and golf course landscaping. Mining waste is accepted and landfilled as part of the reclamation process for the sand mining operations.



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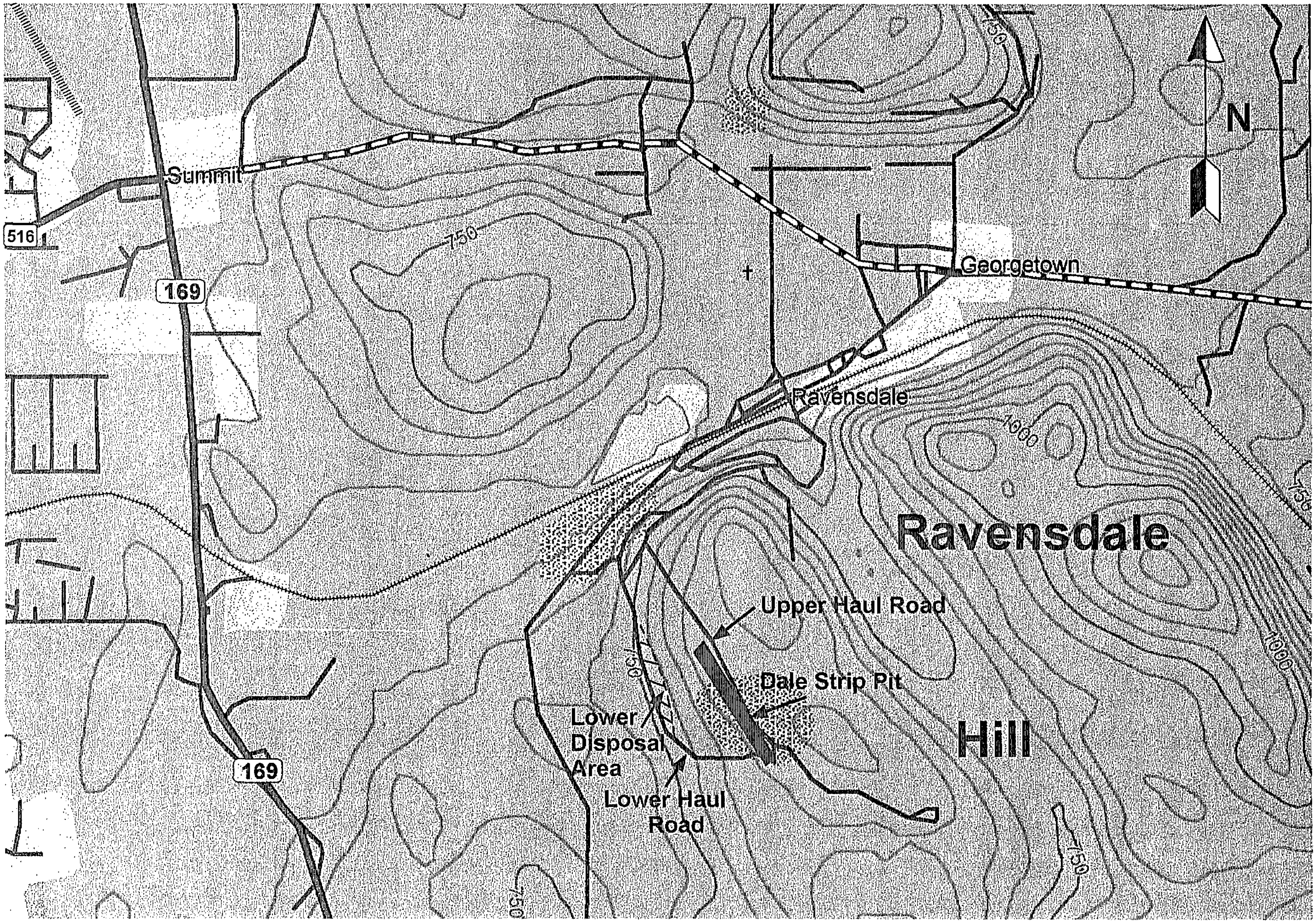
LEGEND

Approximate location of Dale Strip Pit

Approximate location of Lower Disposal Area

Drafted by: Nelson-Couvrette & Associates	Site Location Map	
2579D99	May 2000	Figure 1-1



Drafted by: Nelson-Couvrette & Associates	Site Map	
2579D99	May 2000	Figure 1-2

Scale: 1: 24,000

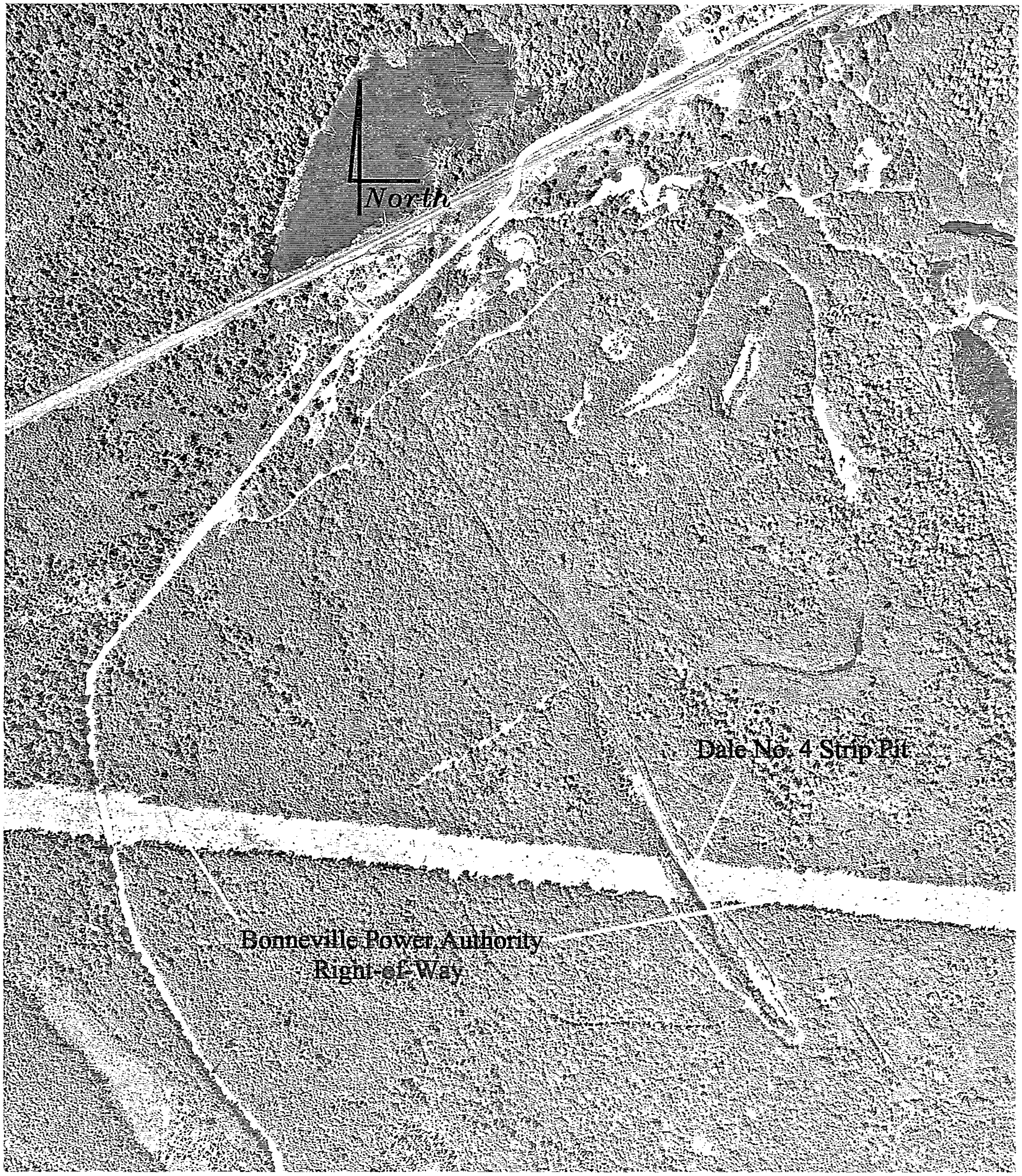


Photo 1-1. 1965 aerial photograph of Ravensdale site. Showing Dale No. 4 Strip Pit and the initial phase of brushing prior to construction of BPA powerlines.

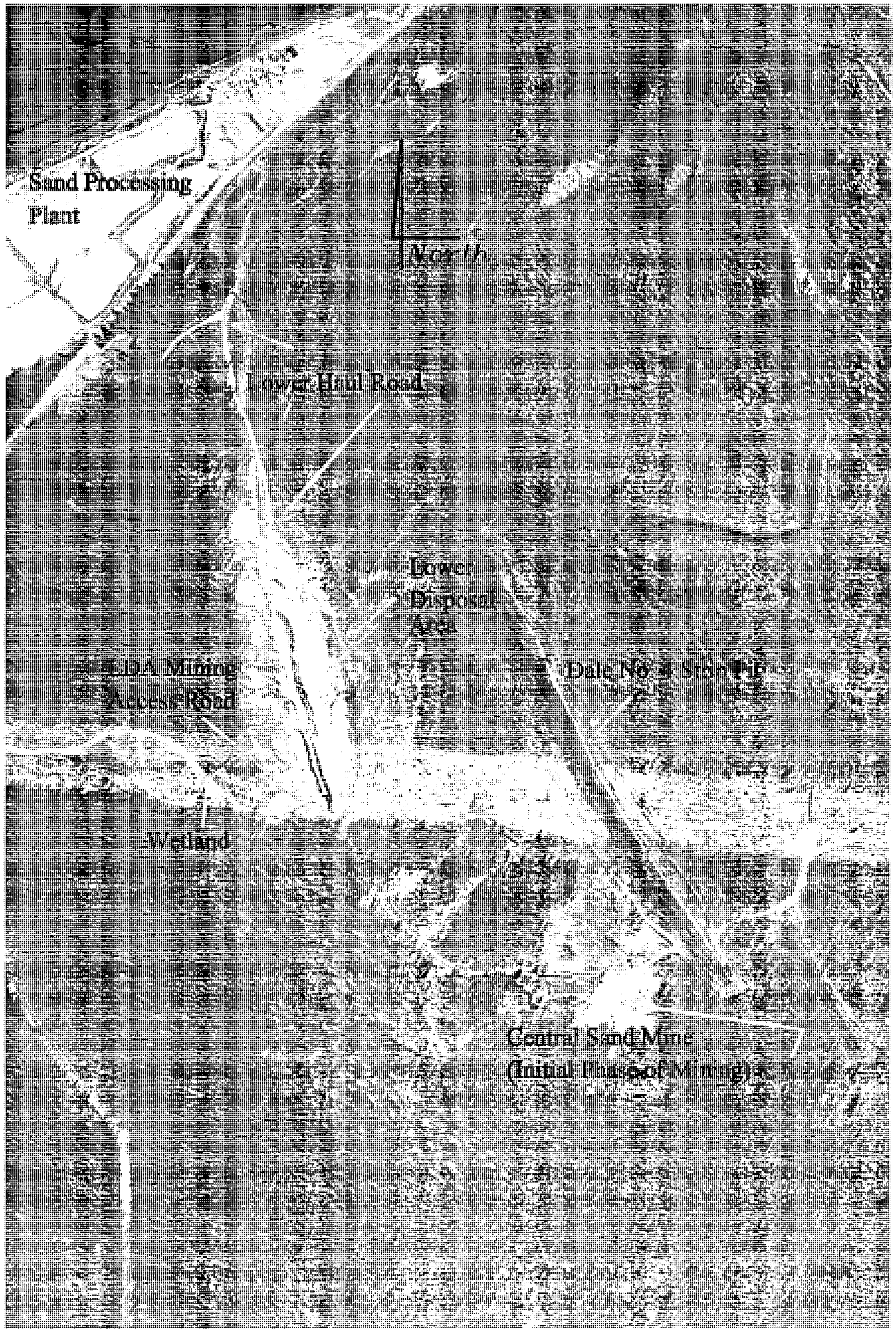


Photo 1-2. 1974 aerial photograph of Ravensdale site. Showing the maximum extent of excavation at the Lower Disposal Area (LDA). Approximate dimensions of LDA are 1,400 feet north-south by 200 feet east-west. Note that sand mining has begun east of the LDA.

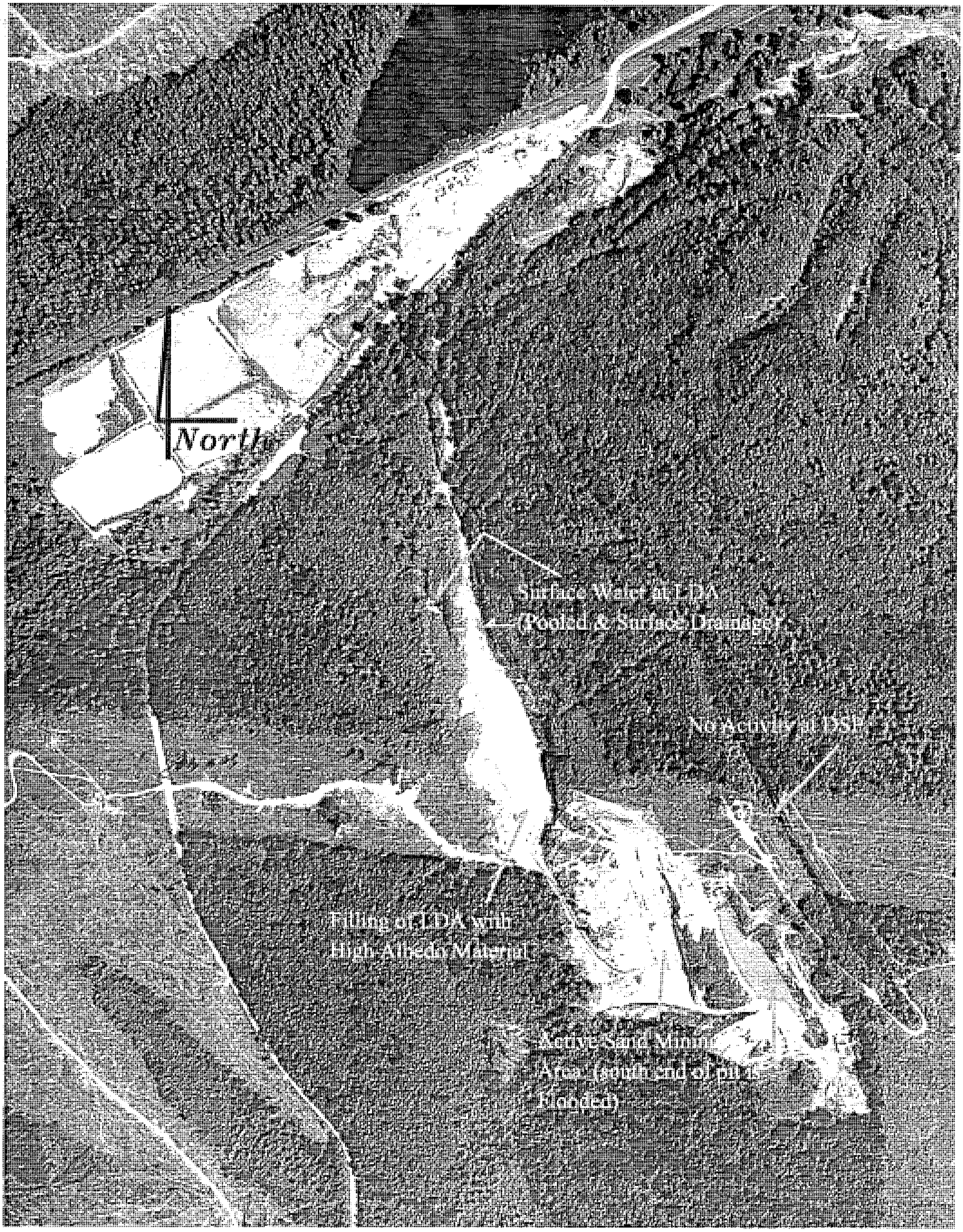


Photo 1-3. 1980 aerial photograph of Ravensdale site. Showing no activity at Dale No. 4 Strip Pit. Landfilling has begun at Lower Disposal Area (LDA). High albedo of CKD fill, compared to native sandstone, is evident. Filling of LDA is from south-to-north and west-to-east. Note flooding of the central sand mine, east of LDA.

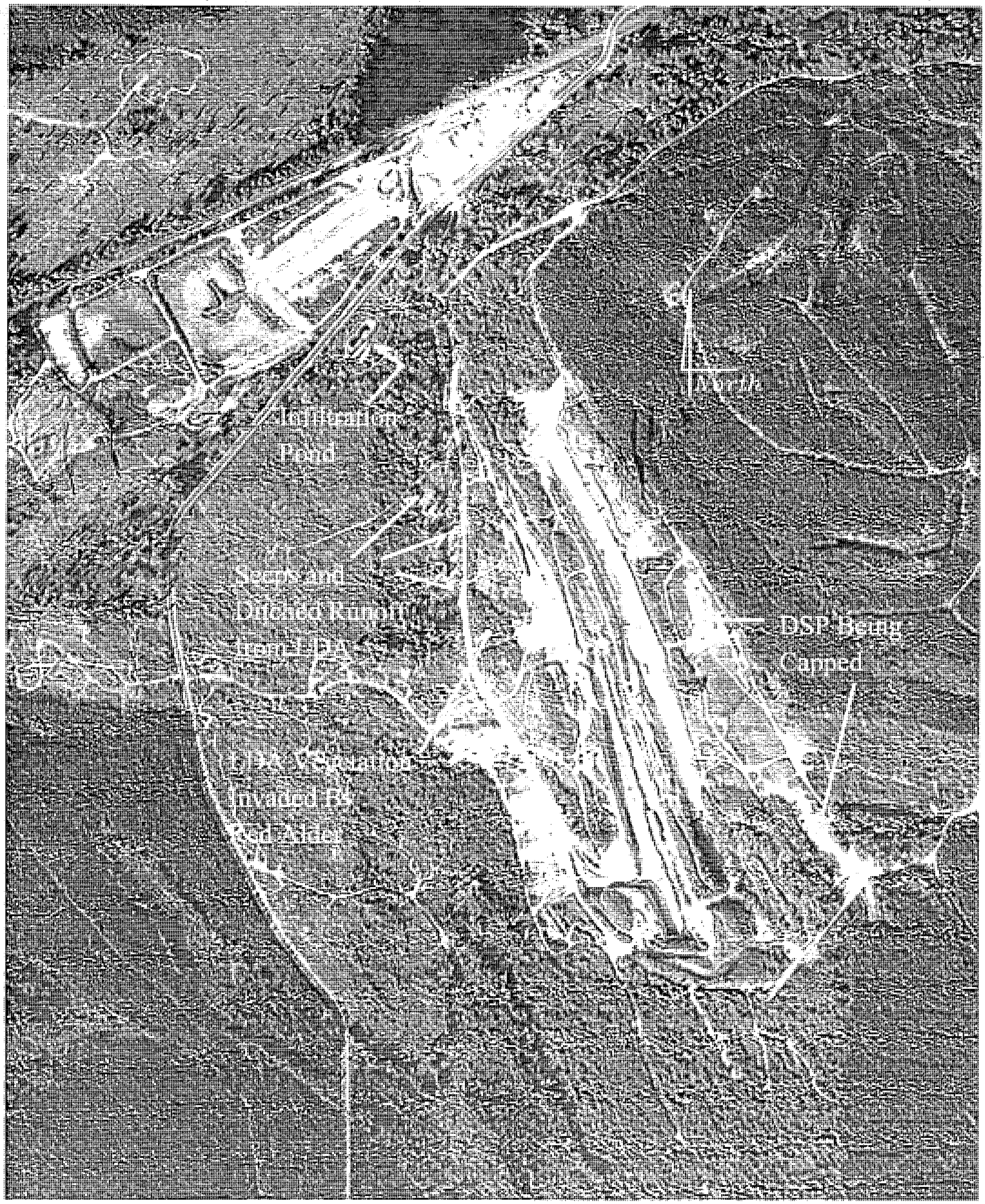


Photo 1-4. 1995 aerial photograph of Ravensdale site. Showing completed landfilling of Dale Strip Pit (DSP). Grading of DSP cap is in progress. Seeps and pooled leachate are present at Lower Disposal Area (LDA). Infiltration ponds can be seen northwest of LDA. Woody vegetation has invaded LDA cap.

2.0 Previous Site-Related Investigations

Several onsite investigations were performed prior to or during landfilling activities at the Ravensdale site. These reports are summarized in this section, and more specific data from the reports are incorporated into other sections of the Preliminary Investigation.

2.1 Metropolitan Engineers

The 1972 Metro Report (see Appendix 1) was prepared for the Municipality of Metropolitan Seattle (METRO). Metropolitan conducted field studies and a literature search of mining records to assess the suitability of the Dale #4 Strip Pit for use as a landfill for the disposal of dewatered digested sludge. This report and it's conclusions are relevant to potential environmental risks at the Dale #4 Strip Pit landfill. Their conclusions are summarized in the report cover letter:

> "We believe this site is suitable for the disposal of dewatered digested sludge provided extensive precautions are taken to prevent ground water contamination. Such measures might include sterilization of the sludge and sealing the bottom of any abandoned strip mines. *Certain hydrologic anomalies exist at the site which indicate that an expensive program would be necessary to insure a positive seal between the deposited sludge and the ground water.*" (emphasis added)

The Metropolitan report estimated the potential volume of the pit at 250,000 cubic yards. They also looked at two adjacent former strip mines as potential landfill locations (McKay Strip Pit 6 and McKay Strip Pit 7).

Ground water flows from the Dale No. 1 mine portal were estimated to be from 700 gpm to 1,100 gpm. In 1972, ground water apparently flowed from a subsidence pit approximately 350 feet upslope and to the southeast of the Dale No. 1 mine portal. It should be noted, TESI has not observed major subsidence flow in this area during the years we have been onsite.

Standing water was reported in the north two-thirds of the pit all year to a depth of 10 feet. The south one-third was seasonally flooded. Water quality data were collected from water standing in the pit and from the mine portal in 1972. Dye and salt were introduced into the strip pit at the north-end and south-end ponds and conductivity and chloride concentrations of the subsidence and mine portal water were monitored over time. After 32 days of continuous monitoring, higher concentrations were detected down-gradient. Metropolitan concluded that most of the problems with detection of tracers were caused by dilution due to very large estimated volumes of ponded water entering the system.

They concluded that the standing water in the north two-thirds was due to ground water accumulation and the standing water at the south one-third of the Dale Strip Pit was primarily due to surface water drainage. The water in the south part of the pit was augmented with overflow from the ponded (ground) water from the north end of the pit. Furthermore, the investigation surmised that water was infiltrating into the old Dale No. 1 works from the south end of the strip pit.

Further assessment of seeps at prospect trenches and observations of the local geology lead the Metropolitan geologist to hypothesize that ground water in the Dale No. 4 strip pit was probably not naturally hydraulically connected to the lower elevation portal area. Metropolitan surmised that most natural ground water movement in these formations is probably parallel to the bedding planes rather than across the steeply inclined beds. Fracturing and mining conduits not with-standing.

The 1972 Metro Report conclusions concerning the suitability of the pit for placement of landfill material were based on estimated risk of ground water contamination and the risk of leachate entering the former mining system and eventually reaching the surface at the port or from a subsidence pit. The report suggests that there was an unacceptable probability of leachate from landfill materials entering ground water in the south 300 to 400 feet of the Dale Strip Pit due to the contact of the pit with subsurface chutes and passageways. Because ponded water at the north end of the pit did not fluctuate significantly, the report concluded there was a lower probability of leachate reaching the mine workings from the north end of the pit.

Finally, the report strongly recommended draining the north end of the pit of approximately 4,000,000 gallons of standing water. However, the report stated that the water not be discharged into the south end of the pit due to the unknown effect of introducing such a volume of water into the underground workings. For reasons not articulated in the reviewed documents, METRO did not use the Dale #4 Strip Pit to landfill it's sludge.

2.2 Ideal Basic Industries

The Ideal Basic Industry reports were written to supplement a petition to the State of Washington to permit landfilling of cement kiln dust (CKD) at the Ravensdale site (1984 Ideal Report and 1987 Ideal Report, collectively the Ideal Reports). Ideal and IMP used CKD and locally derived soil/rock to fill the lower disposal area (LDA) prior to the submission of the 1984 petition. The Ideal Report, "includes a description of the current CKD disposal site at the Dale Strip Pit Reclamation Site near Ravensdale, Washington, and presents evidence that it is the most ecologically and economically viable disposal site available to Ideal." (1984 Ideal Report, p5) Filling of the LDA with CKD began in June 1979 and continued to October 1982. Landfilling at the DSP commenced in November 1982 and continued into 1995, when capping of the Dale Strip Pit (DSP) was underway.

Although the primary function of the Ideal Reports was to petition for continued use of the Ravensdale property for CKD disposal, the reports present a valuable record of landfilling activities at the site. The reports document studies and tests on CKD and the landfill sites in establishing their environmental compatibility. Finally, they record the perspective of the regulatory agencies in the form of memoranda and letters with respect to landfilling of industrial materials and prescription of measures to protect the environment.

The technical chapters in the reports that are most useful from the perspective of environmental science are:

- The physical descriptions of the landfill sites prior to filling;
- The detailed description of filling and capping activities at the LDA;
- Physical and chemical characterization of CKD material being landfilled at the sites; and
- Ground- and surface-water data for the Dale No.1 portal water, DSP resource protection wells and neighboring wells down-gradient from the mine portal.

2.2.1 Pre-Landfill Site Conditions

Lower Disposal Area (LDA)

Mining operations at the site are discussed in the above sections, Section 1.3 *Mining History* and in Section 3.1 *Metropolitan Report*. Sand mining at the west side of the LHR began in the mid-1960s. Smith Bros. (ca. 1968) reported mining 60,000 to 70,000 cubic yards of sand per year from this mine (referred to here as the LDA). Sand mining was stopped at the LDA due to problems with water infiltration into the mine (Glennda McLucas, IMP and Jerry Veenhausen, IMP and Reserve Silica Corp., personal communications). According to former IMP personnel, water entered the mine from the wall at the south end of the mine from a gravel channel in the bedrock under the BPA power lines and at the north end near or at the bottom of the excavation (at the 60 foot depth of excavation). The presence of an extensive body of pooled water is evident in aerial photographs in the 1970s.

Dale Strip Pit (DSP)

The Dale Strip pit was originally mined into the Dale No. 4 coal seam, which had also been mined from below, see Section 1.3 *Mining History* and in Section 3.1 *Metropolitan Report*. The DSP was approximately 1800 feet long (north-to-south), averaged 140 feet wide (east-to-west) and averaged 40 feet deep, with an estimated volume of 250,000 cubic yards. The sides of the pit were steep and heavily vegetated. The north end of the pit contained perennial ponded water, which was noted to attain a fairly constant surface elevation. The south end of the pit contained seasonally ponded water and exhibited more rapid infiltration than the north end of the pit.

The more rapid infiltration rate at the south part of the pit was attributed to connectivity with access shafts and mine workings. A berm was either constructed or left (from surface mining activities) across the pit (east-to-west) to contain ponded water at the north. The Metropolitan Report had cautioned that the estimated 4,000,000 gallons of water contained at the north end of the pit could have catastrophic results down gradient of the mine portal if rapidly released into the south end of the pit, possibly flooding the old Dale No. 1 mine workings. The berm may have been constructed to prevent this occurrence, but this is not made clear in any of the reports reviewed. The 1984 Ideal report states that the berm area is also the probable location of an old timber chute constructed during subsurface mining days to get mining timbers into the mine.

2.2.2 Landfill Filling & Capping

Lower Disposal Area (LDA)

The 1984 Ideal Report states that IMP accepted 175,000 tons of CKD as fill material from June 1979 to October 1982. Descriptions and photographs in the 1984 report, and aerial photographs from Walker Associates and Washington State Department of Natural Resources, indicate that CKD fill was placed at the LDA by unloading trucks directly into the bottom of the pit. CKD fill was placed directly into water collected in the pit. Apparently, the pit was not sealed and placement of fill was not monitored for compaction and permeability. This may have been done because of IMP and Ideal's stated belief that the CKD would provide an adequate landfill seal when hydrated with pit water (1984 Ideal Report, p171).

Access to the pit bottom was from a west access road under the BPA power lines near the south end of the pit. During filling operations, the lower haul road (LHR) was not likely to have been used to access the upper parts of the property. The 1984 Ideal report indicates that when the CKD fill reached to elevation of the old haul road, a berm was constructed to contain overflow of CKD material. Remnants of the old haul road are still visible at the west edge of the LHR where leachate seeps are located today. Placement of a non-engineered berm on top of the old haul road to contain additional CKD is likely a primary cause of seepage at the contact between the old LHR surface and the berm.

When the final height of the CKD was attained, the CKD surface was contoured, a two foot layer of clay material was added to the top and a seven foot layer of overburden from sand mining operations was placed on the top and re-contoured. The cap was planted with Alta fescue grass seed. Additional restrictions from the property owner (Burlington Northern Railroad) stated that the reclamation of the site would also include "drainage control for the reclaimed site." See Photo 2-1.

Dale Strip Pit (DSP)

Prior to filling the DSP, IMP further built up the existing east-west berm separating the north and south of the DSP into a haul road. The surface of the east-west haul road was filled to the surface of the surrounding land. Aerial photographs from the 1980s suggest that this berm was in the vicinity of where the BPA power lines cross the DSP. IMP placed 79,556 cubic yards of material at the north part of the pit from November 1992 to November 1984. The 1984 ideal Report states about the south one-third of the DSP:

> "Because of the uncertain method and degree of backfilling the chutes, it is doubtful that an effective sealing of the pond bottom could be assured through the duration of the product. In view of this, the possibility of leachates draining into the workings and out the Dale Mine Portal could not be eliminated on the basis of present information. For this reason, it is assumed that the use of this end of the pit would be unacceptable."

Results of our field investigations indicate the south third of the DSP was eventually filled and the fill may contain CKD. The berm constructed to separate the north two-thirds of the DSP from the south one-third is composed of "clay-rich till and mining wastes."

2.2.3 Fill Material

The 1984 Ideal Report presents a considerable amount of information and data on the chemical and physical characteristics of CKD in general and Ideal material in particular. In addition to specific chemical data on CKD, the report appendices contain test results on CKD leachability in different soils, fish bio-assay testing on CKD and CKD as an amendment in various engineering and agricultural applications. We have included tables from the 1984 Ideal Report summarizing the chemical characteristics of the fill material (see Appendix 2).

The Ideal reports suggest that other materials, including mining wastes and bottle manufacturing wastes, were placed in the landfills. We did not locate records that provide specific information on the quantities, amounts, source(s) or chemical and physical characteristics of these wastes.

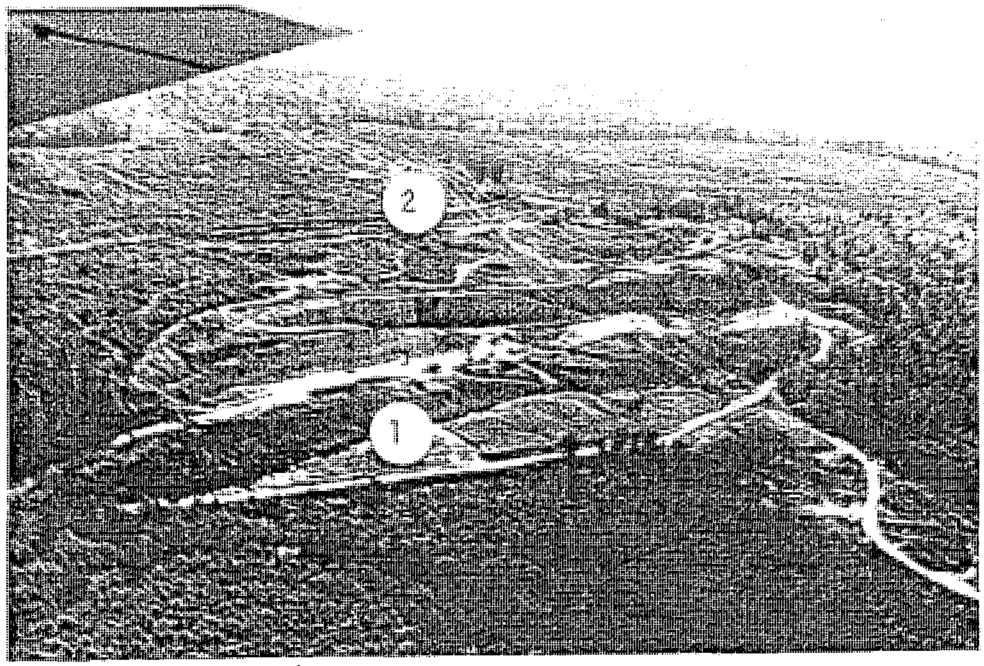
2.2.4 Sampling & Monitoring Data

The 1987 Ideal Report presents data on the chemical and physical characteristics of mine portal effluent and ground water monitoring data. We discuss the characteristics of portal water in Section 3.0 and groundwater in Section 4.0. In those sections we present the 1984 and 1987 Ideal Report data together with TESI data collected since 1996.

2.3 Robinson & Noble Reports

The Robinson and Noble reports (1985 and 1986) present the results of ground water investigations conducted during the preparation of the 1987 Ideal petition report. The results of their investigations are incorporated into our discussion of ground water in Section 4.0 *Subsurface Conditions*, and are included in Appendix 5.

Photo 2-1



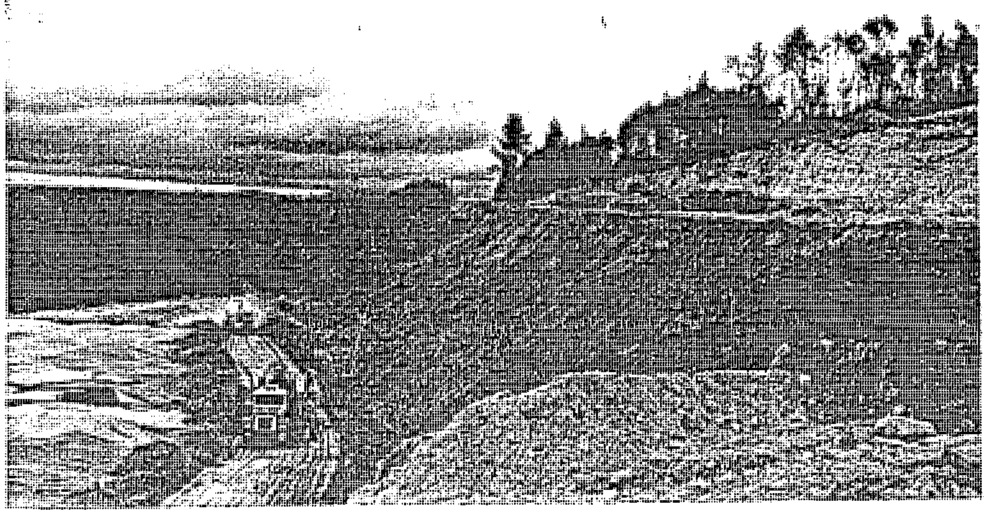
IDEAL Ideal Basic Industries
Cement Division

SCALE:	APPROVED BY:	DRAWN BY
DATE: 1983		REVISED

I.M.P. SILICA SAND MINE, RAVENSDALE

CKD RECLAMATION SITES NOTED | FIGURE 18

1 ORIGINAL CKD FILL
2 DALE STRIP PIT



IDEAL Ideal Basic Industries
Cement Division

SCALE:	APPROVED BY:	DRAWN BY
DATE: 1982		REVISED

ORIGINAL CKD BACKFILL, LOOKING NORTH, IN

3.0 Surface Conditions

This section provides a brief overview of the local geography and presents the results of the topographic survey conducted as part of the Preliminary Investigation.

3.1 Topography

The LDA and DSP are located on the southwest flank of a glacially carved bedrock high, known locally as Ravensdale Hill. Ravensdale Hill is composed of two northwest-southeast trending drumlin-shaped features with intervening drainages. The hill rises from a base elevation of about 600 feet to a summit elevation of about 990 feet northeast of the site. This portion of the hill is separated from the eastern-most portion of the mountain by a north-northwest flowing and a south-southeast flowing drainage. The eastern-most portion of the feature rises to an elevation of about 1230 feet.

The DSP is located on a moderately flat glacial terrace at about the 930 foot level of the mountain. The LDA is located on a moderate to steep slope that declines to the southwest, near the base of the mountain. The topography has been modified by the excavation of three silica sand and one coal pit. The pits trend north-northwest along the strike of the sedimentary beds. The eastern-most excavation has been filled and is known as the Dale No. 4 Strip Pit.

The western-most pit has been filled and is known as the LDA. The eastern-most sand pit, known as the Upper Pit, is over 100 feet deep with a base elevation of about 820 feet. This pit is currently being filled with filter-pressed clay at the north end of the pit. The "Middle " pit is between the LDA and the "Upper" pit. The base elevation of this pit was about elevation 755 at the start of our study. Additional sand has been excavated from the south end of the pit. We do not have the current base elevation. This pit was a maximum of about 125 feet deep prior to the current mining based on the most recent mine maps.

3.2 Setting of Ravensdale Hill & Surrounding Area

Ravensdale Hill rises above glacial outwash filled meltwater channels that form the valley floor. The communities of Ravensdale and Georgetown are located at the north end of the hill. Development has also occurred at the south end of Ravensdale Hill, in the Lake No. 12 area. The hill is relatively free from development except for current and past mining areas. The site is surrounded, at present by undeveloped land. The site and surrounding areas have been logged in the past. The site is bisected by BPA power line easement containing three sets of transmission lines.

3.3 E. True & Associates: Topographic Survey 1999-2000

A topographic survey of the Reserve Silica site was performed to locate areas of potential environmental significance relative to past and current mining activities. A copy of this study is attached as Appendix 3. The topographic data will be compared to past mining records to determine, where possible, changes in topography due to mining and reclamation activities at the site. The survey also located the geophysical radar lines, resistivity (VES) points and test pit locations and provided elevation data for drainage identification and location.

The topographic survey of the Ravensdale site was performed by Eddie True of E. True and Associates, Surveying, Yelm, WA. Initial field work was performed in July and August 1999. Periodic site visits to locate additional features at the site have continued through February 2000.

The survey established permanent datum points with a Global Positioning System surveying system (GPS). Vegetation and the presence of high-tension power lines on the site precluded surveying the areas of concern with the GPS system. Data points were, therefore, collected by standard telemetric methods tied into the GPS-established reference points. The data are presented in UTM coordinate format.

The survey was divided into two areas based on our knowledge of the site developed from interview, record searches, and aerial photographic study. The areas surveyed are the Lower Disposal Area (LDA) and the Dale Strip Pit (DSP). Different contour intervals were selected for each area based on the relief of the study area and on the information needed for geophysical investigations of the two areas. During the course of our preliminary investigation of the site and historic records search we identified locations of environmental interest. These locations were marked and located by the survey for inclusion on future maps of the site. These included surface depressions, on-site drainages, existing monitoring well locations, areas of leachate seepage, water-flow gauging weirs, and infiltration ponds. The topographic map includes approximate property boundaries for Reserve Silica's mining property based on the property lines shown on the aerial topographic survey prepared by Walker and Associates for Reserve Silica Corporation, see Appendix 3.

3.3.1 Lower Disposal Area

In the LDA, a two-foot contour interval was chosen to provide sufficient detail of the surface based on the sloping nature of the area. Pieces of steel rebar were driven into the ground on an approximate 250 foot grid to establish points for vertical electrical soundings (VES) that were part of the initial geophysical survey. Topographic survey data were collected after the geophysical program in this area. Following the initial geophysical work, additional VES data were collected and points added to the survey to gain a clearer picture of the subsurface environment at the expected location of the original mine workings and reclamation fill. The surveyor returned to the site following the second round of geophysical survey work to locate the additional points.

The ground penetrating radar (GPR) portion of the survey was performed prior to the establishment of all of the survey points on the LHR below (west) the LDA and along another road above (east) the LDA. These surveys were stationed by the geophysics field crew using a survey wheel. The stations were painted on the roadway with white spray paint. The surveyor drove rebar or rail spikes at each of these locations so data points could be collected later, during the topographic survey.

3.3.2 Dale Strip Pit

A one foot contour interval was selected for the DSP study area based on the generally level nature of the site. The one foot contour interval was necessary to show areas of surface water ponding on the existing cap. Survey points were established along the west side of the upper haul road (UHR) on a grid spacing of about 250 feet. These points were used as reference points for the GPR survey along the UHR. Two steel fence posts were also located on this site by the surveyor. These posts were reference points for Reserve Silica's aerial topographic survey of the site. Collection of these data points aided in rectifying the new topography, based on UTM coordinates and Reserve's topography based on an assumed grid. The surveyor also located test pit excavations by surveying stakes left at each excavation. Permanent reference points were established on existing monitoring well monuments, as shown in Appendix 2.

3.4 Hydrologic Conditions

Numerous faces of sandstone are exposed in the pit walls at the site. We observed no flow of water from either the walls or through the exposed joints. The bedrock units exposed are fine grained and do not appear to infiltrate significant amounts of water. We observed significant amounts of storm water run-off following strong storm events. We expect that most storm water is directed off the site by surficial flow as soon as the shallow weathered glacial sediments are saturated and that most of the inflow into the DSP and LDA is via overland flow and perched water.

The mine operators have reported some inflow from the floor of the mine pits. We have not been able to confirm or refute this. Therefore, we assume some water enters these areas from the base of the pits. We expect this inflow is significantly less than inflow from surface and perched water based on our current information. The question of ground water inflow into surface mines is one that has been explored and debated on more than one occasion (Metropolitan, 1972; Ideal, 1984, 1987). To date, there has been no definitive determination on ground water movement into and out of surface mines other than at the south end of the former DSP, where infiltration of collected surface was disappearing into the subsurface environment, presumably via former Dale No. 1 mine workings.

3.4.1 Surface Drainage

We located no natural year-round drainages on the site. Drainage basins mapped for the 1984 Ideal Report are shown in Figure 3-3. Surface water derived from storm events and seepage below the LDA currently exit the site in several areas. Storm water from the north end of the site flows down roadways to the northwest corner of the site in the vicinity of the Dale No. mine portal, where it is conveyed under the LHR via culvert to the leachate infiltration ponds adjacent to the east side of the highway. Mine portal water is conveyed north along the LHR and lower site access road to the Ravensdale-Black Diamond Road (R-BDR); surface runoff across the LHR is shown in Photo 3-1. This water combines with water from the plant's sand washing facilities conveyed via culvert under the highway where it gradually infiltrates into the gravels underlying the valley bottom.

Storm water from the sloping portions of the LDA flows west down-gradient toward the LHR. The flow is collected in a ditch on the south half of the LDA. This flow mixes with seepage from the LDA in the ditch, then is diverted to the west side of the LHR through a culvert. The culvert discharges into a swale cut into fill. The water flows down the slope of the fill into a swampy area west of the LDA. This area has built up considerable amounts of fine sediment over the years from cap material, fill material, road base and stockpiled sand. The water flows northward through this swampy area, mixing with seepage discharged from under the west side of the LHR. The mixed water collects in a pond/swamp west of the north end of the LDA. TESI constructed a weir at the north side of this area and collects flow data prior to the water entering constructed infiltration ponds at the northwest corner of the property adjacent to R-BDH, see Photo 3-2.

Storm water in the vicinity of the DSP generally flow from north to south along the east side of the UHR until it reaches the vicinity of the power-line easement where it collects east of the road. Flow from the easement area west of the road appears complicated with portions flowing east through the swale and some of the water collecting in the south in ditches at the southeast end of the DSP fill. Raising the grade of the UHR over the years has resulted in some flow onto the cap of the DSP in the northern end of the fill. The water collects in low areas in the cap where it evaporates and/or infiltrates, see Photo 3-3. Rainfall also accumulates on the fill cap in the middle portion of the DSP where uncompacted fill has been dumped on the cap. Runoff from the southern end of the cap appears to be flowing into a depression at the southwest end of the pit. The water appears to infiltrate or evaporate from this depression also.

Surface water flow has collected in unreclaimed and active mine workings. This water is pumped to a ditch south of the mine access for the active portion of the middle pit. The water flows west from this area into a settling/infiltration pond southwest of the LDA. The overflow from this pond is designed to direct water to a drainage west of the site. Surface water from west of the LHR naturally flows west through a series of swampy areas towards the Ginder Lake area southwest of the site.

3.4.2 Stormwater Detention & Infiltration Facilities

Reserve Silica currently maintains two storm water ponds at the site. The south pond, located in the southwest portion of the site, serves as a storm water detention/infiltration pond. The northern pond, located in the northwest portion of the site near Black Diamond-Ravensdale Road, consists of a series of three infiltration ponds.

The southern detention pond is located south of the Reserve Silica stockpile, southwest of the LDA. This pond receives storm water from the pits and the south end of the site. The storm water flows overland and through the shallow weathered soil zone above the bedrock and till into the mine excavations where it ponds. Reserve Silica pumps water from the eastern-most pit onto the ground surface south of the open mine pits. It flows overland south of the west mine workings into a man-made drainage. This drainage has been excavated into the bedrock on the south side of the access ramp to the west mine workings. Here it flows south into a culvert under the LHR. The water ponded in the west mine workings is pumped from the pit periodically at the access ramp into the same drainage ditch. The combined flow then flows west through the culvert into the detention pond. Water stored in this pond evaporates or infiltrates into the ground. An overflow from the pond is located on the northwest side of the pond. The overflow is towards a drainage basin west of the site. The infiltrated water may flow into the same drainage basin. A detailed analysis of the drainage basin and it's hydraulic connection to other sources is beyond the scope of this investigation.

The north infiltration ponds are located at the north end of a series of ditches, eroded channels and swampy areas that collect leachate discharge from seeps and storm water from the LDA and LHR. Water collects along the base of the hill on the west side of the LDA and is channeled to three connected ponds. The ponds are designed to allow fines to filter out from the runoff. The water infiltrates into gravelly alluvium or outwash. Portions of these ponds extend onto adjoining property based on recent surveys conducted by E. True & Assoc. as part of this investigation. Infiltrated water may move under R-BDH to the northwest, but we could find no specific information to document the ground water flow direction and this determination was beyond the scope of the Preliminary Investigation. Surface water runoff during storm events flows north along the LHR then erodes channels across the LHR and flows to these infiltration ponds north of the weir.

Mine portal water combines with storm water that is not directed towards the ponds. This water flows north, along the LHR, to ditches on the south side of the R-BDH near the access road intersection with the highway.

3.4.3 Leachate Collection & Infiltration

Leachate exits the LDA via seeps on the downslope side of the fill and potentially through weathered shallow soils. Seepage zones were located east of the LHR on the south end of the LDA, across the road from the Reserve Silica stockpile area and west of the LHR along the central and northern sides of the LDA. The leachate at the seeps is characterized as a dark brown to black colored liquid. The leachate exhibits a pH in the range of 10.5 to >11.3, generally greater than 11.0.

The seepage from the east side of the road is collected in a ditch then directed through a culvert across the LHR at the north end of the stockpile. It flows across the stockpile via a ditch, then flows down the remainder of the slope to the base of the hill. Here it flows along the base of the hill, into a swampy area along the northwest side of the LDA. The ditch at the west side of the LHR exposes a cut-bank revealing material suspected of being placed in, or native to the west edge of the landfill and the base of the LHR. Material noted in the bank and base of the ditch includes melted glass, coal, ASARCO slag, CKD and sandstone.

Seepage along the east-side of the road flows from the slope onto the original mine road surface about 8 to 10 feet above the base of the slope. Water flows north along this roadway and across the roadway into the swampy area. The water flowing along the roadway collects in a small depression near the north end of the LDA, then infiltrates or flows across the road into the swampy area. The swampy area is bounded on the north end by a gravel roadway. A culvert through this road directs the leachate into a ditch that flows to the north-northwest to the northern infiltration pond complex, see Photos 3-4 and 3-5a,b.

The new weir is downstream of the swampy area, to allow monitoring of the flow from the swampy area towards the infiltration ponds. We also excavated a channel through the old roadway at the north end of the seepage to drain the shallow depression collecting leachate into the swampy area.

3.4.4 Surface Water Quality

Water quality data at the site have not been collected on a regular basis. The 1984 Ideal report, together with appended documents from regulatory agencies proposed a scheduled water quality monitoring program. TESI could not locate data from such a program. Water quality monitoring of water discharging from the Dale No. 1 mine portal was conducted from 1981 to 1987 and a summary of results is presented in the 1987 Ideal report. No data from the period 1987 to 1996 was found. Holnam Inc. had TESI prepare Standard Operating Procedures for sampling portal water and ground water in the fall of 1995. A sampling and monitoring plan was approved by King County Health Department and Department of Ecology in the winter of 1996. TESI implemented the sampling and monitoring program approved by the agencies and continues to conduct monitoring to this date, see Appendix 8.

TESI constructed a weir down-gradient of the seeps and up-gradient from the infiltration ponds in the fall 1999. Intermittent sampling was done in fall 1999 and winter 2000. Recorded flow in the fall ranged from 2.9 gpm to 71 gpm. Flow during the winter was generally about 20 gpm. These values may be representative of the lower limit of storm water and leachate seepage currently entering the infiltration ponds, excluding the amount that Reserve sometimes diverts from the LHR surface into these ponds. It is likely some leachate infiltrates into the sandy/gravelly substrate on the property.

Water quality data for the mine portal are graphed from 1981 to 2000 in Figures 3-1 and 3-2. Note there is a data gap of nine (9) years indicated on the figures. Data prior to 1987 were collected by the mining company. Data from 1996 to present were collected by Holnam's consultants, TESI. Figure 3-1 presents data for pH in mine portal water. Statistical analysis of these data indicate the log-average pH from the 3rd Quarter 1981 through 2nd Quarter 1987 is 6.9 and the average from 4th Quarter 1995 to 1st Quarter 2000 is pH 7.4. It is likely the pH difference reported for these two periods is real and represents gradual increasing alkalinity in the mine portal discharge.

The trend from 1982 to the present for selected physical and chemical parameters are presented in Figure 3-2. Again, there is an indicated data gap from 2nd Quarter 1987 to 2nd Quarter 1996. The data collected in the 1980s were analyzed by different types of instruments, by different analytical techniques and without documented QA/QC than data collected from 1996 to present. Therefore, it is difficult to assess potential trends in the data. There appears to have been an increase in conductivity and total dissolved solids in the period from the 4th Quarter 1982 (when landfilling began at the DSP) to at least the 2nd Quarter 1996. There is a trend of decreasing conductivity and total dissolved solids since 1996. Bicarbonate and Calcium in mine portal discharge water have both increased over the past 19 years. The mean calcium concentration prior to the data gap was 59 mg/L and post data gap 71 mg/L. There is a statistically significant difference between these two means.

It is unlikely that the LDA has had an influence on water quality discharged at the mine portal. There is no evidence that they are hydraulically connected. Previous investigators and the data collected from the monitoring wells at the north end of the DSP suggest the absence of a direct hydrologic connection between subsurface and infiltrating surface water at the north end of the DSP and the Dale No. 1 portal water. The south end of the DSP is suspected to exhibit a hydrological connection with the Dale No. 1 portal water. The trend in ground water from monitoring wells at the south end of the DSP suggest that material is leaching from the upper levels into nearby coal mine galleries. The south end of the DSP was the last part to be filled and may yet affect the quality of water discharge at the Dale No. 1 portal such that the portal water should continue to be monitored on a regular basis.

Figure 3-3

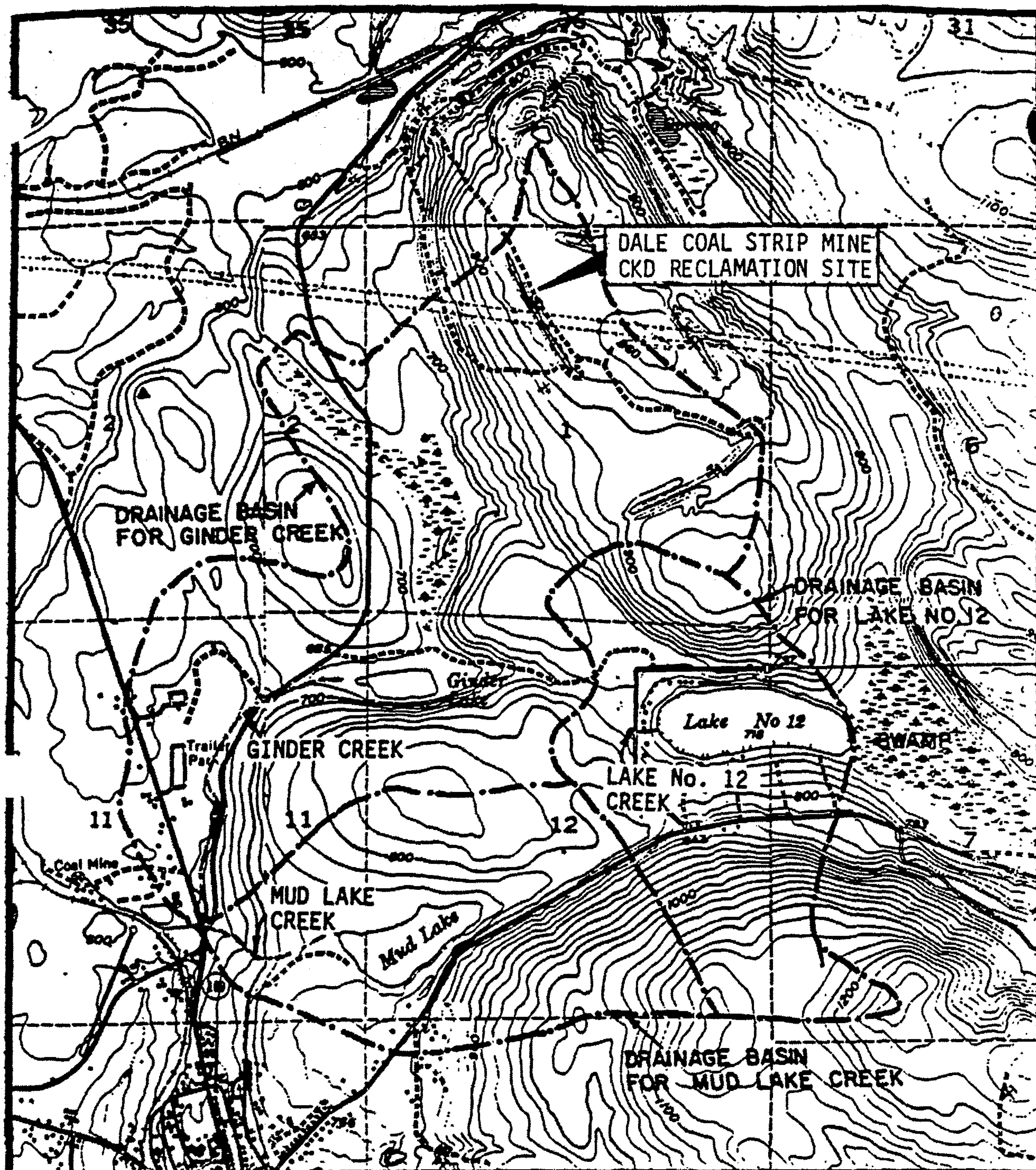


FIGURE 32

Scale 1"=2000'

JOHN HENRY NO. I MINE

BLACK DIAMOND, WASHINGTON

EXISTING TOPOGRAPHY
DRAINAGE BASINS

DESIGNED BY

APPROVED BY

DRAWN BY

DATE 4/18/83

DRAWING NO.

SHEET

Exhibit II-6

PACIFIC COAST COAL COMPANY, INC.

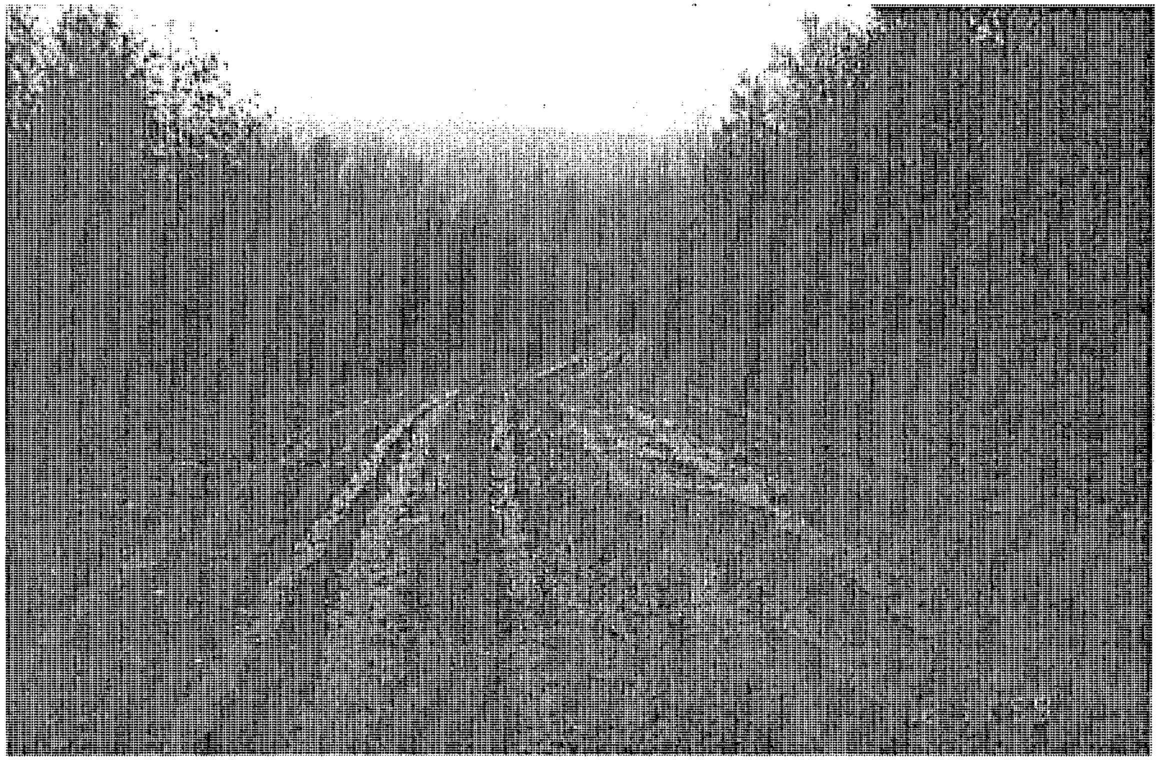


Photo 3-1 LHR. On LHR wet of LDA. View to north showing storm water runoff channelling on road surface and flowing to north.

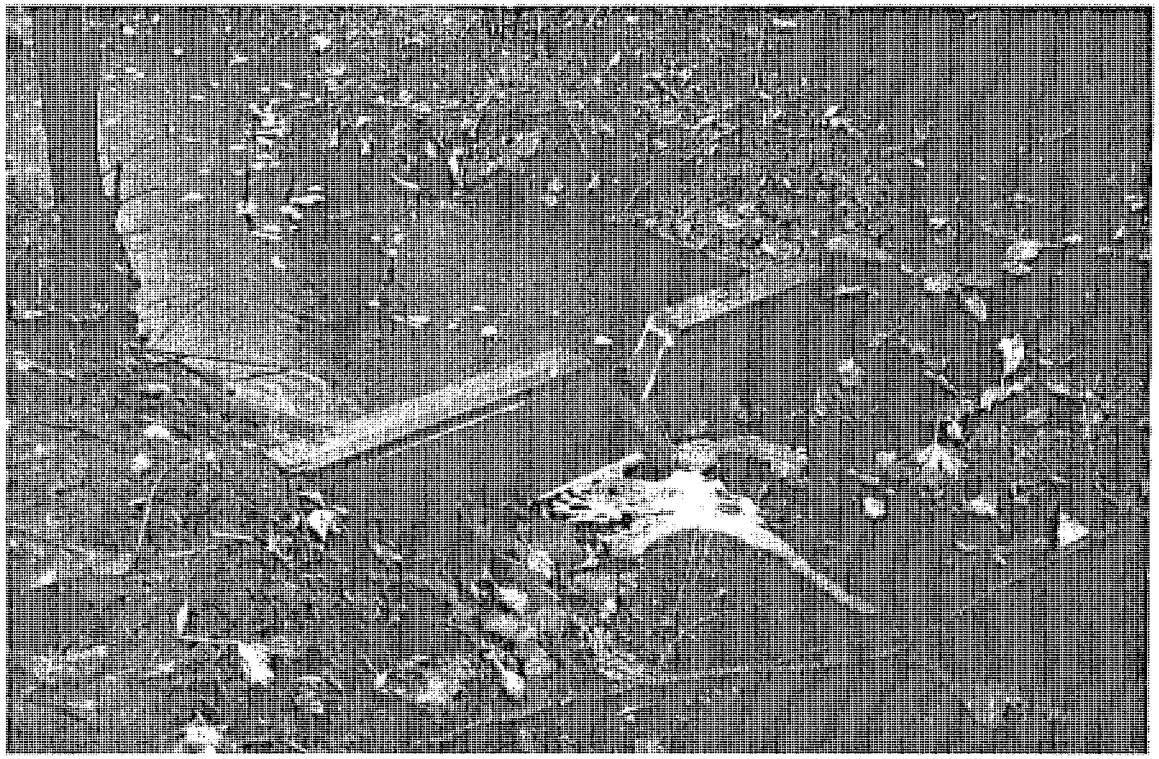


Photo 3-2 At Seepage Area. West side of LHR, below LDA. View to southwest of seepage water ponded behind flow monitoring weir.

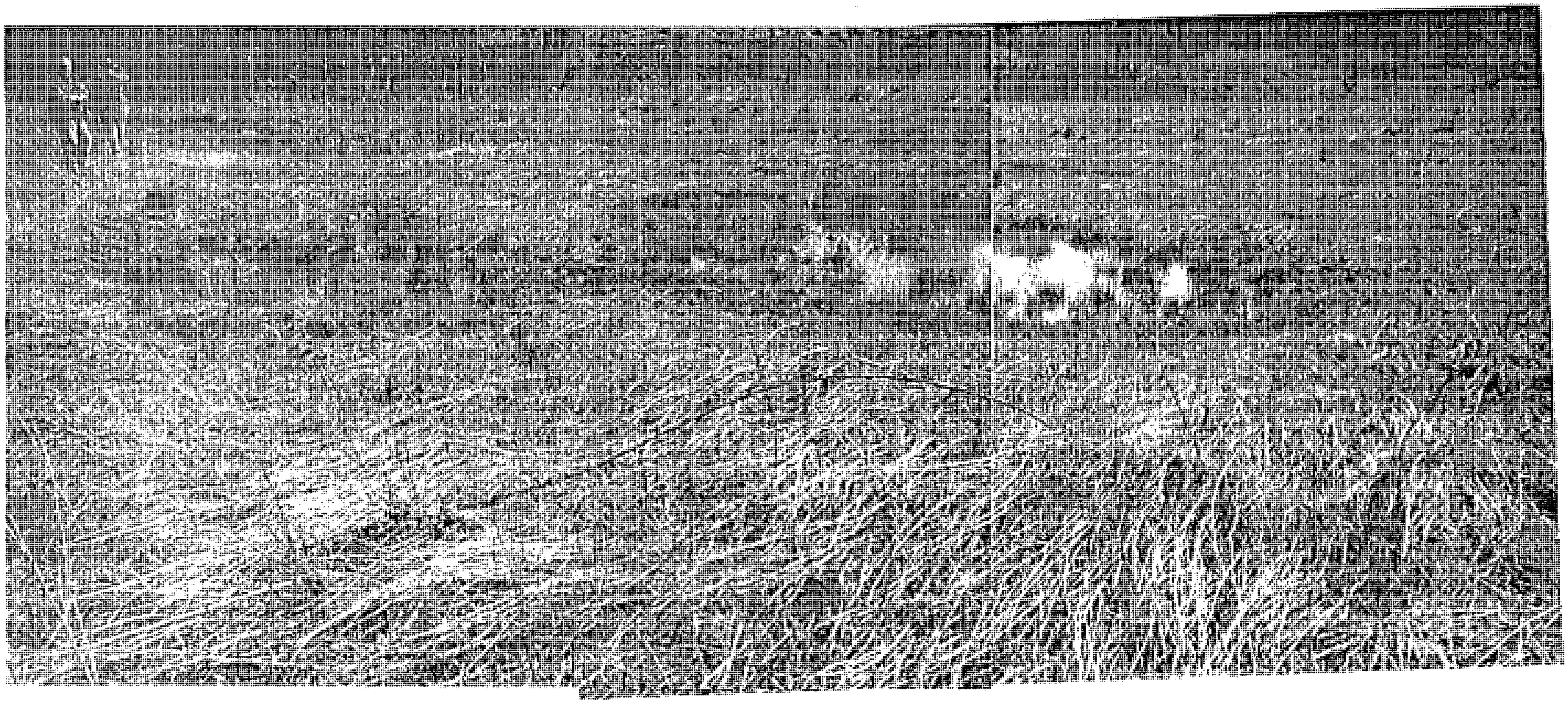


Photo 3-3 DSP. View to east from west-central edge of DSP. Showing pooled water on cap of DSP and nascent wetland vegetation ("A"). Roadway in distance ("B") is UHR. Elevation of UHR is two to eight feet higher than DSP cap. Stormwater runoff from UHR drains onto surface of DSP.

Photo 3-4 LDA. View to south at north end of seepage diversion channel at infiltration pond access road. Showing dark brown color of water. (pH measures ca. 10.5 during storm events.)

Matchline

Photo 3-5 (a) LDA. Views north and northeast from infiltration pond access road. Showing west (photo this page, "A") and east infiltration ponds (photo next page "B"). Water first flows to east pond, overflow then occurs into west pond. East pond generally contains water and exhibits slower infiltration rates than the west pond, which only receives water during large storm events.

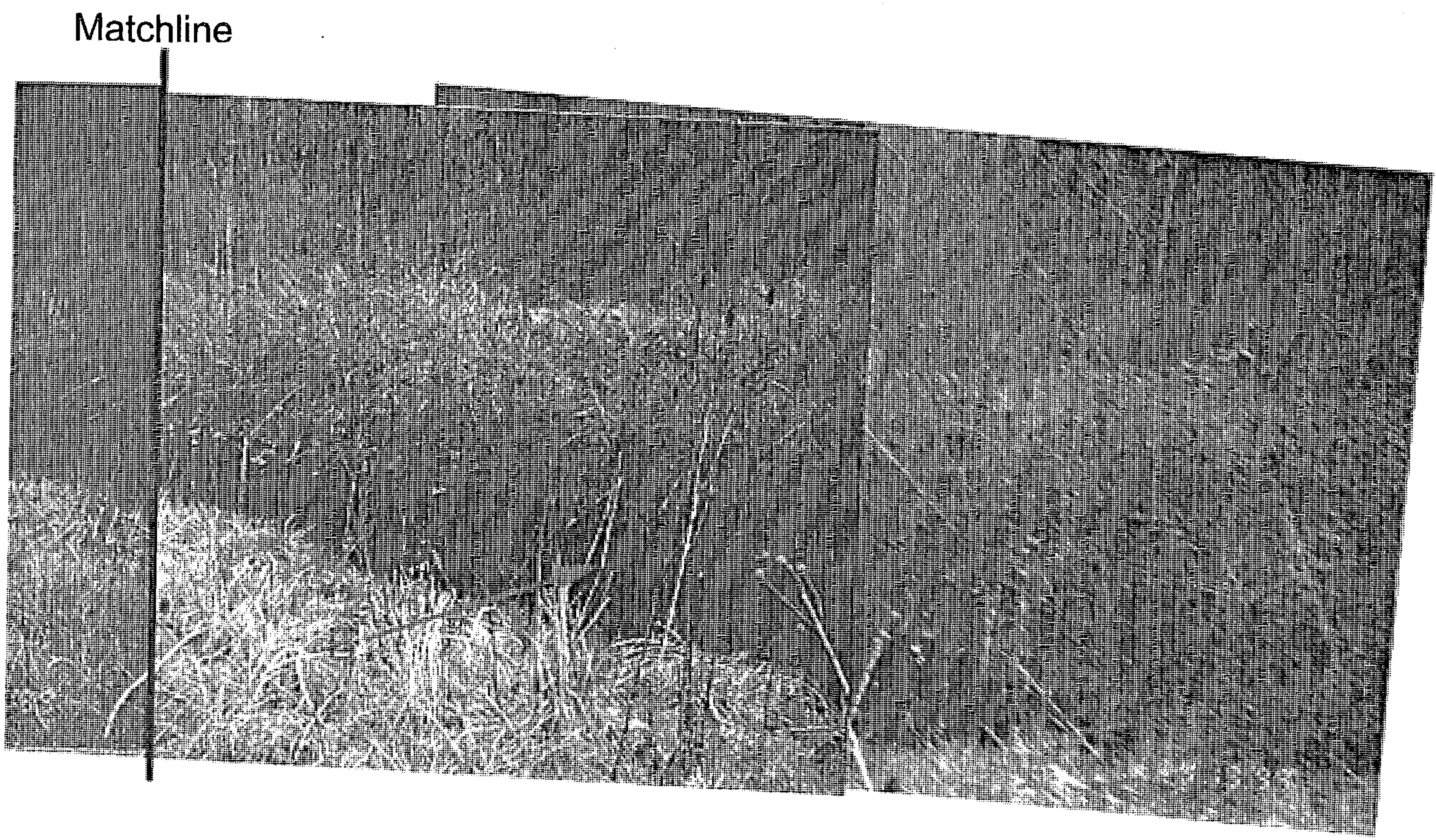


Photo 3-5 (b) LDA. Showing east infiltation pond ("B").

4.0 Subsurface Conditions

Subsurface conditions at the site were investigated by reviewing existing site-specific literature; local and regional geologic monographs and maps; speaking with professional geologists, engineers and mining personnel; and conducting onsite investigations. Onsite investigations consisted mostly of non-intrusive methods such as visual observations, electrical resistivity survey and ground penetrating radar. Test pits were excavated outside the suspected fill areas to ground true the radar survey. These investigative methods are treated more completely in Section 5, Field Investigations, together with the results of the surveys.

4.1 Regional Hydrogeologic Characterization

The regional hydrogeology of the site area has been documented in Robinson and Noble's reports on the DSP (1985, 1986). We also reviewed the Occurrence and Quality of Groundwater in Southwestern King County, Washington, by D. G. Woodward, F.A. Packard, N. P. Dion, and S. S. Sumioka (USGS, 1995) for the regional hydrogeology. The regional aquifers in the site area are mainly in the advance outwash deposits overlying the bedrock, particularly in the alluvial valleys.

We reviewed 13 well logs found in our search of Washington State Department of Ecology (Ecology) records. The approximate well locations are shown on Figure 4-1, Local Water Supply Wells. The locations are mapped as close to their location as available data allowed. Some well log descriptions only allow the well to be mapped to the nearest 1/4 section. These logs are presented in Appendix 4. These wells are all in alluvium except wells 11, 12, and 13. Wells 12 and 13 are east-southeast from the site and are expected to be in units underlying the pit areas. A shale unit underlies the DSP. This unit and the fine-grained nature of the sandstone units in the mine area make it unlikely any water that infiltrates through the pits migrates into these wells. Well 11 is down-gradient from the site and in sandstone beneath 34 feet of coal. This lithology is similar to that found in the mine area, however, there is no evidence they are in the same unit given the complex geology and their relative positions on the syncline. We expect, therefore, that this well is in a younger, shallower, unit. We do not expect there is lateral flow across different rock units towards these wells at shallower depths based on the observed lack of flow through rock faces in the mine pits as shown on Figure 5 of the 1985 Robinson & Noble report, see Appendix 5, and in Photo 4-1.

4.1.1 Site Hydrogeologic Conditions

Test pits were dug at the locations shown on the topographic survey maps in Appendix 2. Groundwater seepage was encountered in Test Pits 5, 7, 8, and 9 at depths ranging from 8.3 to 10 feet below the ground surface. This appears to be a perched groundwater that may be restricted to shallow weathered portions of the drift. We did note wet areas in the weathered sandstone and expect some groundwater could be perched in the more severely weathered sandstone. Perched water is a condition that occurs when water infiltrates through a more permeable soil or rock unit and collects and moves laterally along the top of a less permeable soil or rock unit. The water that moves laterally along the less permeable horizon is termed "perched." Perched water is not considered a regional water table. It should be noted that the local volumes of perched groundwater will vary depending upon the time of year, the up-slope recharge conditions and the fact the quantity of perched groundwater will vary laterally depending on the fines content of the residual soils.

The previous reports on the site concluded most of the ground-water flow from the site is along bedding planes in the bedrock. Minor flow was noted across beds through joints. The 1972 Metro Report indicated this flow was about 1 gallon per minute where found. Of more significance in the Metropolitan Engineers report is their report of mine collapse features in the base of the south end of the DSP. The filling of these areas of collapse was reportedly not to engineering standard. The 1972 Metro Report suggests that water seeping into this area of the pit could be entering the mine workings. Salt tests conducted for their report concluded water was percolating into the mines. We have not been able to substantiate these findings. Water at the mine portal does not appear to be affected by CKD leachate based on it's pH levels. However, the lack of high pH levels in the portal water could result from a combination of dilution and neutralization by local coal beds. The coal beds are often high in sulfur, usually in the form of iron sulfides. These compounds rapidly form acids on contact with water, raising the acidity of the water. The acidity of the water may be neutralizing the high pH water.

4.1.2 Groundwater

The potential for adverse impacts on groundwater in the vicinity of the mine has driven most of the regulatory oversight of mining and reclamation activities. The valley fill west of the site contains a local aquifer with extremely high transmissivity (Robinson & Noble, 1986 and others). The local aquifer southwest of the site and surface water bodies such as Ginder Lake may be hydrologically connected to, and down gradient from, the site.

Landfilling activities at the DSP precipitated a lengthy and expensive groundwater investigation during the process of petitioning the State for a Dangerous Waste Exemption enabling the mining company to use CKD as fill material. The steep inclination of the geologic formations at the site, together with nearby geologic faults and subsurface mine workings, have initiated much discussion and speculation about the potential for landfilled material to migrate into aquifers and discharge into surface waters. One result of this is a long-term groundwater monitoring program at the DSP.

Monitoring wells were installed in the vicinity of the DSP in February 1985 (MW-1 and MW-2) and April 1986 (MW-3 and MW-4). Monitoring wells 1, 2 and 4 are indicated on the E. True & Associates topographic maps (Appendix 3). Well MW-1 consists of a pair of wells, one shallow and one deep, located at the west side of the DSP near the geographic north-south midpoint of the pit, under the BPA power lines. Well MW-2 was drilled in a sandstone unit east of the DSP and the UHR, located near the geographic midpoint of the DSP. MW-2 has historically served as a "background" well; intended to be a comparison well for the other wells developed in the same geologic formations as the DSP. MW-4 consists of a cluster of three wells developed at shallow, medium and deep elevations at west side of the of the DSP near the north end of the pit. MW-3 is another cluster of three wells of shallow, medium and deep elevations at the northwest end of the DSP. Not all wells are being monitored at this time and well cluster MW-3 may have been removed by Reserve Silica Corp. during construction activities in 1999. Groundwater monitoring began in the first quarter 1985 at the DSP and continued at least to the first quarter 1987. Monitoring results were not found in the records reviewed for the period from the second quarter 1987 to the first quarter 1996. In 1996, a quarterly monitoring program was begun under the oversight of King County Health Department and Washington Department of Ecology.

Monitoring results for selected parameters and analytes are presented in Figures 4-2, 4-3, 4-4 and 4-5. The data suggest that chemical species that contribute to increased ionic strength have trended higher at MW-1 Shallow and MW-1 Deep. The data for pH, total dissolved solids (TDS), calcium (Ca) and bicarbonate have increased over the past 19 years and the plots of the data indicate that these parameters have pretty much moved up and down together. This apparent synchronous characteristic of these data may be a function of increased flow rates through the cap surface and down into the old mine workings. For comparison we have also included data for the Dale No. 1 mine portal water on the monitoring well plots. We have not completed a time-lag analysis of these data, but the data plots suggest that portal water quality may be tracking that of MW-1Shallow and MW-1Deep (see especially the plots for pH).

Calcium concentrations in the MW-1 wells have increased considerably since the mid-1980s relative to portal, MW-2 and MW-4 water quality. While bicarbonate concentrations are demonstrably higher at all monitoring points today than they were in the mid-1980s, the groundwater chemistry is complex for chemical species like bicarbonate, carbonate and sulfates which form bonds and dissociate with cations in complex patterns at different levels of pH and in different geologic formations. The dynamics of chemical speciation in this environment is especially marked when these ions are in contact with organic material, such as coal seams. It is likely that that dark brown color and high pH of leachate material is one result of this complex chemistry.

The 1972 Metro Report suggests that the south end of the DSP may be more prone to infiltration and leaching of CKD leachate has been substantiated to some extent when the entire data sequence is viewed. The 1987 Ideal Report compared the limited amount of data collected at the time that report was written with data from water supply wells in the vicinity of the site. The conclusions of the 1987 Ideal Report were that while the concentrations of analytes were greater in onsite groundwater than in nearby water supply wells, they (onsite wells) were "in the range of ambient groundwater for the Ravensdale-Black Diamond area." Given the higher concentrations of analytes detected at onsite wells in the late 1990s, the case for a favorable comparison with local water supply wells may not be warranted.

The speculations presented in the 1984 and 1987 Ideal reports about the positive effects that mine water would have on dilution and pH amelioration of CKD leachate is somewhat supported by the data. pH has not increased dramatically over the years, nor do the data show spikes that exceed either the State groundwater standard ($8.5<pH_{gw}>6.5$) or surface water standards ($9.0<pH_{sw}>6.0$). A likely reason for the suppressed pH of water in the wells and at the portal is that organic matter, together with acid-producing sulfur and iron compounds in these formations, likely lower the pH of the groundwater solution.

4.2 Regional Geology

The site is located on the eastern margin of the Puget Sound Basin in the foothills of the Cascade Range. A hill, locally known as Ravensdale Hill, is the predominant topographic feature in the area. Bedrock on Ravensdale Hill is comprised of Tertiary sandstone, siltstone, claystone, carbonaceous shale and coal of the Puget group. The bedrock was faulted and folded during the Eocene Epoch, 30 to 40 million years ago. The faulting and folding was probably associated with uplift and volcanic activity in the general area of the Cascade Range.

Quaternary glaciations have incised valleys, truncated and shaped the hills and mantled the foothills with varying depths of glacial sediments. Recession of the glaciers resulted in the infilling of the valley floors with recessional sand and gravel outwash deposits. These outwash deposits have subsequently been modified by river erosion and deposition to create the present-day topography. The regional geology is shown in the 1972 Metro Report..

4.2.1 Mine Geology

A brief history of mining at the Ravensdale site was presented above in Section 1.3, *Mining History*. This section relates the mining history to the local geologic setting. The site has undergone two periods of mining. The initial mining at the site was for coal in the underlying Puget Group sediments. Coal mining began underground in 1924 and continued intermittently until 1948. A strip mine, the Dale Strip Pit (DSP), was begun in 1946. Coal strip mining at the site stopped about 1954. Access to the underground mines was through a portal north of the Lower Disposal Area (LDA). This portal is now collapsed. A pipe draining water from the collapsed portal drains into the ditch east of the Lower Haul Road (LHR) north of the LDA.

Silica sand mining began at the site in the 1960's and has continued to the present. Silica sand mining began in the LDA area and in an area west of the DSP. The mine strips high silica sands from the Puget Group. Mining consists of excavating chemically suitable sandstone down-dip along the axis of the beds. Lateral variations in the beds result in some mine areas being abandoned due to chemical impurities. Water flow is reported to have entered these mines from the floor of the pit, from gravel deposits in the high-wall face at the south end of the LDA, as well as from storm water inflow during storm events (John Freeman, Reserve Silica mining engineer and John Melfi, Reserve Silica plant manager, personal communications). Mining activity ceased in the LDA area due to storm water inflow (Glenda McLucas, mining geologist, personal communication), and may have been limited in other areas due to storm water inflow. Stormwater and formation water entering the DSP is reported to have collected in the bottom of the north one-third of the DSP. Water entering the south third of the DSP is reported to have rapidly infiltrated into the underlying collapsed mining tunnels, see 1972 Metro Report.

Currently, stormwater from the active strip mines lying between the LDA and the DSP collects in abandoned and existing workings and is pumped into a ditch at the southwest end of the access road to the middle pit. It drains through a culvert under the LHR to a settling/infiltration pond south of the LDA. The overflow from this pond empties into an off-site drainage to the southwest of the mine area.

Future plans call for mining to continue south of the existing middle pit, and in the north end of the middle pit. The second area is east of the north end of the LDA. Site drainage for storm water is also to be improved as part of the next mining phase (John Freeman, personal communication). Reclamation efforts include continued filling of the east pit.

4.2.2 Site Geology

The site geology has been documented previously by Metropolitan Engineers (1972), Glennda McLucas (1984), and Robinson and Noble (1985, 1986). We also reviewed the Geologic Map of the Black Diamond Quadrangle, King County, Washington, (USGS, 1965) and the Geology of the Renton, Auburn, and Black Diamond Quadrangles, King County, Washington, (USGS, 1970), both by Donal R. Mullineaux, for the site geology.

The site is underlain at depth by Tertiary sedimentary rocks (arkosic sandstone, siltstone, claystone and coal) of the Puget Group. The bedrock in the area has been folded and faulted into a series of synclines and anticlines. The site is on the north limb of a northwest plunging syncline. The axis of the syncline intercepts the ground surface to the south-southwest of the site, see Figure 4-6 and Plate 3 of the 1972 Metro Report. Bedrock dips 50 to 80 degrees to the west-southwest on the site. The general dip of the sedimentary beds across the mine area is shown on Figure 5 in the Robinson & Noble Report, see Appendix 5. The syncline is bounded on the north and south by northwest-to-southeast and east-to-west trending faults. It has been uplifted relative to the surrounding bedrock.

The bedrock surface is unconformably overlain by glacial sediments of Vashon Age. The Robinson and Noble well logs indicate the glacial sediments are locally over 30 feet thick. These sediments are also up to 30± feet thick in future mine expansion areas south of the LDA (John Freeman, personal communication).

Lower Disposal Area

No subsurface explorations were performed in the LDA. The geology of this area was determined by visual examination of historic aerial photographs, mining exposures, road cuts, and fill slopes. Detailed geologic mapping of the area was beyond the scope of the Preliminary Investigation. The mining exposures and aerial photographs indicate the area is underlain by tertiary bedrock. Cut faces in the mine access ramp east of the LDA indicate bedrock contains at least three coal seams between the LDA and silica mine excavations east of the LDA. A highly shattered, dirty, coal seam, similar to the west-most coal seam in the ramp area, was located at the surface, east of the west central portion of the LDA. Mine activity in recent years to relocate the lower haul road and a road east of the LDA have resulted in additional fill placement on and east of the LDA. This fill is largely locally derived bedrock. Some imported fill has been placed in old mine workings east of the LDA. Fill observed on eroded surfaces at the LDA consist of CKD, glass wastes, and bedrock.

Glacial sediments were not observed in the LDA area. We expect these sediments are thin in the area or may have been removed by historic mining activities.

Dale Strip Pit

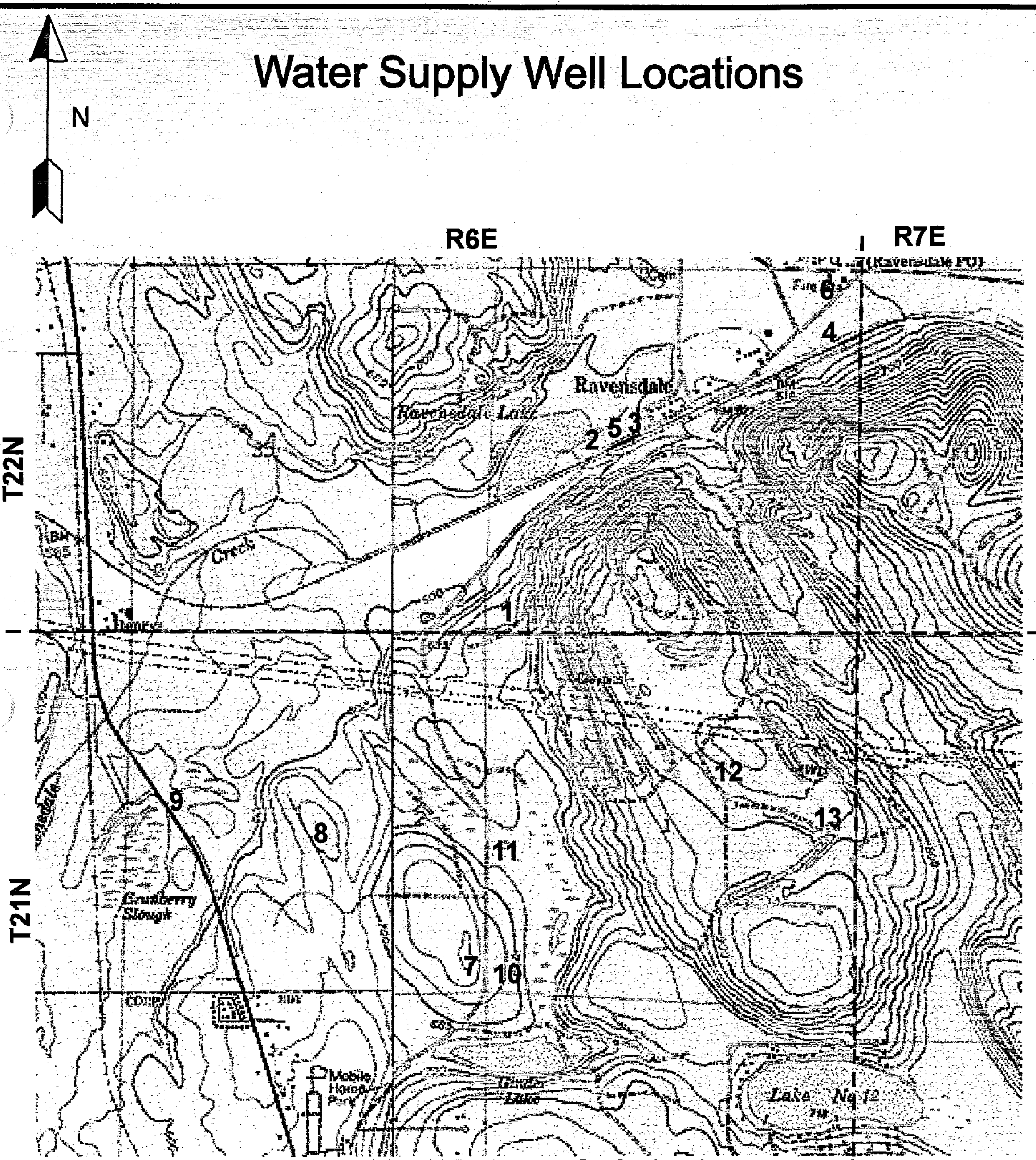
The subsurface conditions at the site were explored on August 5, 1999. Nineteen test pits were excavated with a rubber-tired, Case 580K Extendahoe. The depths of the backhoe test pits ranged from 5 to 13.5 feet below the existing ground surface. The test pit locations were staked and later located by a licensed surveyor. The locations of the test pits are shown on the Site Topographic Survey, Sheets 1 and 2, attached as Appendix 3. Soils and geologic conditions encountered during test pit excavation were noted and recorded at the time of excavation. The soils were visually classified in general accordance with the Unified Soil Classification System, a copy of which is included in appendix 6. The logs of the test pits, edited to reflect examination of soil samples in the laboratory, are in Appendix 6.

Explorations encountered a surficial layer of fill and/or topsoil ranging from about 1 to 8 feet thick in Test Pits 1, 2, and 4 through 19. The topsoil and fill consisted of local and off-site derived loose fine sand with varying amounts of silt, gravel, roots, wood, cobbles and organic matter, except Test Pit 3. Test Pit 3 was excavated in the south end of the DSP. It encountered fill throughout it's 13 foot excavation. The fill in Test Pit 3 consisted of 6.5 feet of silty fine sand with glass, debris, brick and suspected cement kiln dust (CKD). The bottom 4.5 feet of fill in Test Pit 3 consisted of silty fine sand with gravel, glass and coal.

Glacial drift was encountered in Test Pits 5 through 13 and 18. The glacial drift consisted of silty fine to coarse sand with varying amounts of gravel and scattered fine to medium sand interbeds or lenses. The upper portions of the drift were weathered to varying degrees and were locally water-bearing. The glacial drift extended beyond the bottom of all test pits in which it was found. The drift was observed mostly in the low swale east of the UHR in the vicinity of the power line easement.

Sandstone underlying the topsoil and fill was encountered in Test Pits 1, 2, 4, 14 through 17 and 19. The sandstone was composed of fine to medium sand with trace silt and was iron oxide stained. The sandstone was weathered to varying degrees and was locally wet.

Water Supply Well Locations



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LEGEND

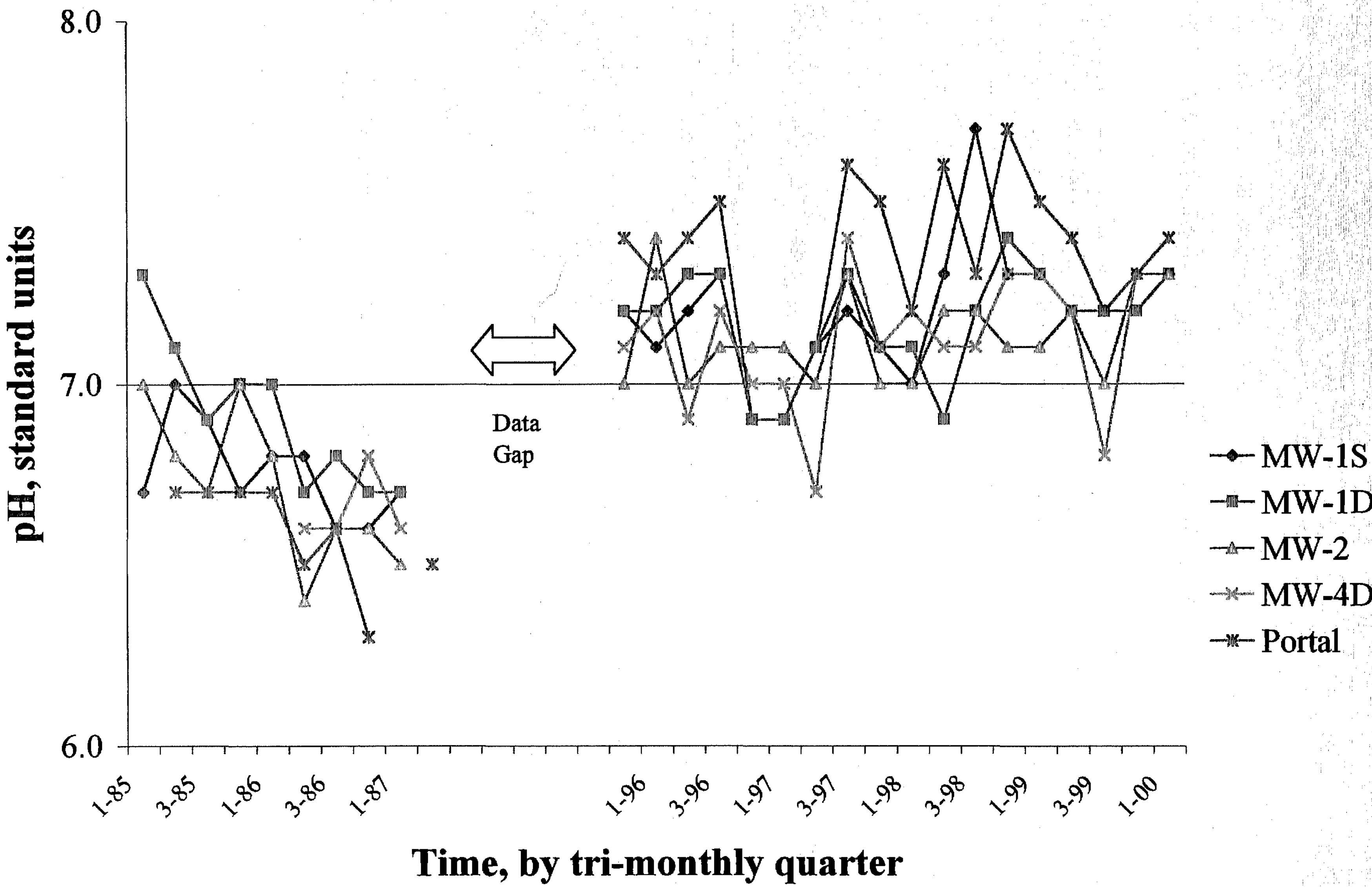
1 Water Supply Well Location

Figure 4-1
Holnam
September 1999

Figure 4-2

Water Quality Trend - pH
Resource Protection Wells
1985-2000

Ravensdale Preliminary Investigation



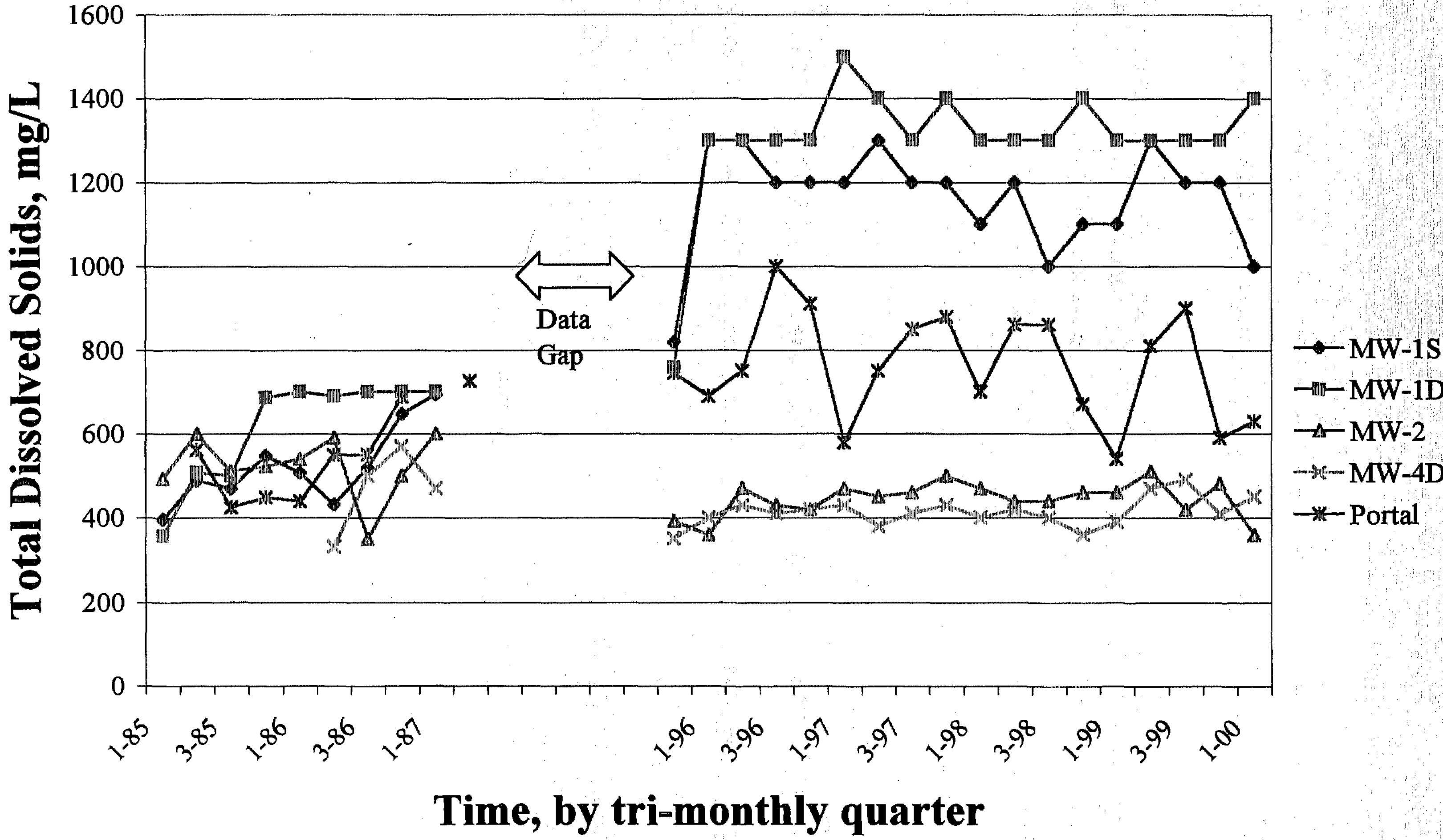
Prepared By: TESI
000719
MW pH Chart 1

Figure 4-2

Figure 4-3

Water Quality Trend
Total Dissolved Solids (TDS)
Resource Protection Wells
1985-2000

Ravensdale Preliminary Investigation



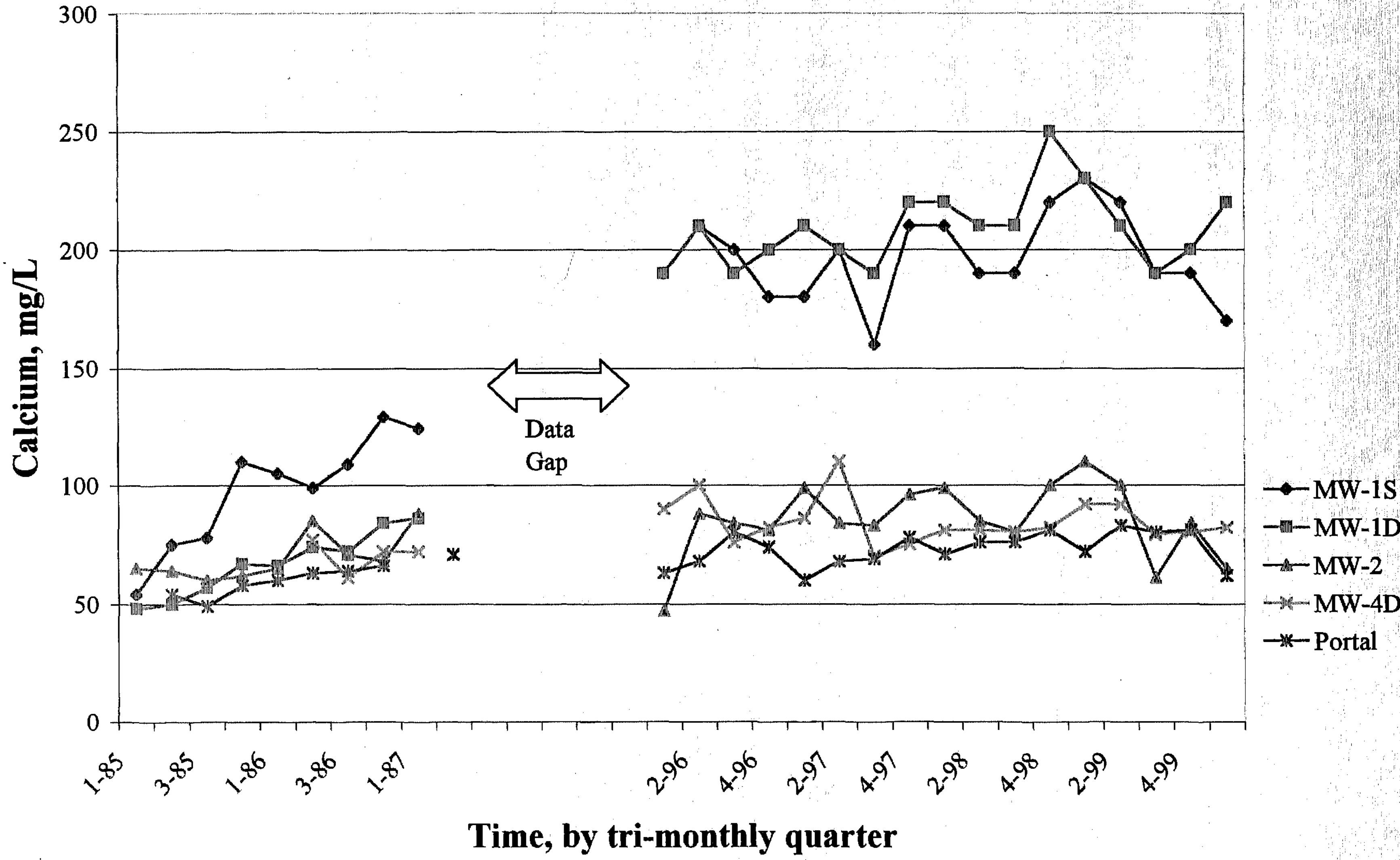
Prepared By: TESI
000513
MW TDS Chart 2

Figure 4-3

Figure 4-4

Water Quality Trend - Calcium
Resource Protection Wells
1985-2000

Ravensdale
Preliminary
Investigation



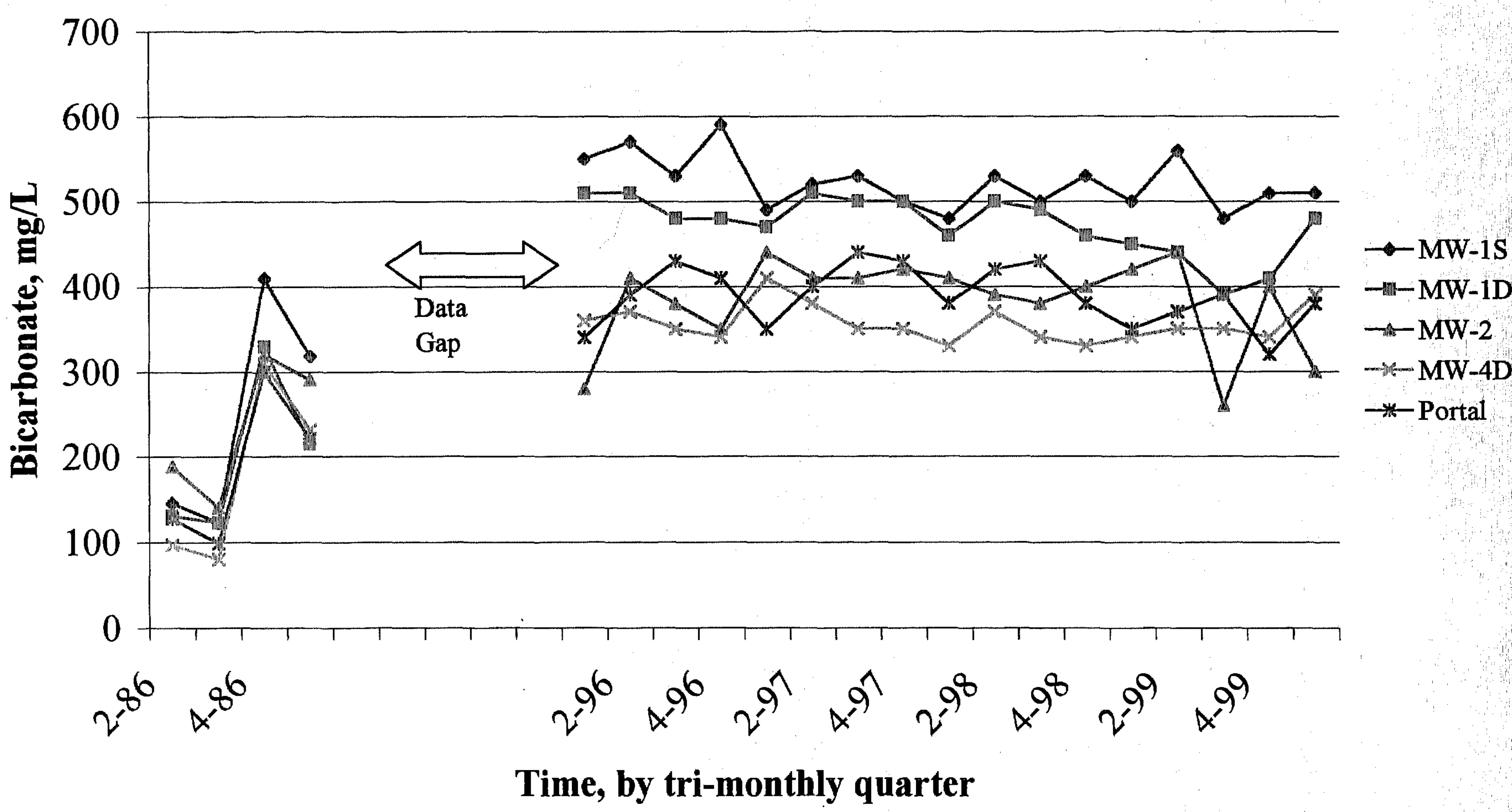
Prepared By: TESI
000513
MW Ca Chart 2

Figure 4-4

Figure 4-5

Water Quality Trend - Bicarbonate
Resource Protection Wells
1986-2000

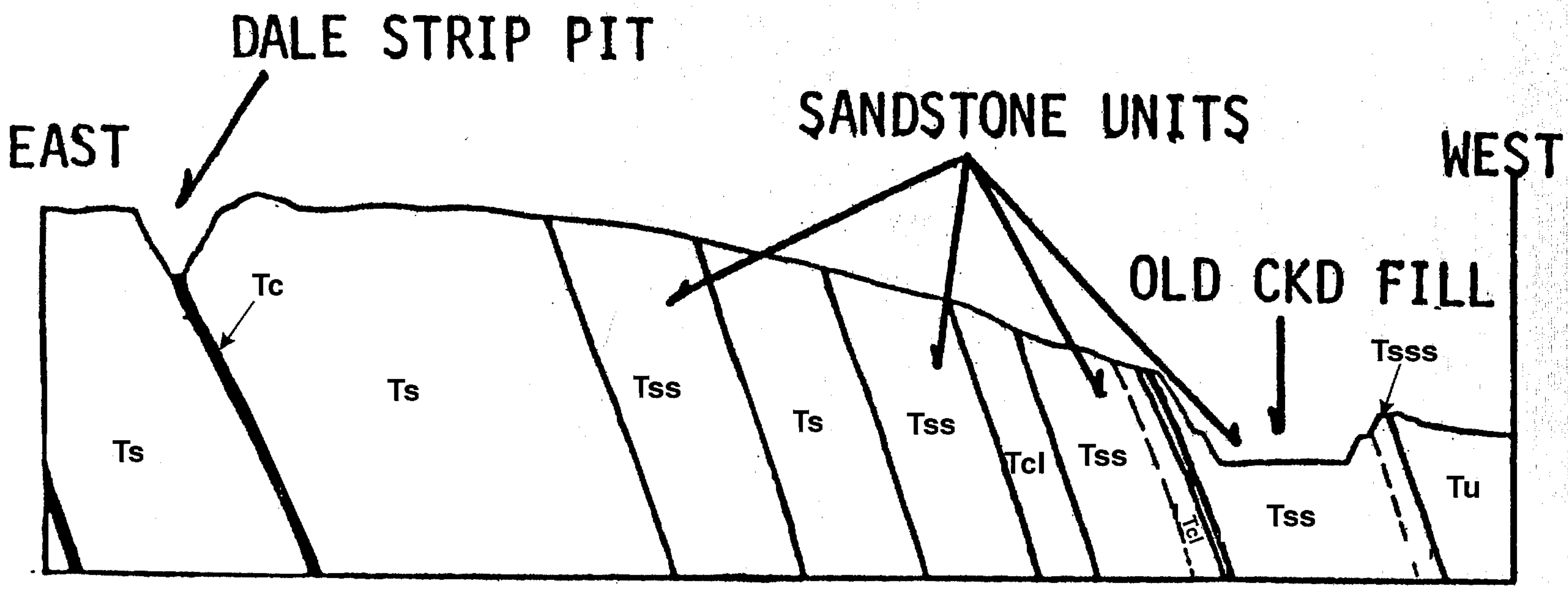
Ravensdale Preliminary Investigation



Prepared By: TESI
000719
MW Bicarb Chart 1

figure 4-5

Cross Section



LEGEND

Tc — Coal	Tss — Silica Sandstone
Ts — Siltstone, minor clay	Tsss — Sideritic Sandtone
Tcl — Clay, some siltstone	Tu — Undifferentiated sedimentary deposits

Reference: Cross-section is based on Figure 41, titled "Detailed Geologic Map and Cross Section of the I. M. P. Silica Sand Mine, Ravensdale, WA," from a report titled " Individual Exemption Petition to Washington State for Cement Kiln Dust Solid Waste Designation", dated November, 1984, by Ideal Basic Industries, Cement Division.

Drafted by: Nelson-Couvrette & Associates	Schematic Geologic Cross-Section	
	FILE NO. 2579D00	FIGURE 4-6

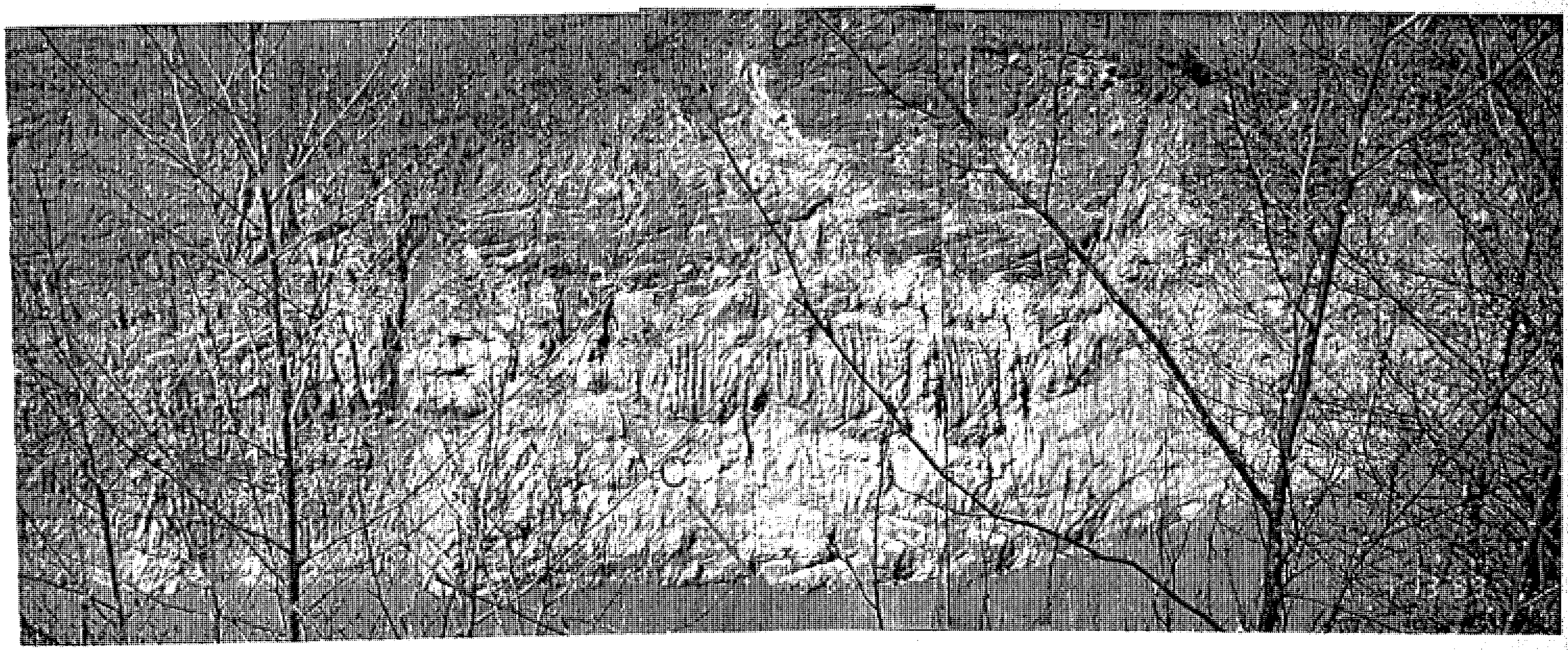


Photo 4-1 Central Sand Mine. View west from rim at west edge DSP. Showing formation jointing (at "A" and "B") in sandstone formation. This formation is adjacent to the eastern edge of the LDA. Note the ponding of water in the mine ("C").

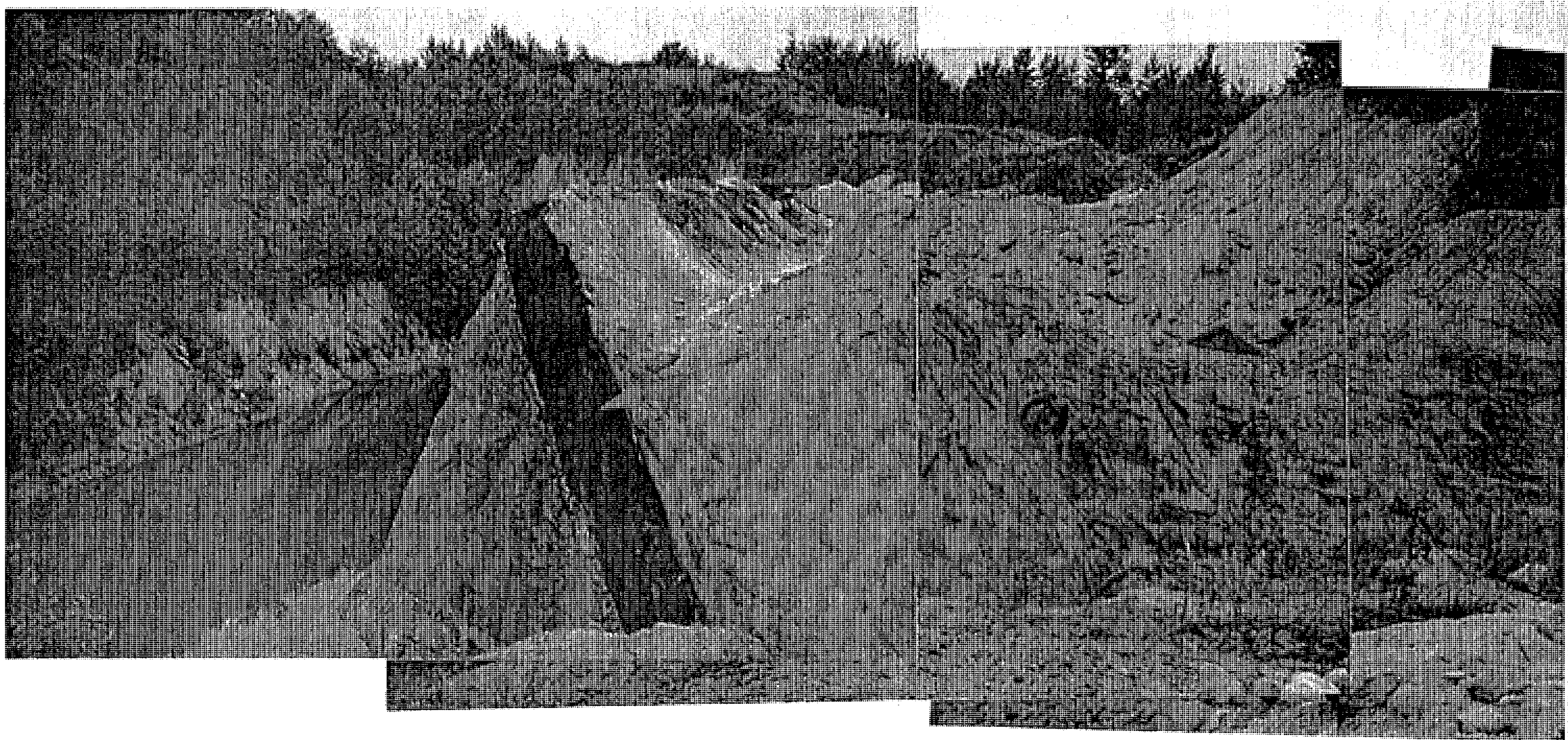


Photo 4-2 Former Sand Mine. View south of former sand mine located south and east of LDA. Showing dip of formations in the vicinity of the LDA and DSP. Measured dip of coal seam "A" is 55 degrees. Note the presence of water in the bottom of this pit. This pit is directly south of the DSP. June 1999.

5.0 Field Investigation Methods

Objectives of the 1999 field investigations were to develop background and baseline data on the DSP and LDA. No reliable information on the location and shape of the LDA pit existed prior to this investigation. On both the DSP and the LDA, we were interested in potential sources for ground water and surface water entering the pits and whether we could identify areas where surface and ground water could be passively and economically intercepted prior to reaching the pit areas. The geophysical surveys were proposed to develop preliminary data relative to four parameters at the site. The first two parameters were water conditions on and near the DSP and the LDA and potential areas of shallow flow onto or off the areas. The methodologies recommended by the geophysicists at Apollo Geophysics, Inc. were ground penetrating radar (GPR) and resistivity. Electro-magnetic (EM), self potential, and reflection/refraction over anomalous areas were also discussed and not used due to cultural effects (power line interference), and/or cost effectiveness relative to the type of data produced for a preliminary investigation of this nature. Test pits were planned to ground truth the GPR data upgradient from the study areas and to determine if ground water in the test pits was as expected based on the GPR data.

The other two parameters of concern at the site were related to the LDA. These two parameters were location and depth of landfill material. Through review of the literature, field reconnaissance, and interviews of persons with a working knowledge of the site, we determined the approximate location of the LDA. However, we were uncertain about the actual location and depth of excavation/filling.

The GPR was chosen to investigate the first two parameters because it has been found to be an effective method to look at shallow water tables and disturbed, weathered, and/or unweathered soils and rock. The method also has been effective in distinguishing between rock or soil types, provided the nature of the two rock/soil types are dissimilar enough to produce sufficient dielectric contrast. In our opinion, the soils, rock, and fill at the site were dissimilar enough for contrast. Two different antennas were used to look at different depths. The higher frequency, 450 mega-Hertz (MHz) antenna produced higher resolution data with less penetration. The lower frequency, 150 MHz, antenna gives less resolution, but better depth. Combining the plots for the two frequencies by computer analysis permits a deeper cross section to be synthesized with higher resolution near the surface.

Electrical resistivity was chosen to augment the radar in the LDA area due to the expected contrast between the bedrock and the fill materials. Additionally, we knew from field testing of seepage from the LDA that the water exhibited high pH (>11) with high conductivity (>1000 µS). A material's resistivity is inversely proportional to the conductivity. We expected the high pH materials or ground water would contrast with the other fill materials and rock. Also, the fill soils were expected to have lower resistance than the bedrock because the literature suggested that clay-type materials had been incorporated into the fill. The resistivity analysis also can differentiate between areas of similar soils with different moisture contents.

Two resistivity methods were considered, 1-D and 2-D arrays. 1-D was considered more cost effective for preliminary survey than the 2-D method. 2-D resistivity is a more expensive method and may be proposed for use in a later phase of the investigations to refine the data collected during the Preliminary Investigation. Lack of sufficient background knowledge could have resulted in running very expensive 2-D lines in areas that would add little to the preliminary characterization of the site. To ensure sufficient coverage and depth by 2-D without sufficient background would have required thousands of feet of line, which would have significantly increased the cost of exploration. 1-D allowed us to look at the general area, then based on that background, look at additional areas of interest.

The GPR survey indicated there was not a widespread shallow aquifer in the glacial soils and/or in weathered bedrock in both areas. The test pits, excavated up-gradient of the DSP to ground truth the radar, confirmed that the water was in isolated areas, and perched on less weathered soils or bedrock and that the radar could distinguish between the soils and the bedrock. The test pits were not excavated in this phase of the study up-gradient from the LDA, because the GPR data indicated there was a potential for a cut-off trench and we could ground truth the data during installation of the trench, if necessary. We decided it was more economically efficient to conduct additional resistivity surveys in an effort to provide better location data for the LDA.

The initial resistivity survey at the LDA was performed on a random grid to delineate pit location identify anomalous areas that could be the source of high pH water seepage. Based on the absence of a detectable water table from the radar data and the results of the initial resistivity survey, we modified the study in the LDA area. We opted to perform additional resistivity points to better define the pit location. The additional work provided a better, but not complete, picture of the limits of fill at the LDA. Additional geologic and geophysical work will be necessary to more reliably determine the extent and nature of fill materials. The additional work should include borings as well as non-intrusive geophysical testing measures.

5.1 Field Investigation Results

The GPR data at the DSP area correlated well with test pits dug for ground truth, see Figure 5-1a-f and the location of cross section A-A□ on the topographic maps in Appendix 3. The complete dataset for GPR and resistivity are found in the Apollo Geophysics report, see Appendix 7. GPR and resistivity data from the Apollo report have been synthesized with topographic and test pit data and are included as figures in this report.

The GPR was able to distinguish between several different soils/rocks. We interpret these soils to be fill, weathered and unweathered glacial drift/till and weathered and unweathered sandstone based on the nearby test pits. Additionally, the radar located a lower unit in the area, which may correspond to a shale unit found during construction of monitoring well MW-2 at a depth of 32 feet (Robinson & Nobel, 1985). Alternatively, this may be a less weathered or compositionally different unit below the surficial sandstone. Our interpretation is based on review of previous geologic reports in the area and nearby borings, test pits and monitoring well logs.. Our interpretations of the geophysical data are shown on Figure 5a-f.

At the LDA, the GPR sections generally show three units see Appendix 7, GPR cross sections B-B□ and C-C□. The shallow unit may be road fill (and the lower unit is bedrock. The middle unit may be either weathered bedrock or fill on section B-B□ and is fill on section C-C□, based on our current understanding of historic mining activities at the site and test pit data. Insufficient data exists to correlate this data to site geology.

One notable feature absent from the data is any indication of significant amounts of ground water. We think this is due to the surveys being performed during a period of dry weather. A shallow ground water surface usually appears on the radar record as a solid black line with concomitant decreased radar penetration into underlying units. In our test pits east of the DSP, we found discontinuous perched ground water. This is typical for weathered glacial sediments, like those found in our test pits east of the UHR. With fill, as expected in the LDA, there may be either continuous or a discontinuous shallow water table, based on the nature of the fill. With granular or openwork fill from lightly weathered rock fragments similar to those found on the ground surface east of the LDA, the shallow water table may be continuous.

The absence of a water signature on the records indicates little water was probably flowing through the fill at the time of our survey. We did observe significant amounts of surface flow during site visits that coincided with heavy rainfall. We expect that the fill becomes rapidly saturated during periods of heavy rain and water will perch on the rock surface. We do not have data on the direction of flow and recommend sufficient monitoring wells be installed on the perimeter of the LDA to determine perched water flow directions. A 2-D resistivity program should be considered during wet season storm events to obtain more data. This program would be designed to look for potential flow into or out of the LDA and locate potential monitoring well locations. Addition of 2-D resistivity lines east-west across the LDA would allow a better definition of the pit.

The radar data indicates a strong potential that soils/rock suitable for cut-off trench installation exists at relatively shallow depth up-gradient of both the DSP and the LDA. In the LDA area, potential directions of perched water flow should be determined before cut-off trenching is designed. East of the DSP, the trench could be designed with the information and data available collected during this preliminary investigation.

The vertical electrical soundings (VES) of the resistivity survey were able to distinguish fairly well between rock and fill. A resistivity measurement was taken on a surficial exposure of a white compound in the LDA suspected to be CKD. This compound had a low resistivity. Similar low resistivity values were found in VES points 1, 2, 3, 7, 8, 9, 13, 17, 18, 19, 20, 21, 22, 23, 24, and 25, see Apollo report (1999). VES points 17 through 25 were located based on our initial 16 VES points. The low resistivity values in VES points 7, 8, 9, 24, and 25, on the LHR, also correlate well with areas of high pH seepage down slope of the LHR. This data was used to develop a rough idea of the location of the LDA fill and pit location.

5.2 Lower Disposal Area

The geophysical data collected in the LDA identified three areas of interest. The radar data suggest, when coupled with resistivity data, that a layer of fill and/or weathered bedrock capable of transmitting storm water towards the LDA cap and fill exists at shallow depths. The material is best identified at resistivity point VES-1, see Appendix 7, Figure 4-Geo-Electric Cross Section C-C□. The fill shows up as the shallow upper units in the upper 10 feet of the vertical section. We are able to correlate this material as fill because of an open fill face above the LDA west of VES-1. The fill thins in the section towards VES-3. This correlates well with observation of bedrock and *in-situ* coal at the ground surface near VES-3. The section also demonstrates the potential problems associated with limited subsurface data investigations for this area. The material with a resistivity of 31, together with the low resistivity material detected at depth (resistivity of 9) at VES-3, are not, in our opinion, fill or CKD. We expect the resistivity 31 material is the coal bed identified at the surface nearby and that the resistivity 9 (VES-3) and 21 (VES-1) material is a siltstone, claystone or coal seam at depth. These interpretations would have to be confirmed by borings. The areas shaded in gray in VES-15 and VES-16 may show an extension of coal seams visible in the pit access cut south of the LDA or could be due to a clay or siltstone lens in the bedrock.

The second areas of interest in the LDA fill are best shown on Geo-Electric Cross Sections D-D' and G-G' and the Geo-Electric Cross Sections Figures 5 and 8 and G-G', see Appenidx 7. The shaded area on G-G' shows the possible north-south extent of the LDA and the area denoted as Potential Non-Native fill under VES-2 and VES-19 on section D-D' shows the possible east-west configuration of the pit. The shaded area below VES-10 and VES-11 could represent a subsurface flow of conductive (high pH) water flowing beneath the Reserve Silica stockpile, or could be due to conductive bedrock such as claystone, siltstone or coal. The interpretations need to be confirmed by site exploration.

The third area of interest is best shown on Geo-Electric Cross Section A-A', see appendix 7. This cross section was run along the lower haul road. The significance of this cross section is that high pH seepage which discharges at the surface below the road was noted between VES-7 and VES-8. The surface seepage occurs at an elevation similar to the upper area between VES-7 and VES-12 identified as Potential Non-Native/Native Fill Mixtures or Conductive Water. If this is indicative of leachate seepage from the fill, as suspected, the seepage producing the surface discharge could be continuing below the ground surface south of the areas of observed surface discharge. The thickness of the shaded area of potential seepage may be the saturated thickness of water moving through the fill in this area, at the time of the survey. We expect the thickness of the saturated flow will vary seasonally, depending on the amount of water entering and exiting the pit. Drilling and ground water sampling would have to be done to confirm this.

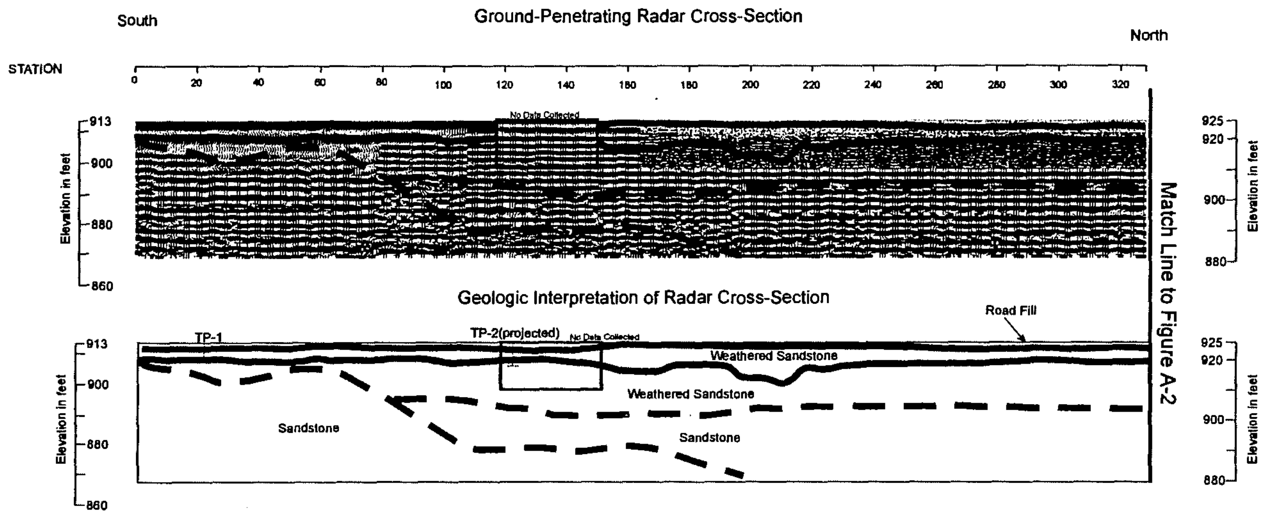
5.3 Dale Strip Pit

The areas we interpret as weathered and unweathered glacial drift are shown on Figure 5-1b through e, between stations 480 feet and 1460 feet. We interpret this geophysical unit as drift based on our observation of drift soils between Test Pits 5 and 13, approximately between stations 465 and 1400. Drift at Station 465 in Test Pit 5 and at 480 on the geophysical line may have been encountered due to the test pit being east of the road surface. The road in this area is on a bedrock topographic high. The location of the drift is significant because it defines a low in the bedrock topography that provides a potential source for shallow perched ground water to enter the DSP. There were insufficient data to determine the direction of ground water flow in the area.

The weathered drift overlies a more compact glacial drift or till unit. The weathered unit is more permeable than the underlying till unit. This results in water perching within the weathered drift. The weathering is variable through the unit resulting in zones with differing degrees of permeability. The more permeable zones typically transmit the perched ground water as opposed to having a pervasive water-bearing zone through the whole formation. This type of situation was observed where water was encountered in Test Pits 5, 7, 8, and 10.

The bedrock was encountered near the ground surface at each end of the upper haul road in our nearby test pits. This corresponds very well with the geophysical data showing a deeper unit that underlies the drift that shallows north and south of the stations 480 and 1460, respectively. We interpret the geophysical boundaries within the sandstone areas to be weathered based on the nearby test pits. The distinctions in the geophysical data are, however, based on dielectric variations within the unit. These variations may be due to changes in chemical composition that we did not locate in our test pits or could be due to changes in other parameters, such as moisture content. This condition of differential moisture, may be due to variable amounts of weathering of the bedrock.

Cross-Section A-A'



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES (see note)

TP-1 TEST PIT LOCATION AND DEPTH

0 30 60

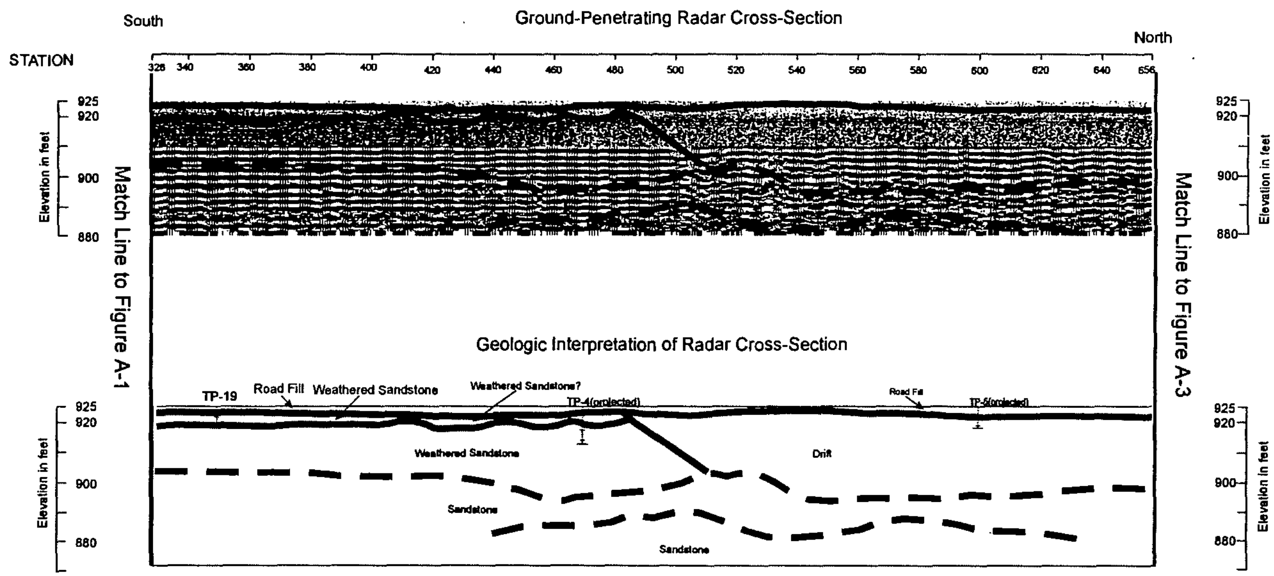
Horizontal and Vertical Scale 1" = 30'

Reference: Cross-Section created by NCA from "Ground Penetrating Radar Cross-Section A-A'," by Apollo Geophysics, dated November 18,1999. Elevations based on March 2000 Topographic Map by E. True and Associates.

Note: Geologic Interpretation of the Subsurface Soils and Bedrock is based on TESI and Nelson-Couvrette's review of existing geology reports and test pit and monitoring well logs. The geologic boundaries shown reflect Apollo Geophysics' interpretation of the Ground-Penetrating Radar data.

Drafted by Nelson-Couvrette and Associates	Davis Pit #4 Ravensdale, Washington	FIGURE 5-1a
	FILE NO. 2579D99	DATE March 2000

Cross-Section A-A' (cont.)



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

TP-1 TEST PIT LOCATION AND DEPTH

0 30 60

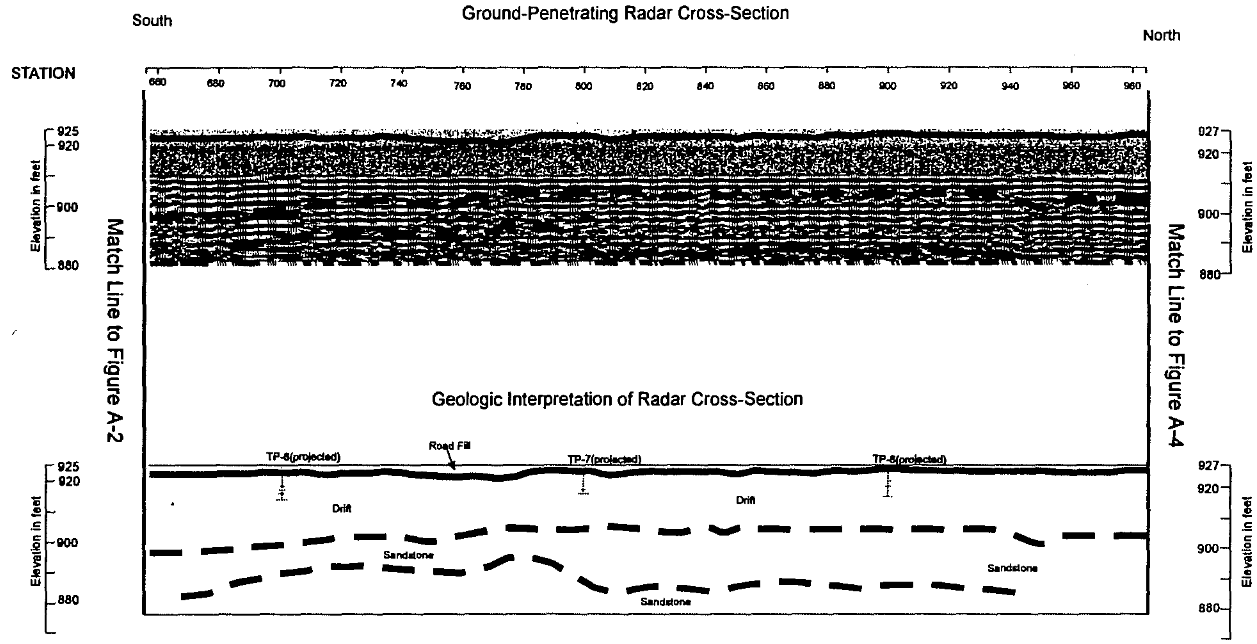
Horizontal and Vertical Scale 1" = 30'

Reference: Cross-Section created by NCA from "Ground Penetrating Radar Cross-Section A-A'," by Apollo Geophysics, dated November 18,1999. Elevations based on March 2000 Topographic Map by E. True and Associates.

Note: Geologic Interpretation of the Subsurface Soils and Bedrock is based on TESI and Nelson-Couvrette's review of existing geology reports and test pit and monitoring well logs. The geologic boundaries shown represent Apollo Geophysics' interpretation of the Ground-Penetrating Radar data.

Drafted by Nelson-Couvrette and Associates	Davis Pit #4 Ravensdale, Washington	FIGURE 5-1b
	FILE NO. 2579D99	DATE March 2000

Cross-Section A-A' (cont.)



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

TP-1 TEST PIT LOCATION AND DEPTH

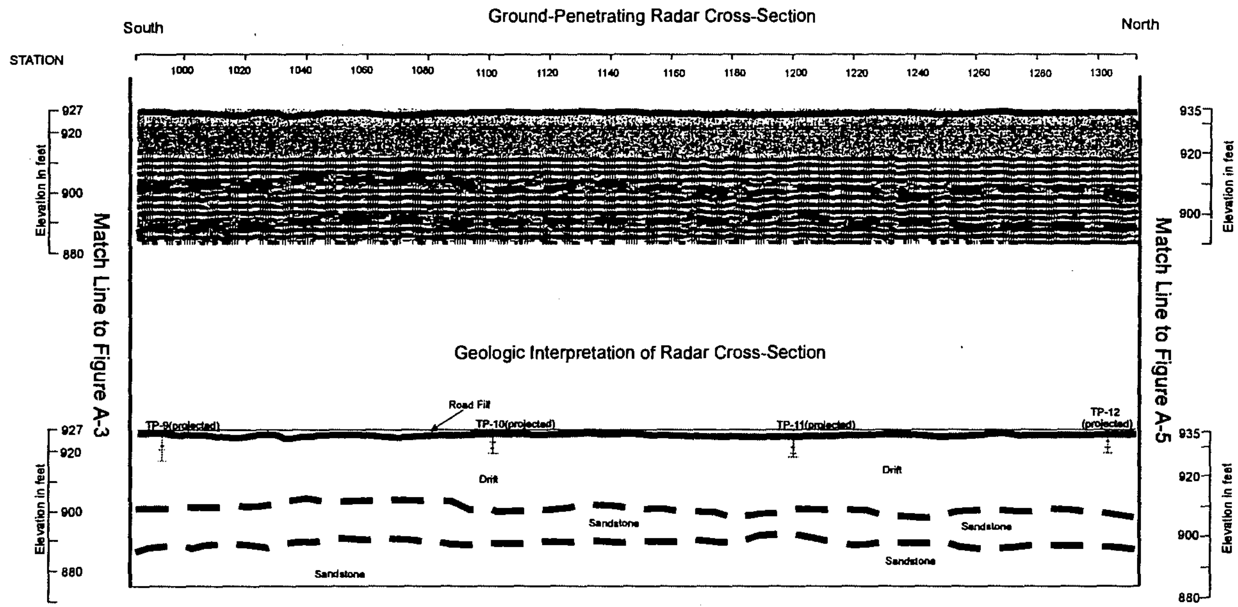
Horizontal and Vertical Scale 1" = 30'

Reference: Cross-Section created by NCA from "Ground Penetrating Radar Cross-Section A-A'," by Apollo Geophysics, dated November 18,1999. Elevations based on March 2000 Topographic Map by E. True and Associates.

Note: Geologic Interpretation of the Subsurface Soils and Bedrock is based on TESI and Nelson-Couvrette's review of existing geology reports and test pit and monitoring well logs. The geologic boundaries shown represent Apollo Geophysics' interpretation of the Ground-Penetrating Radar data.

Drafted by Nelson-Couvrette and Associates	Davis Pit #4 Ravensdale, Washington	FIGURE 5-1c
	FILE NO. 2579D99	DATE March 2000

Cross-Section A-A' (cont.)



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

TP-9 TEST PIT LOCATION AND DEPTH

0 30 60

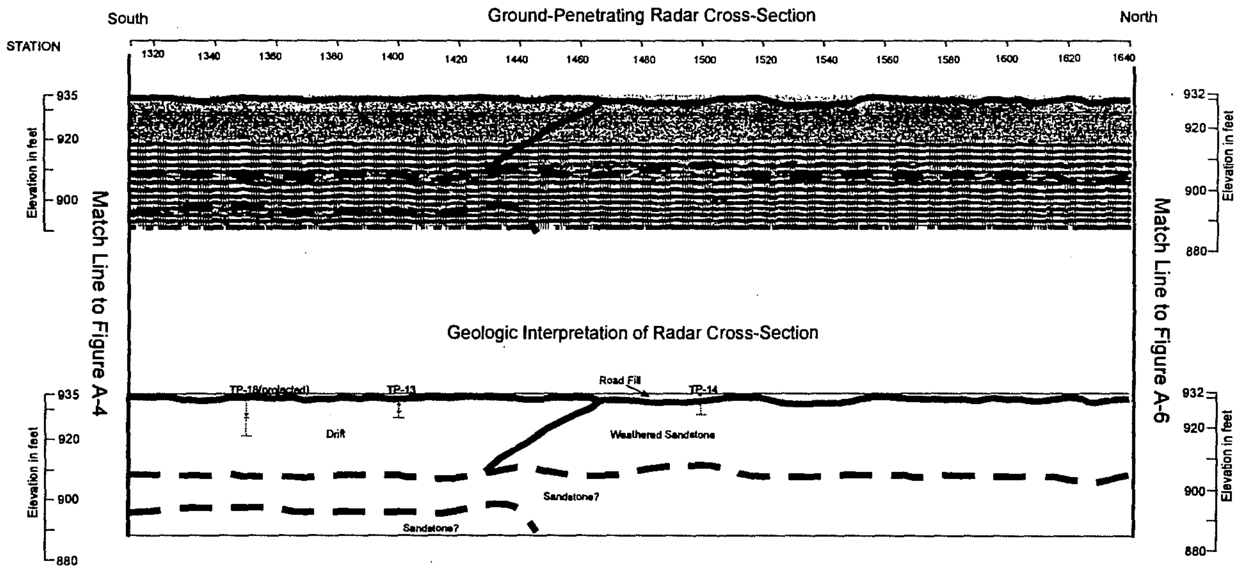
Horizontal and Vertical Scale 1" = 30'

Reference: Cross-Section created by NCA from "Ground Penetrating Radar Cross-Section A-A'," by Apollo Geophysics, dated November 18, 1999. Elevations based on March 2000 Topographic Map by E. True and Associates.

Note: Geologic Interpretation of the Subsurface Soils and Bedrock is based on TESI and Nelson-Couvrette's review of existing geology reports and test pit and monitoring well logs. The geologic boundaries shown represent Apollo Geophysics' interpretation of the Ground-Penetrating Radar data.

Drafted by Nelson-Couvrette and Associates	Davis Pit #4 Ravensdale, Washington	FIGURE 5-1d
	FILE NO. 2579D99	DATE March 2000

Cross-Section A-A' (cont.)



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

TP-1 TEST PIT LOCATION AND DEPTH

0 30 60

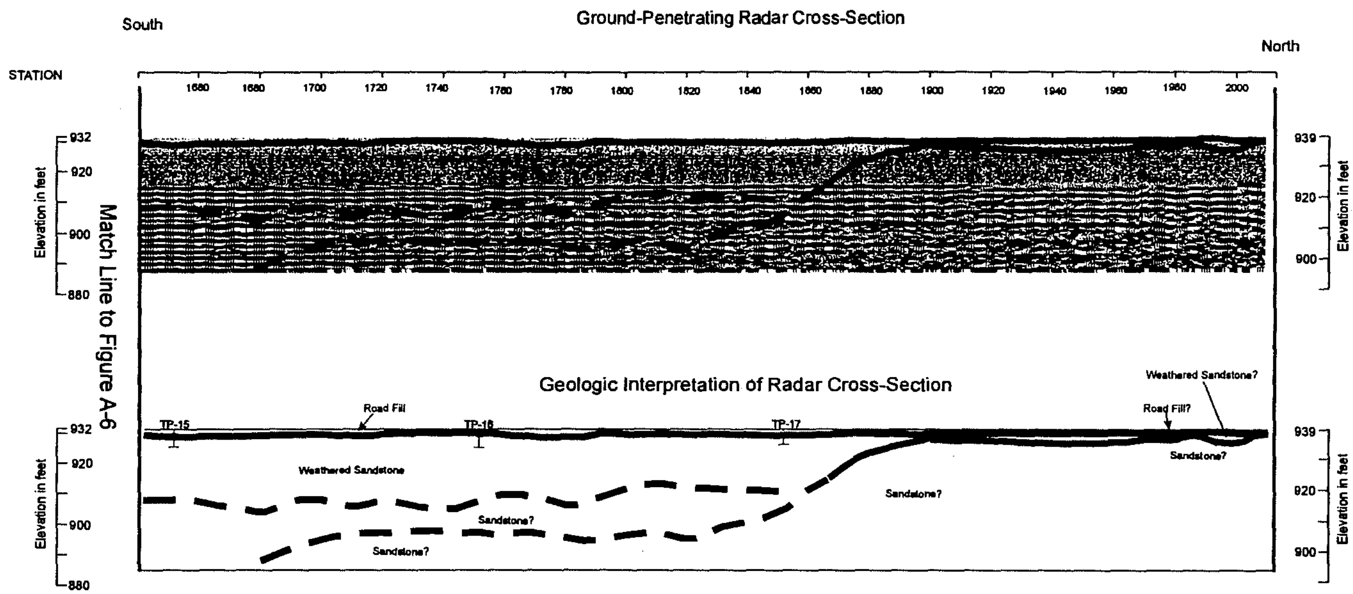
Horizontal and Vertical Scale 1" = 30'

Reference: Cross-Section created by NCA from "Ground Penetrating Radar Cross-Section A-A'," by Apollo Geophysics, dated November 18, 1999. Elevations based on March 2000 Topographic Map by E. True and Associates.

Note: Geologic Interpretation of the Subsurface Soils and Bedrock is based on TESI and Nelson-Couvrette's review of existing geology reports and test pit and monitoring well logs. The geologic boundaries shown represent Apollo Geophysics' interpretation of the Ground-Penetrating Radar data.

Drafted by Nelson-Couvrette and Associates	Davis Pit #4 Ravensdale, Washington	FIGURE 5-1e
	FILE NO. 2579D99	DATE March 2000

Cross-Section A-A' (cont.)



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

TP-1 TEST PIT LOCATION AND DEPTH

0 30 60

Horizontal and Vertical Scale 1" = 30'

Reference: Cross-Section created by NCA from "Ground Penetrating Radar Cross-Section A-A'," by Apollo Geophysics, dated November 18, 1999. Elevationd based on March 2000 Topographic Map by E. True and Associates.

Note: Geologic Interpretation of the Subsurface Soils and Bedrock is based on TESI and Nelson-Couvrette's review of existing geology reports and test pit and monitoring well logs. The geologic boundaries shown represent Apollo Geophysics' interpretation of the Ground-Penetrating Radar data.

Drafted by Nelson-Couvrette and Associates	Davis Pit #4 Ravensdale, Washington	FIGURE 5-1f
	FILE NO. 2579D99	DATE March 2000

6.0 Investigation Results and Interim Corrective Measures

The information and data gathered from historical reports, photographs and field investigations are summarized in this section of the report. Two primary areas of interest were identified – the Lower Disposal Area (LDA) and the Davis Strip Pit (DSP). Each area has features and characteristics that are unique and other ones that are shared. Similarly, some mitigation measures for the two areas will be similar and can be implemented simultaneously. Others either will be sufficiently different or have different time constraints, e.g. placement of fill material at the DSP and LDA.

6.1 Lower Disposal Area

Our investigation and observations document several structural and operations failures of the current system at the lower disposal area (LDA). Issues investigated as potential sources of risk include:

1) Cap degradation,
2) Inadequate drainage control,
3) Continued use of the area for activities incompatible with landfill functions,
4) Structural deficiencies that fail to isolate fill material from ground and surface water,
5) Uncontrolled runoff on to the surface of the LDA,
6) Absence of a written operations and maintenance plan for the facility,
7) Lack of a monitoring program that tracks site conditions, and
8) Lack of a response plan to respond to changing site conditions.

The surface has been degraded since construction and seeding in 1983. Aerial photographs from the 1980s and 1990s show that vehicle access on the cap surface was not controlled after construction. This uncontrolled access has at the very least contributed to cap degradation from mechanical abrasion. Aerial and ground photographs from the 1980s to the present show that the LDA has also been used for temporary storage of overburden and fill material.

Aerial photographs from the 1980s to present, inspection by the King County Health Department and onsite investigations conducted by TESI indicate there has been hillside surface seepage of leachate from the LDA for several years. Leachate production is likely a function of inadequate design and engineering controls in place at the time of construction together with the lack of controlled surface and near-surface drainage on and near the LDA.

6.1.1 LDA Slope Stability

The design cap for the LDA shows the cap inclined parallel to the slope surface, see Figure 6-1 and Photo 6-1. We found no documentation regarding actual cap installation. For the purpose of this investigation, we assume that the cap was installed as indicated on this diagram. Water flow across an inclined CKD and clay-liner surface would be expected to produce a plane of weakness that could result in slumping. We noted shallow slumps on the cap surface similar to what would be expected with the storm water flow on to the cap, see Photos 6-2 and 6-3.

Additional surface slumps and failures were noted upslope of the lower haul road (LHR) on the southwest side of the LDA. These slumps are small and appear to be related to the

CONFIDENTIAL - ATTORNEY - CLIENT PRIVILEGED development of surface drainage on the LDA and ditch cleaning along the LHR. Soil erosion and periodic maintenance along the road accounts for most of the soil buildup in the ditch. Removal of the infill has resulted in local undercutting of the cap along the east side of the LHR. Areas undercut in this manner have frequently resulted in exposure of CKD material. Where CKD is exposed, calcified seeps develop with black-colored, high pH (>10.5), water discharging into the drainage ditch (TESI field observations from 1998 to present). To date, laboratory analysis of the water at this location has not been done.

As CKD has been exposed, Reserve Silica has filled over the exposed areas. This filling is cosmetic and results in additional, previously uncontaminated, material, combined with stormwater, commingling with leachate and then being transported to adjacent down-gradient areas and eventually to the infiltration ponds. Covering of exposed CKD should be accompanied by stormwater control, construction of an engineered cap and a fixed operation and maintenance routine, discussed below. Redesign of the ditches and/or relocation of the LHR away from the cap area could improve this situation.

6.1.2 LDA Cap Integrity

LDA cap integrity has been compromised in the past by lack of maintenance and both vehicular and equipment traffic on the cap. Numerous trails over the cap were noted in historic photographs and aerial photos. The trails were left open and appear to have resulted in erosion in some areas of the central and northern portion of the LDA cap. Ditches have also been cut into the south part of the LDA cap to enhance drainage. Continued surface water flow through these features and exposure of CKD at the surface, raise questions about cap integrity see Photos 6-4 and 6-5.

Evidence of shallow sloughs on the cap were observed. The sloughs result in erosion of exposed soil and ponding of storm water on the cap. Storm water also ponds at the east-central cap and the area immediately east of it. The ponding near the east edge of the cap is probably the result of regrading, road building and placement of non-engineered (non-structural) fill onto the cap and adjacent area. Storm water seeps into the fill and appears to move laterally onto the cap. Areas of ponded water develop in these regraded areas and on the cap as shown in Photo 6-6.

Furthermore, it is likely that poor cap integrity results in stormwater infiltrating onto and possibly *into* buried CKD. If stormwater is contacting the underlying CKD it would migrate laterally to the drainage ditch at the LHR, north to the fill underlying the LHR (where seepage drains from the hillside below the LHR), or downward into the underlying aquifer. A detailed investigation of these three migration pathways was beyond the scope of this investigation. Additional investigation of leachate and monitoring to determine the effectiveness of engineering and management controls is recommended.

6.1.3 LDA Stormwater Diversion, Treatment and Infiltration

The 1984 Ideal Basic Industries Exemption Petition (cf. Appendix C-8) documents that the State Department of Ecology (Ecology) approved the Landfill Application subject to four primary items:

1) Monitor surface and groundwater quality to ensure that leachate seepage from the landfill meets surface and ground water standards;

2) Control site access by fencing the landfill;

3) Sign the area to warn persons of the potential health hazards of the leachate; and
4) Keep records of material and material quantities placed in the landfill.

Ecology told Industrial Minerals Products (IMP), a precursor to Reserve Silica, that a catch basin should be constructed at the top of the hill (at the northwest corner of the landfill). The basin was intended to catch high pH leachate and stormwater, treat it with acid, and provide a monitoring point prior to release to infiltration ponds constructed at the base of the hill. Apparently, IMP indicates in the letter contained in Appendix C-8 that they preferred an alternative system whereby leachate and contaminated storm water would be piped along the side of the LHR to the mine portal. At the base of the hill, the high pH leachate-storm water mixture would be diluted with mine portal water, prior to being conveyed to infiltration basins.

IMP indicated that this latter alternative was preferred because of site control issues associated with an acid addition apparatus. It is unclear what was constructed because specific documentation was not located. IMP's preferred alternative, as set forth in Appendix C-8, has some economic merit providing that the system is maintained and the effluent is monitored. No evidence was found that resource protection wells were ever constructed to monitor ground water quality. Surface water monitoring data documenting whether or not the leachate-storm water and mine portal water mixture met State ground water standards were not found. Mixing of the leachate with mine portal water and/or stormwater could lower the pH of the leachate by dilution, but no evidence confirming the efficacy of this procedure was found.

Our investigation suggests that the one to two gallons per minute leachate production volume reported in Appendix C-8 are lower than current leachate production volumes; even during the dry season. During fall, winter and spring storm events very high volumes of storm water commingle with the leachate. The State surface water standards require the pH of effluent discharge to be within the range of pH 6.0 to 9.0 and the regulatory standard for discharge to ground water is in the range pH 6.5 to 8.5. Field measurement of pH in surface water entering the infiltration ponds during storm events during this investigation was usually in the 10.2 to 10.5 range; pH of surface water in the vicinity of the seeps near the LHR is frequently greater than pH 11.5.

6.1.4 LDA Traffic and Site Control

Vehicular traffic should be strictly limited to landfill maintenance activities. The aerial photographic survey indicates that mining, reclamation and recreational vehicles have traditionally used the landfill cap surface. Unrestricted vehicle use has produced rutting and cap disturbance. Once incised in this manner, erosion is rapid and unremitting.

6.1.5 LDA Revegetation and Maintenance

Most of the existing surface area of the cap is covered with invasive red alder and black berries. Grass cover cap vegetation consists of remnant stands of perennial grass. The woody vegetation is unacceptable cover for a landfill because the root systems are deep and increase the infiltration of incident surface water into the CKD fill.

6.1.6 LDA Groundwater Monitoring

Presently, the only ground water monitoring being performed in the vicinity of the LDA is at the drain pipe from the original mine portal north of the LDA. Monitoring should be performed up- and down-gradient from the LDA in both the shallow unconfined ("perched") water and in the bedrock. Ground water should be monitored for the analytes and parameters that Washington State Department of Ecology has specified for the Dale Strip Pit (DSP) and Mine Portal monitoring program, see Appendix 8. A sample quarterly monitoring report detailing groundwater parameters and analytes currently being monitored at the site is included in Appendix 8.

Compliance records from the DNR files note that a surface water overflow from the mine pit may have flowed over the southwest side of the LDA, where Reserve Silica is currently stockpiling sand, toward Ginder Lake. The geophysical survey results indicate a potentially high conductivity flow area beneath the stockpile. Seepage along the road adjacent to the LDA has a high pH. The Ginder Lake area is considered a part of Indian Tribal Fishing Grounds.

Monitoring wells should be installed to determine ground water conditions in the following areas: upgradient and downgradient from the LDA, upgradient and downgradient from leachate collection ponds; and at the south end of the DSP. We currently have no data on ground water chemistry or water table parameters where it flows from Reserve Silica property onto adjacent properties.

6.1.7 LDA Surface Water Monitoring

A systematic sampling plan should be developed for surface water flow in the vicinity of the LDA. Water quality should be monitored for the same analytes specified for ground water, with the addition of turbidity, suspended solids and some measure of flow. Sample points should be specified and formalized with witness posts or weirs. All monitoring efforts (ground water, vegetation and surface water) should be performed and recorded according to a formal sampling and monitoring plan which specifies:

1) When and what will be monitored;
2) Standard Operating Procedures that document sample collection, quality control and recordkeeping;
3) Health and safety issues and procedures, including site control, designed and implemented in a manner that minimizes risk to public health and industrial hygiene; and
4) Procedures and format for reporting results to Reserve Silica Corporation and Holnam, Inc.

6.2 Dale Strip Pit

Our investigation and observations note several structural and operations failures of the current Dale Strip Pit (DSP) system. Issues investigated as potential sources of risk include:

1) Cap degradation,
2) Inadequate drainage control,
3) Uncontrolled runoff onto the surface,
4) Site control, including vehicle access, recreational use and dumping,
5) Mining, reclamation and development activities on adjacent areas, and
6) Absence of a written operations and maintenance plan for the facility.

The DSP surface has been degraded by poor surface drainage due to vehicular traffic and placement of non-engineered fill on portions of the southern pit; and topographic lows that accumulate standing water. Fill placement has occurred on the cap as recently as 1999. The recent fill was apparently not installed as structural fill.

Surface runoff from the haul road is presently diverted onto the surface of the DSP cap, resulting in standing water on the cap. Furthermore, bedrock and glacial drift at the north end of the DSP slopes to the haul road. Surface flow from this area flows into and onto the haul road surface material and through the road material onto the DSP cap.

The absence of a mining and reclamation plan that integrates the environmental constraints inherent in the long-term success of an industrial landfill should be explicitly considered. Presently, fill is placed on the surface of the DSP without monitoring compaction, moisture and material characteristics. Mining and filling activities on adjacent areas may pose adverse long-term risks for the success of the DSP as an industrial landfill.

6.2.1 DSP Cap Integrity

DSP Cap integrity has been compromised in the past by the lack of maintenance and vehicle traffic over the cap at the DSP. Historical aerial photographs and onsite survey and monitoring work conducted by TESI indicate heavy off-road use of the cap area. There are numerous trails and roads on the DSP cap used for maintenance and monitoring work, off-road recreational use and hunting, site reclamation and Bonneville Powerline maintenance personnel. The trails have left ruts that have filled with ponded water as shown in Photo 6-7. Improper grading on the cap surface has left depressions in the DSP cap where water stands for extended periods, particularly after major storm events. The absence of an all-weather road system, with access restricted to approved vehicles, has resulted in degradation of the DSP cap. Ponded water can be expected to infiltrate into the DSP cap over time and is considered detrimental to the integrity of the DSP cap.

Non-engineered fill placed in the southern portion of the DSP may not provide a suitable base for the construction of a new structural fill cap on the existing fill surface. The installation of a structural fill cap requires a firm, non-yielding base to allow the new fill to be properly compacted to engineering design specifications. Additionally, wet soils beneath the structural fill will transfer water upward into the new fill soils. This increase in water content typically results in the fill becoming "moist-of-optimum", making it impossible to compact the soil properly. Consequently, some, or all, of the cap fill may have to be removed if it cannot be compacted to a firm, non-yielding surface.

The original, as well as the more recently placed, new fill appear to have been installed by end dumping directly onto the existing surface, and potentially into standing water based on historic photos and site observations. Aerial photographs from the 1980s and 1990s show that the area of new fill was in areas previously occupied by standing water. Much of the recent fill material appears to be screenings from sand and gravel operations. Screenings from a gravel pit in Issaquah are currently being used in other areas of the site for reclamation fill. We have observed that this soil is saturated where it is currently being used. The high moisture content would preclude the fill being compacted to engineering specifications unless it is moisture-conditioned to near the optimum moisture content for proper compaction.

Non-engineered fills typically are not compacted to near optimum conditions. Fills compacted to a lesser density tend to be more permeable and could allow water to seep through the CKD fill causing increased pH in the ground water.

6.2.2 DSP Stormwater Diversion, Treatment and Infiltration

Percolation and movement of storm water incident on the areas adjacent to the DSP east of the haul road are suspected of percolating through weathered glacial till where underlying less permeable till and sandstone units may direct the flow west onto the DSP. Also, stormwater runoff from the haul road is presently either diverted onto the DSP or into ineffective ditches that allow water to percolate and flow toward the DSP. One objective of recommended management measures should be to capture stormwater from the road and divert it away from the DSP. Additional measures should intercept shallow groundwater at the east boundary of the DSP and keep it from flowing west under the DSP cap.

Stormwater is currently flowing onto the DSP cap from roadway surfaces and through the road fill along the northeast side of the DSP. Stormwater ponds on and adjacent to the DSP ground surface. This standing water infiltrates into the weathered glacial till and glacial drift soils to perch on the less permeable underlying soils and bedrock. This water may also flow toward the DSP, however, we have insufficient data to determine if this is the case. A stormwater control plan is necessary for the DSP to minimize stormwater infiltration.

Ponded water on the southwest end of the cap should be drained or pumped from the site. Currently, surface water flow from this area flows to the south or west. This water either goes offsite or into the central sand mine, where it is crosses the site before being pumped into the stormwater detention pond southwest of the LDA. CKD-like fill material near the ground surface was identified at the south end of the DSP, adjacent to ponded water. Stormwater infiltrating through the fill in this area could, therefore, be transporting contaminated water off site.

6.2.3 DSP Traffic and Site Control

Regrading of the UHR has resulted in water flow onto the cap in the northeastern portion of the site. (See discussion of Storm Water in Section 6.2.2) This condition has resulted in additional filling of topographic lows on the cap with standing water. The in-filling of these topographic lows has been a gradual and long term process, evidenced on the aerial photos and personal observation by TESI. This condition has been ongoing for a long enough period of time that wetland vegetation has colonized some of the depressions. Topographic lows in the southwestern portion of the site have resulted in impoundment of surface water from hardened surfaces in the southern pit area.

6.2.4 DSP Revegetation and Maintenance

Most of the existing surface area of the cap is covered with perennial grasses, black berries, red alder seedlings and wetland plant species. The DSP cap also has a lot of bare ground, relative to the LDA. Grass cover cap vegetation consists of remnant stands of perennial grass. The woody vegetation is unacceptable cover for a landfill because the root systems are deep and increase the infiltration of incident surface water into the CKD fill.

It may be preferable to maintain specific vegetative communities in constructed swales and drainage ditches. Specified plant communities can retard flow rates, trap sediment and improve water quality. These functions may be important should it be economically more desirable to divert surface water to the southeast out of the Ravensdale and Ginder Lake watersheds.

6.2.5 DSP Groundwater Monitoring

We do not have any information relative to the flow direction of the perched water east of the DSP. Additional information regarding hydraulic conditions in the area should be collected. Monitoring of the bedrock aquifer should be continued. Replacement wells for some of the existing resource protection wells have been considered in the past and still may be necessary. New wells, other than replacement wells, do not appear to be necessary at present.

6.2.6 DSP Surface Water Monitoring

Collection of surface water samples at the inflow point into the detention pond southwest of the LDA may be advisable to document the water quality before it infiltrates or flows off site. The same analytes should be assessed as are being tested for in the ground water, with the addition of suspended solids, turbidity and estimated flow rates.

6.3 Mining and Reclamation Activities

No current mining is planned at the DSP. There is some potential for removal of some sand from east of the UHR. If this mining is accomplished, the mining plan should take into account potential impacts on the DSP cap and local ground water flow.

Reclamation activities in the central sand mine have consisted of end dumping wet to saturated mine screenings into the deep pit. This has resulted in a significant depth of uncontrolled fill. The fill is potentially unstable. The soil may liquefy in a major earthquake due to its moisture content and the lack of compaction in the fill placement method. Liquefaction could result in a mudslide down the face of the mountain. There may be the potential of sinking into the fill if anyone attempts to walk on the surface of the fill and breaches the crust that forms on the surface of the fill. Vibrations from mechanical equipment on the fill surface could also cause the fill to liquefy locally. This could result in the machinery and/or its operator sinking into the fill. Due to the complex nature of the hydrogeology of the site, and the lack of evidence of significant flow across bedding planes in the bedrock, we are not sure what effect the thickness of saturated soil will have on the landfill.

6.3.1 Mine Dewatering and Storm Water Control

The co-mingling of storm water, leachate or seepage water and mine water potentially creates problems for both mining and environmental concerns. When such waters are commingled it increases the volume of water that mining operations must handle and potentially degrades water quality to an extent that it must receive additional treatment prior to achieving State surface and ground water standards. The collection of storm water and mine water in mining pits near landfill areas poses the additional threat of serving as a reservoir for water that can then seep into adjacent landfill areas.

The geology of the local area is complex and proving or disproving the existence of subsurface hydraulic conductivity between active or abandoned mining areas and landfills is a potentially expensive and time consuming exercise with a reasonable risk of reaching inaccurate conclusions. Some reasonable assumptions based on relative elevations, known properties of geologic materials and formations and direct field observations of seeps, ground water monitoring wells and surface water flows can be made and agreed upon. These characteristics may suggest that a coordinated effort should be made to keep the types and sources of water separate until it can be demonstrated that they meet State water quality standards.

6.3.2 Road Construction and Maintenance

Road construction and repairs in the past have altered the surface water flow by raising the elevation of the road surface. This has resulted in seepage onto the DSP cap in the northeast corner of the cap. Lack of positive drainage along the road has also allowed standing water in the area to migrate to the cap area.

6.3.3 Storage of Overburden and Product

Currently, there is no overburden or product storage in the DSP area. Should on-site overburden be used for cap installation or subgrade preparation, stockpiling may become necessary in the cap area. Materials to be used during construction could be temporarily stockpiled on the cap in or near the work area to minimize additional handling prior to placement. Should such materials be stockpiled over a period when no installation is being performed, a stockpile area will need to be prepared. The area should be graded such that stormwater is not directed towards the fill stockpile. The subgrade of the stockpile area should be properly compacted, low permeability soil so capillary action does not pull moisture up into the fill. The stockpile should be covered with plastic sheeting to keep rainfall away from the soil. The soil will have to meet the moisture constraints necessary for proper compaction and will be evaluated prior to placement. The precautions listed above should be considered a minimum to insure the material remains suitable for structural fill.

If product is to be stored on the site in the future, it should be stored away from the DSP. The stockpile should be located and designed so that it does not degrade the cap and drainage improvements recommended in this report. Prior to stockpile location, the site and design of the stockpile should be discussed with the site management.

6.3.4 Engineering Control & Documentation

We were unable to locate any documentation on the installation of the cap or preparation for installing the DSP fill. Current fill west of the DSP is being end dumped over a bluff into the old sand mine area and is not being installed as an engineered fill see Photos 6-8 and 6-9.

6.4 Recommendations for Interim Actions

This section presents TESI's recommendations for actions that should be taken in the interim while further study of the need for remedial actions is being conducted. These recommendations are interim to final engineering, scientific, management and business decisions. The success in designing, implementing and maintaining these measures will depend on how well they are integrated with mining and other resource management activities at the site. This integration includes consideration of LDA/DSP functions and integrity during mining, reclamation, roadway construction and maintenance and any future site development plans. Explicit inclusion of the potential constraints on the design and operation of these other activities will be required if environmental risks are to be minimized and controlled at the LDA. Activities that need to be integrated with landfill functions and operations are:

Roads and Access

- Road construction and maintenance. The road surface needs to be graded to enhance movement of stormwater away from the DSP. Ditches or swales should be constructed to facilitate water flow away from the cap. Future road improvements should be compatible with drainage and grading plans developed for the DSP cap. Dust and soil dislodged from reclamation dump truck traffic distribute soil on the road surface that can migrate into drainage ditches or swales adjacent to roadways. These drains should be maintained. Potential for siltation of the drains can be reduced by dust control and minimizing spillage from truck traffic. Paving or other dust limiting road surfacing may be advisable, with accompanying maintenance.

- Controlled access of mining vehicles onto landfill sites. Vehicles other than those used to maintain vegetation control should be kept off the cap to minimize rutting and erosion.

- Relocation of LHR. The LHR should either be relocated down-slope to the west or, if kept in its present location, should be crowned and ditched with collected storm water diverted away from the roadway at frequent intervals.

- Control of Dust. Dust control measures, including water trucks, should be used during the dry season to reduce dust build-up in the roadside ditches.

Surface Water & Groundwater

- Stormwater Control. Stormwater diversion and storage and the handling of mine dewatering effluent should be improved and maintained. Stormwater should be re-directed away from landfill and mining areas.

- Mining Impacts on Landfills. Water pooled at mining areas, or flowing from mining areas, toward landfill areas have potentially adverse effects on the amount of groundwater flowing to down-gradient landfill sites. Ponding should be minimized and stormwater, as well as groundwater associated with mining activities should be redirected away from landfill areas.

Site Access & Control

- Access to Water Containment Areas. All surface water detention or infiltration ponds should be fenced, gated and signed.

- Signage. Signing of the DSP and LDA should be considered to alert personnel and trespassers to potential chemical and physical hazards.

- Site Access Control. Both landfills should be fenced; additional gates should be installed on internal roads to discourage short-cutting and unauthorized road use.

Management of Landfill Surfaces

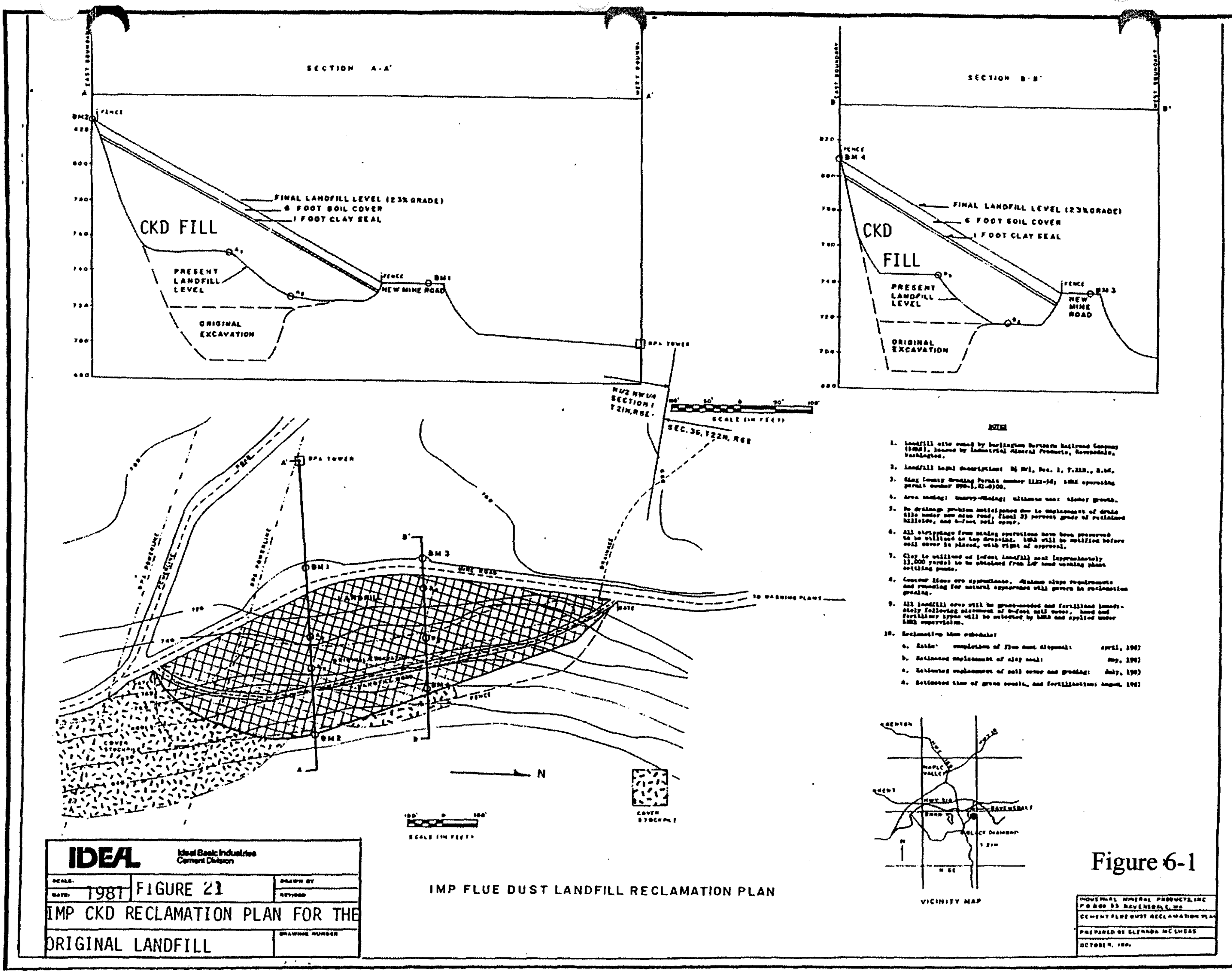
- Mined Materials and Overburden. Storage, removal and wasting of product and mine overburden at landfill areas should be controlled and engineered to minimize cap disturbance. Any vehicle or heavy equipment traffic near landfill areas should have a stormwater management plan designed and implemented to reduce the effects of surface and near-surface stormwater flows on landfills.

- Vegetation Management. Woody vegetation should be removed from the cap areas. Removal or other vegetation control measures, e.g. herbicide use, should be part of a comprehensive cap maintenance program. Such a program should take into consideration cap integrity and stormwater quality. Perennial grass cover on the cap should be planted and maintained to control erosion.

Documentation

- Plan Preparation. Written plans on activities that could adversely affect landfill integrity or may result in additional operations and maintenance costs down-the-road should be prepared and submitted for approval by the appropriate regulatory agencies. These plans should be coordinated with Holnam Inc. during preparation, implementation and monitoring.

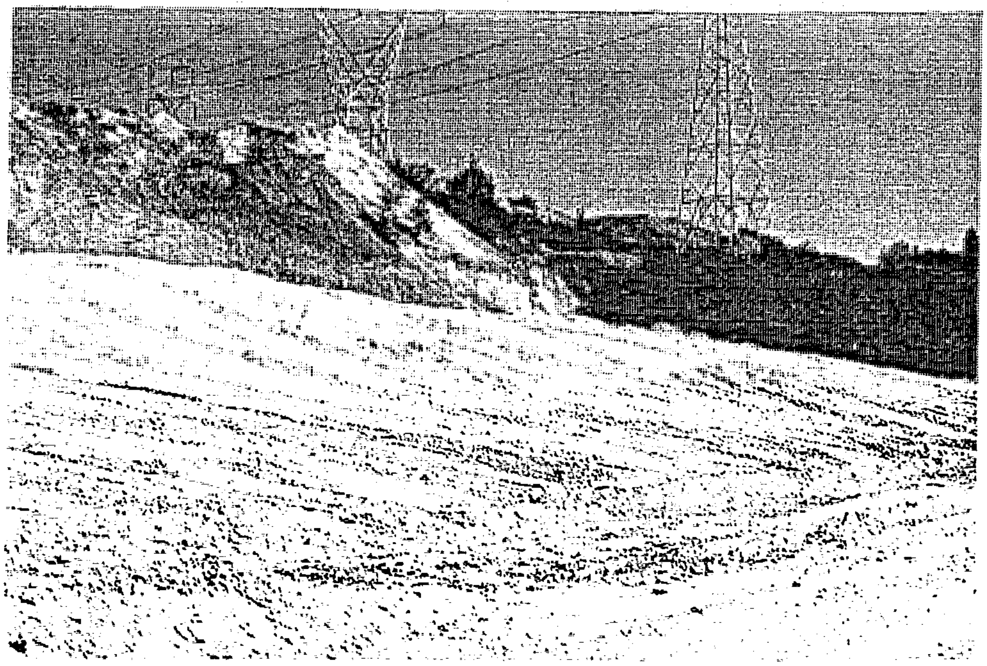
- Recordkeeping and Reporting. Records of action and incidents that may affect landfill operation, maintenance, and threats to landfill integrity should be kept in a log. This log should be conveyed to Holnam on a quarterly basis.



SECTION A-A'
EAST BOUNDARY
WEST BOUNDARY
BM2
FENCE
FINAL LANDFILL LEVEL (23% GRADE)
6 FOOT SOIL COVER
1 FOOT CLAY SEAL
CKD FILL
PRESENT LANDFILL LEVEL
ORIGINAL EXCAVATION
NEW MINE ROAD
BM1
BPA TOWER
SECTION B-B'
BM 4
BM 3
NEW MINE ROAD
N1/2 NW1/4 SECTION 1 T21N, R6E
SEC. 36, T22N, R6E
SCALE (IN FEET)
NOTES
TO WASHING PLANT
GATE
FENCE
COVER STOCKPILE
N
VICINITY MAP
IDEAL
Ideal Basic Industries
Cement Division
1981
FIGURE 21
IMP CKD RECLAMATION PLAN FOR THE ORIGINAL LANDFILL
IMP FLUE DUST LANDFILL RECLAMATION PLAN

Figure 6-1

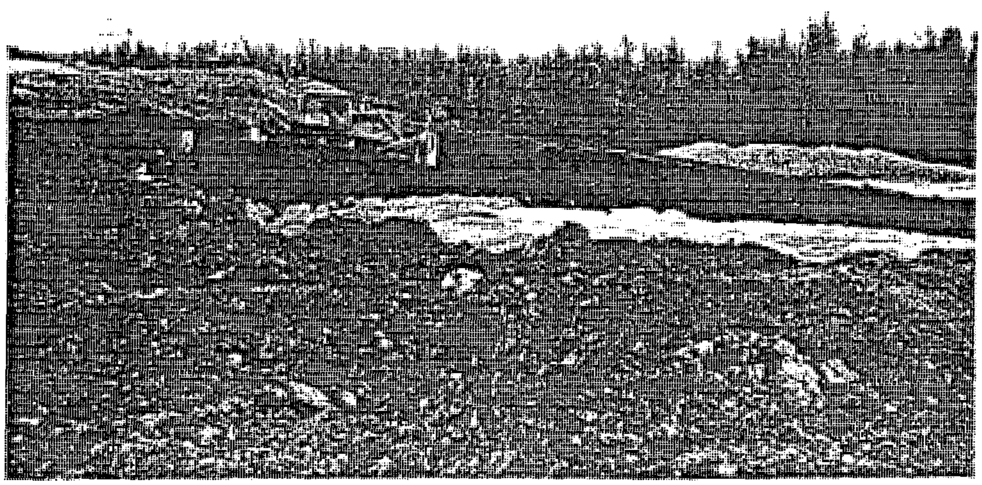
Photo 6-1



IDEAL Ideal Basic Industries
Cement Division

SCALE	APPROVED BY	DRAWN BY
DATE 1982		REVISED

CONTOURED SURFACE OF THE ORIGINAL CKD
RECLAMATION SITE FIGURE 23



IDEAL Ideal Basic Industries
Cement Division

SCALE	APPROVED BY	DRAWN BY
DATE: 1983		REVISED

RECLAMATION OF ORIGINAL CKD BACKFILL AREA
CLAY AND SOIL PLACEMENT FIGURE 24

Photo 6-2 LDA. Surface erosion and cap failure ("A") on central part of the LDA.

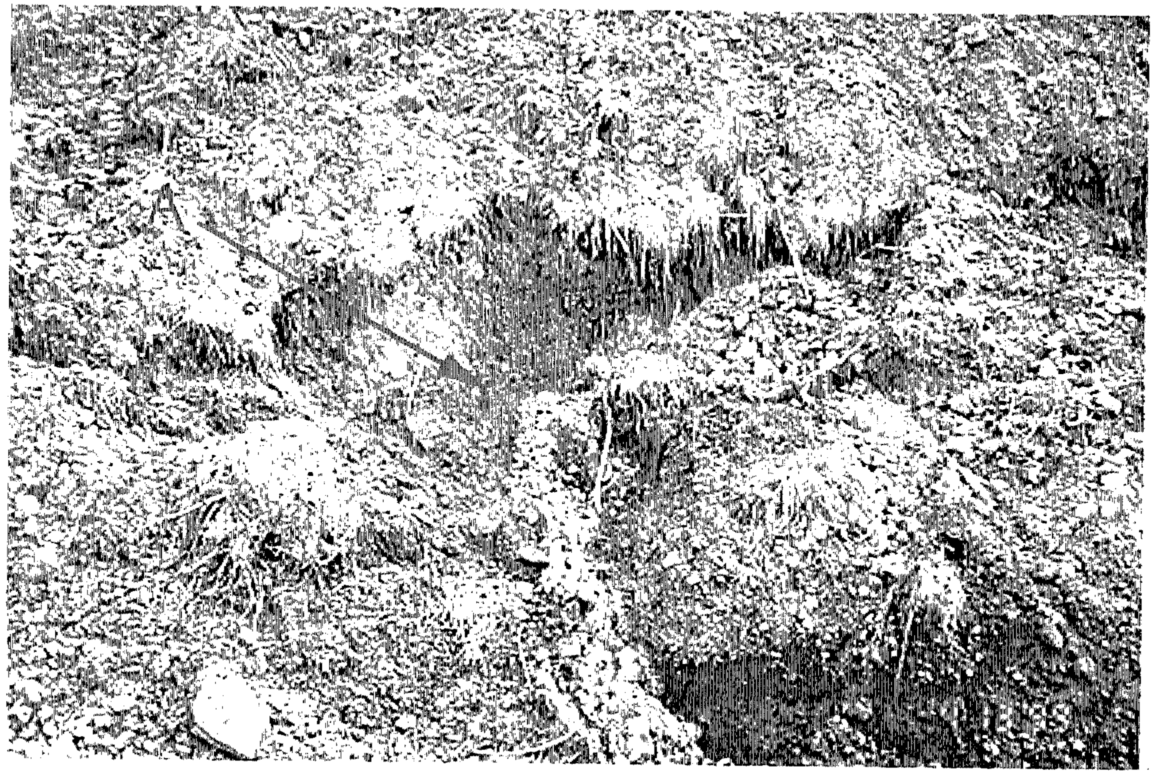


Photo 6-3 LDA. Showing erosion and material slumping off cap, "A". Area is adjacent to ditch bordering west edge of LHR, east of silica sand stockpile.

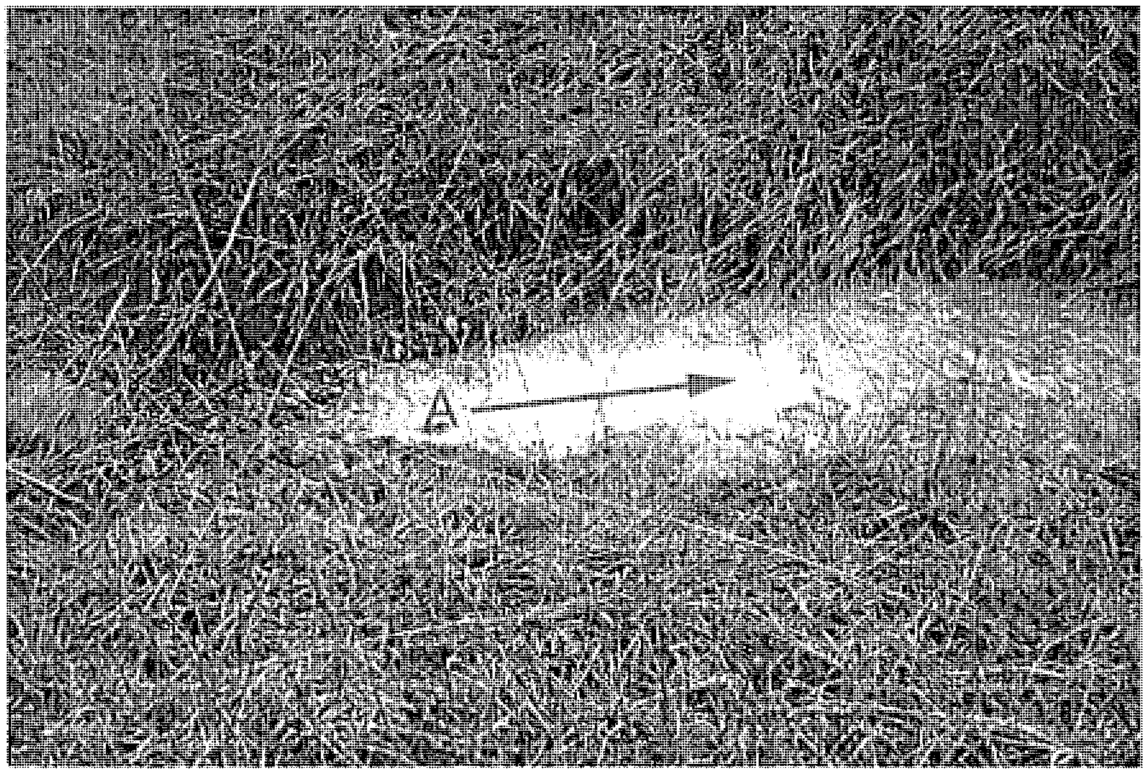


Photo 6-4 LDA. Closeup of eroded cap at south 1/3 of LDA. Whitish material ("A") may be CKD (cf. S. Weiss, Holnam). This eroded area is part of a larger east-west trending surface drainage pattern across the LDA cap surface. Surface drainage either infiltrates into the cap or runs off cap surface in ditch next to LHR.

Photo 6-5 LDA. View to northeast from southwest part of LDA. Showing incised surface drainage patterns ("A-B") on LDA cap. Note exposed CKD in bottom of drainage at "A".

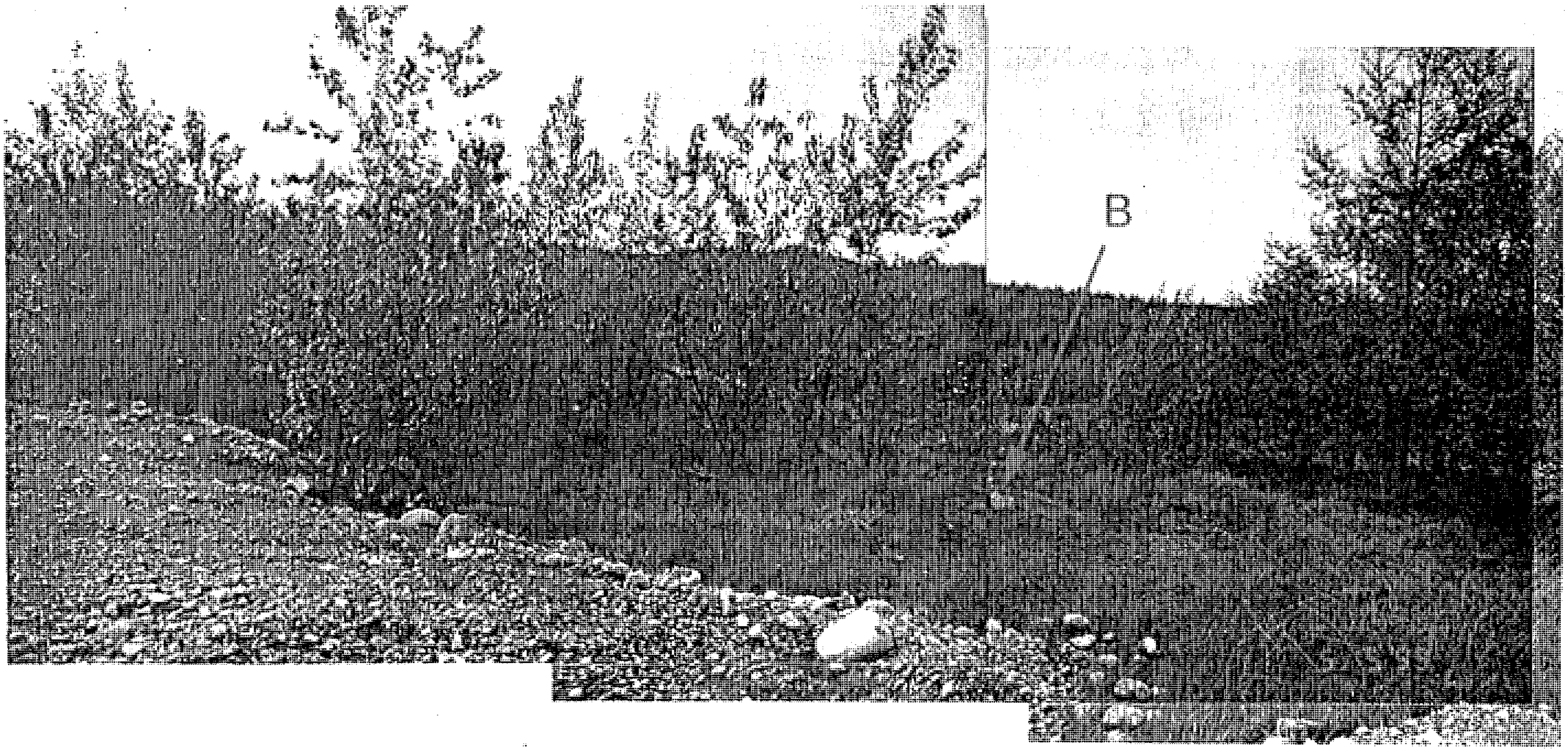


Photo 6-6 LDA. View of LDA to southwest. Showing recently placed fill at up-slope (eastern) edge of LDA "A". Note surface ponding at "B". LDA cap cover consists of red alder, perennial rye grass, and bare ground with exposed fill.

Photo 6-7 DSP. View from east-central part of DSP cap to the north. Showing ponded water in vehicle ruts on cap surface. Vehicle access is not restricted and the property receives heavy recreational vehicle use. UHR is visible at right of photo. June 1999.

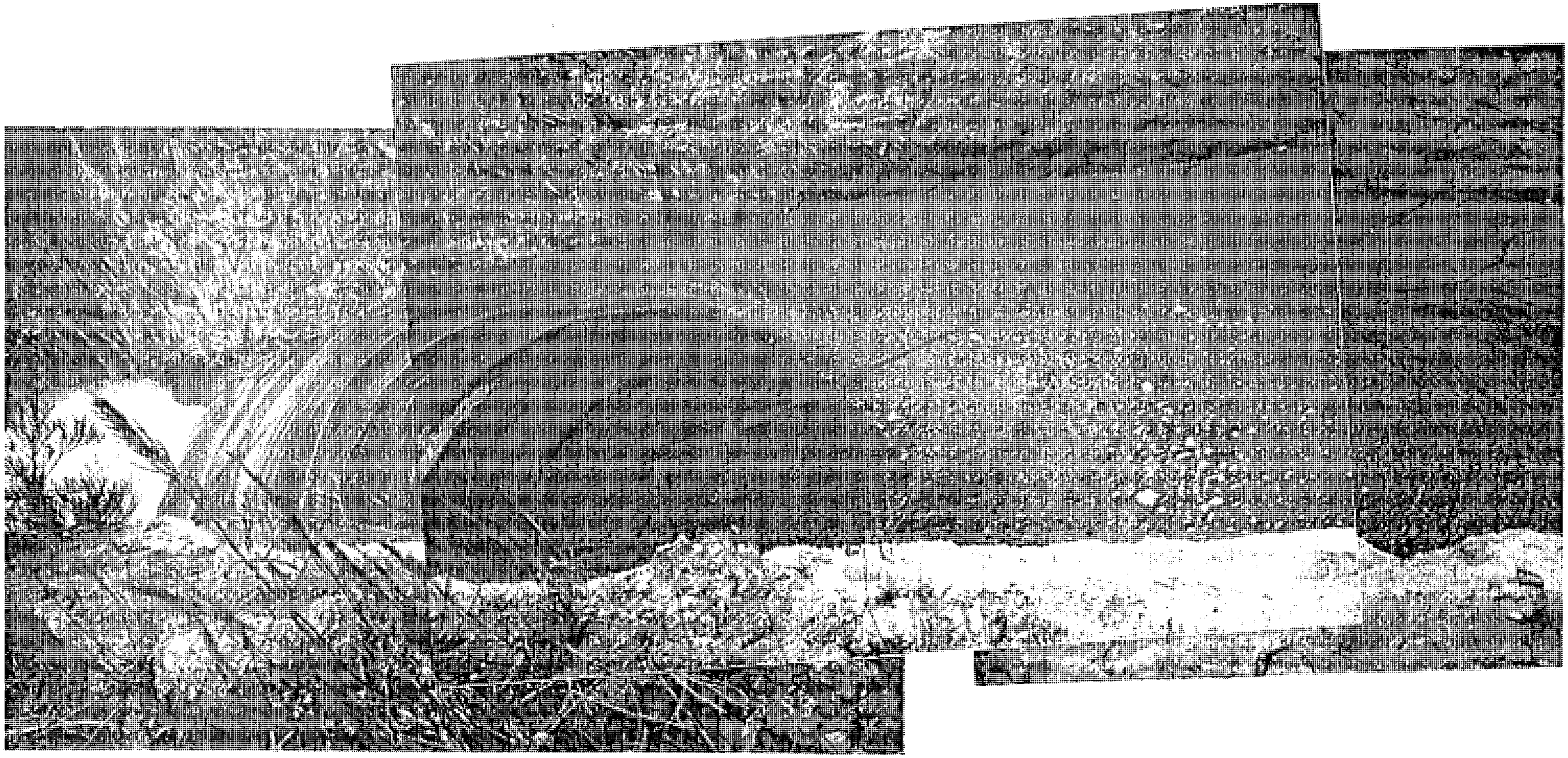


Photo 6-8 Central Sand Mine. View from western edge of DSP.
View is down into the pit. Showing slurry fill material ("A") being
placed in mine for reclamation. The water noted in Photo 4-1
is visible at far left in photo.

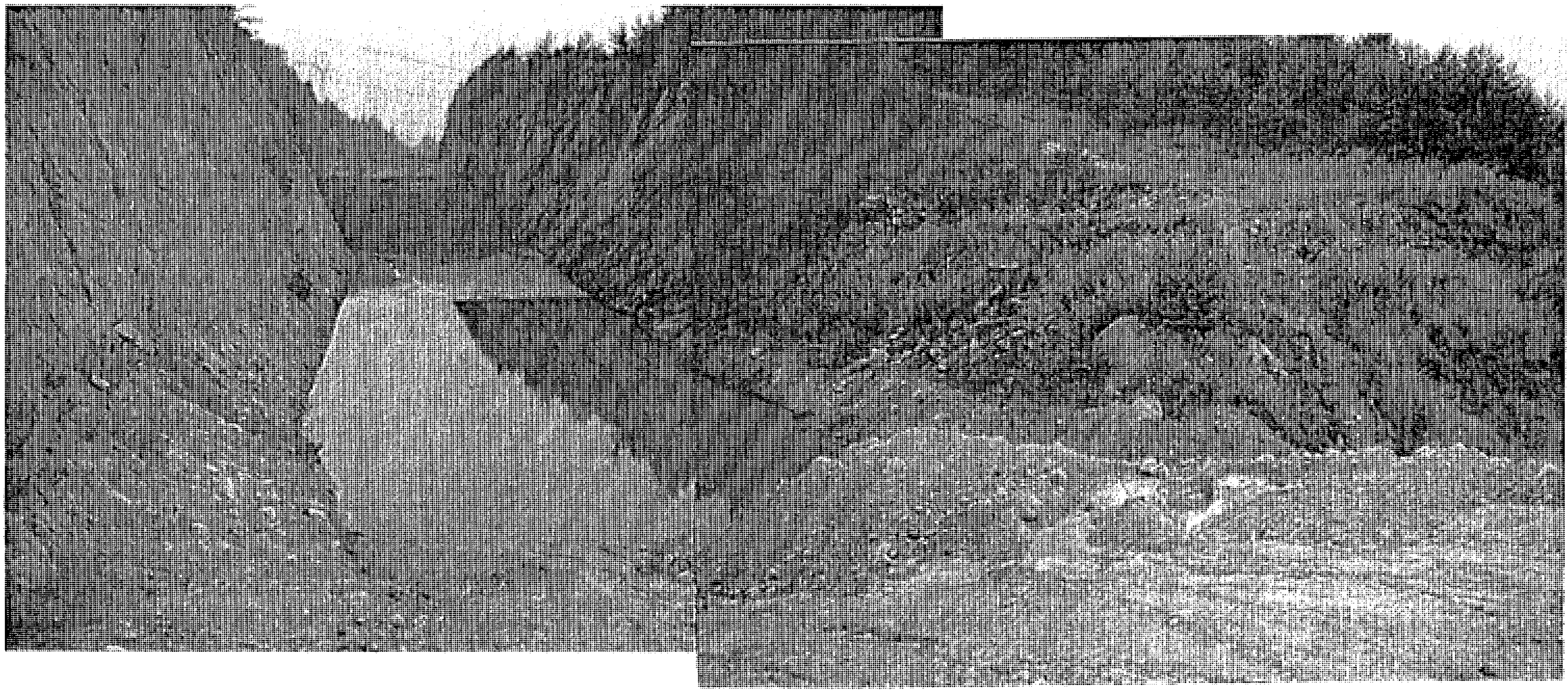


Photo 6-9 Middle Sand Mine. View looking south. Landfilling with screenings from Associated Gravel - Issaquah Pit. Water ponded in bottom of pit. Fill materials end dumped from top of cut on left. Fines migrated into ponded water below fill.

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Appendix 1: Metropolitan Engineering Report

MUNICIPALITY OF METROPOLITAN SEATTLE

King County, Washington

FINAL REPORT
GEOLOGIC AND HYDROLOGIC CONDITIONS
SLUDGE DISPOSAL SITE(S)
NEAR RAVENSDALE, WASHINGTON

This report is provided separately

September, 1972

Metropolitan Engineers, Consulting Engineers
100 West Harrison
Seattle, Washington
98119

Ron Free

Appendix 2: Chemical Analysis of Material

CHEMICAL ANALYSES OF FILL MATERIALS

CONCENTRATION AND SOLUBILITY OF SELECTED ANALYTES IN IDEAL CKD (FROM IDEAL, 1984)

Component	CO_3^{-2}	OH^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
Soluble							
mg/kg CKD	–	4,573	–	2,044	0	3,000	11,120
meq/g CKD	–	0.27	–	0.10	0	0.13	0.28
Total							
mg/kg CKD	327,000	4,573	57,000	355,000	4,200	3,700	11,600
meq/g CKD	10.9	0.27	1.2	17.8	3.46	0.16	0.29
% Soluble	–	100	–	0.6	–	81.0	96.0

TYPICAL HEAVY METAL CONCENTRATION IN NATIVE BEDROCK AND CKD, MG/KG (FROM IDEAL, 1987)

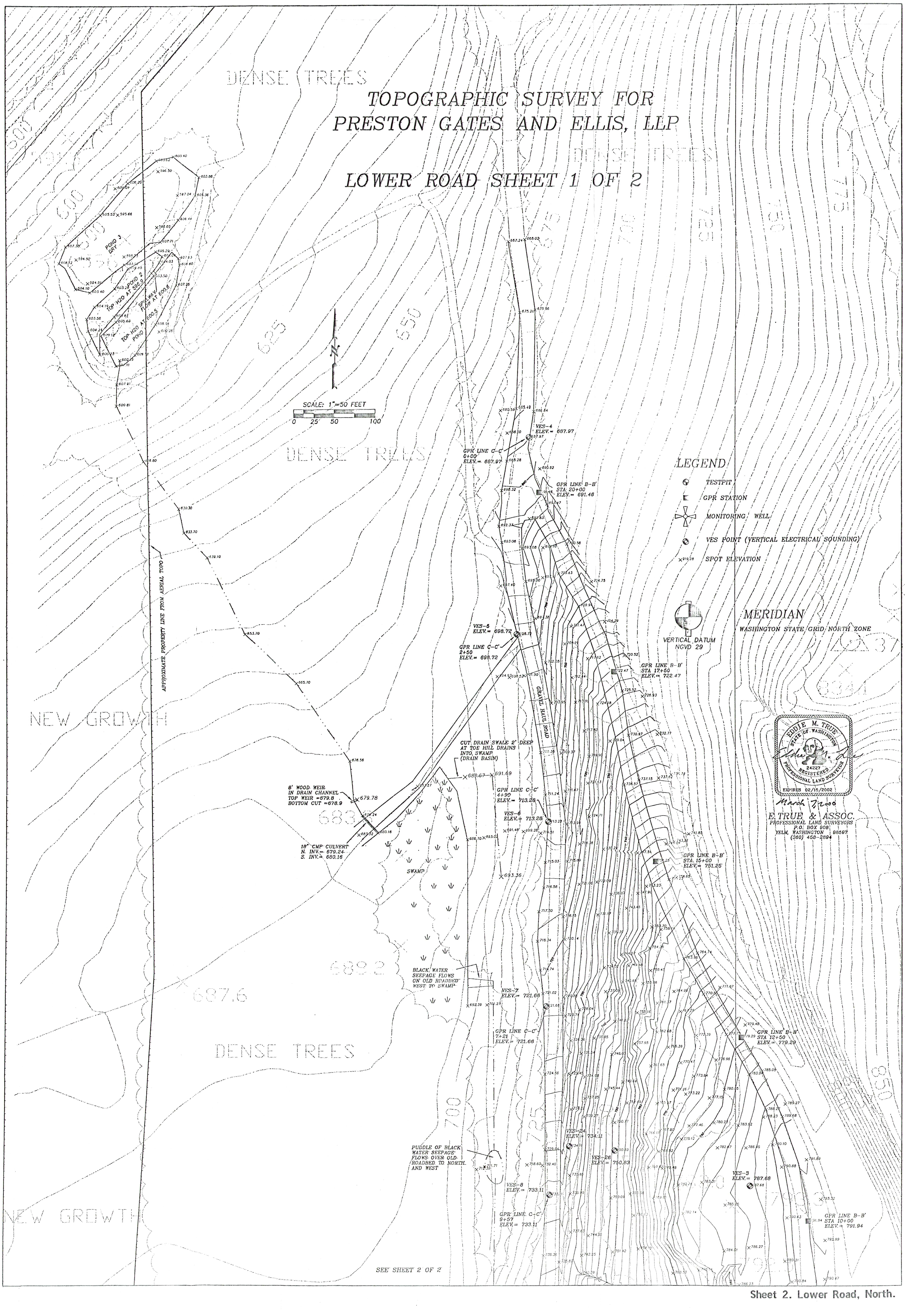
Sample Type	Chromium	Copper	Lead	Zinc
Sandstone	64	4	28	40
Coal	86	51	27	86
Ideal CKD	9	35-110	320-380	680-700

COMPARISON OF MAJOR CHEMICAL CONSTITUENTS IN IDEAL CKD & SOIL, PERCENT (FROM IDEAL, 1984)

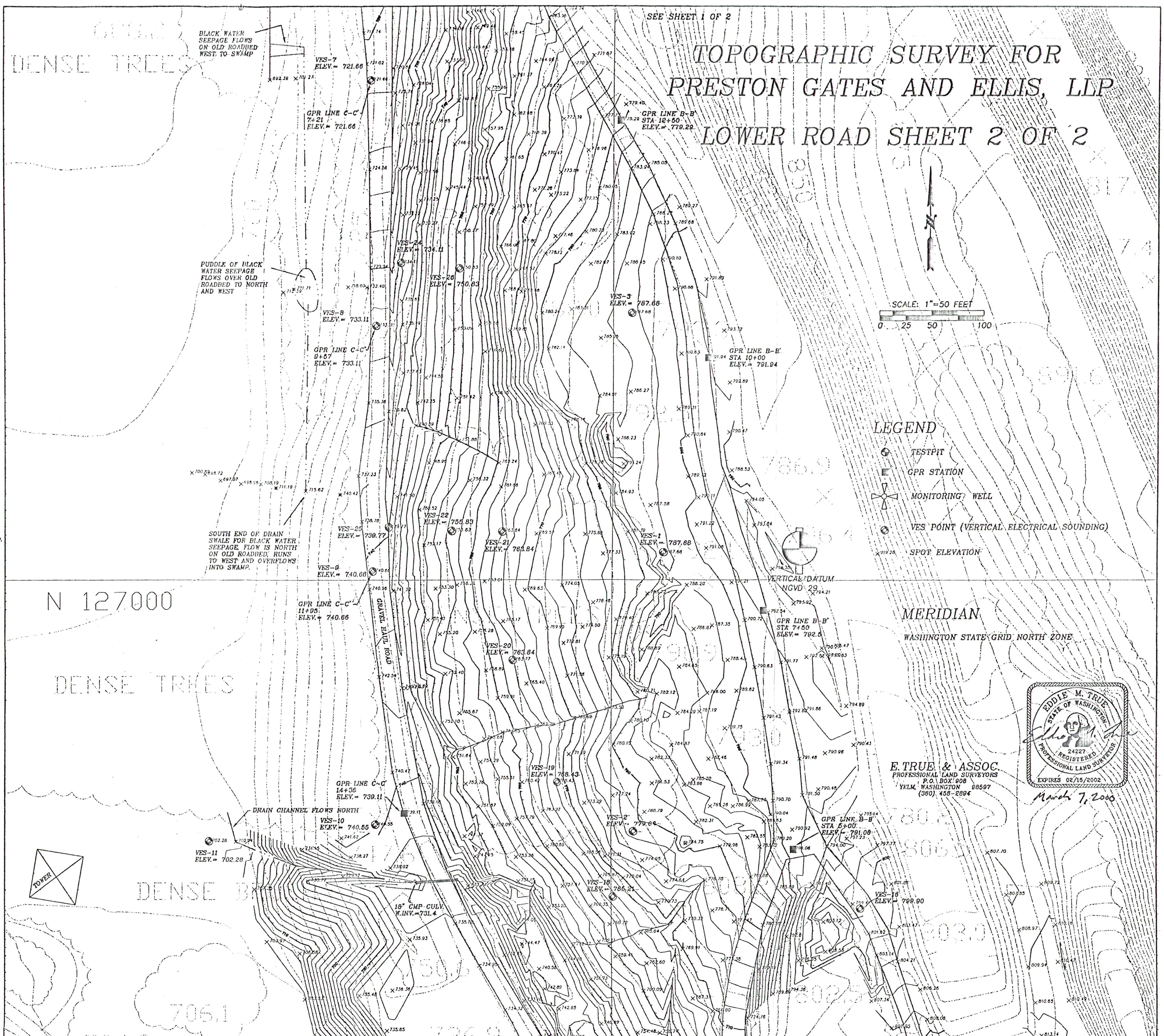
Constituent	Kiln Dust (Ideal)	Typical Soil(*)
SiO	12.5	70.5
Al_2O_3	2.9	13.7
Fe_2O_3	1.9	3.8
CaO	49.7	2.0
MgO	0.7	0.8
SO_3	4.8	0.2
Na_2O	0.5	1.5
K_2O	1.4	2.2
* Cited in Ideal Report: C.F. Marbot, 1935& W. Lindsey, 1979		

Appendix 3: Topographic Maps

Sheet 1. Upper & Lower Areas.

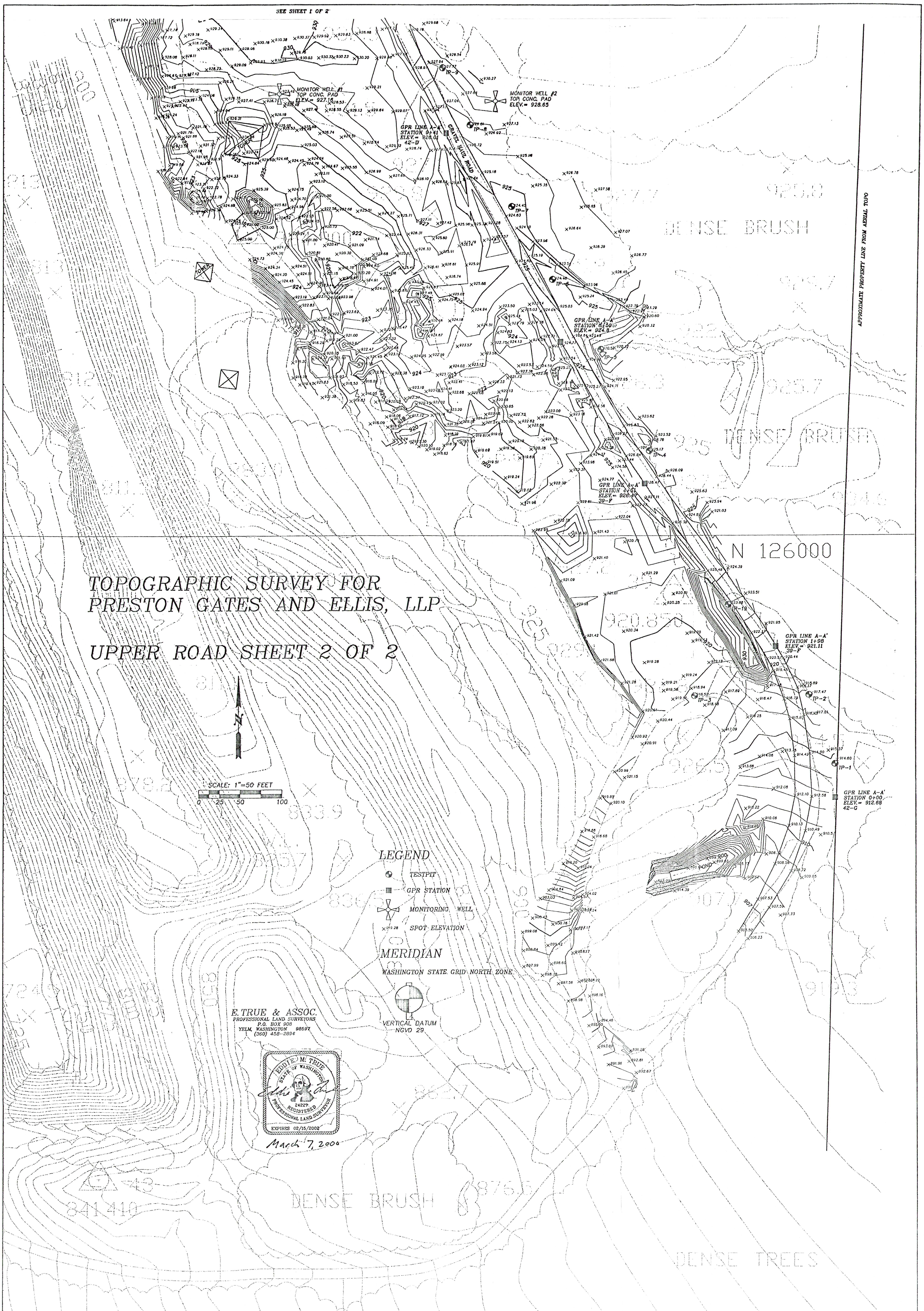


Sheet 2. Lower Road, North.



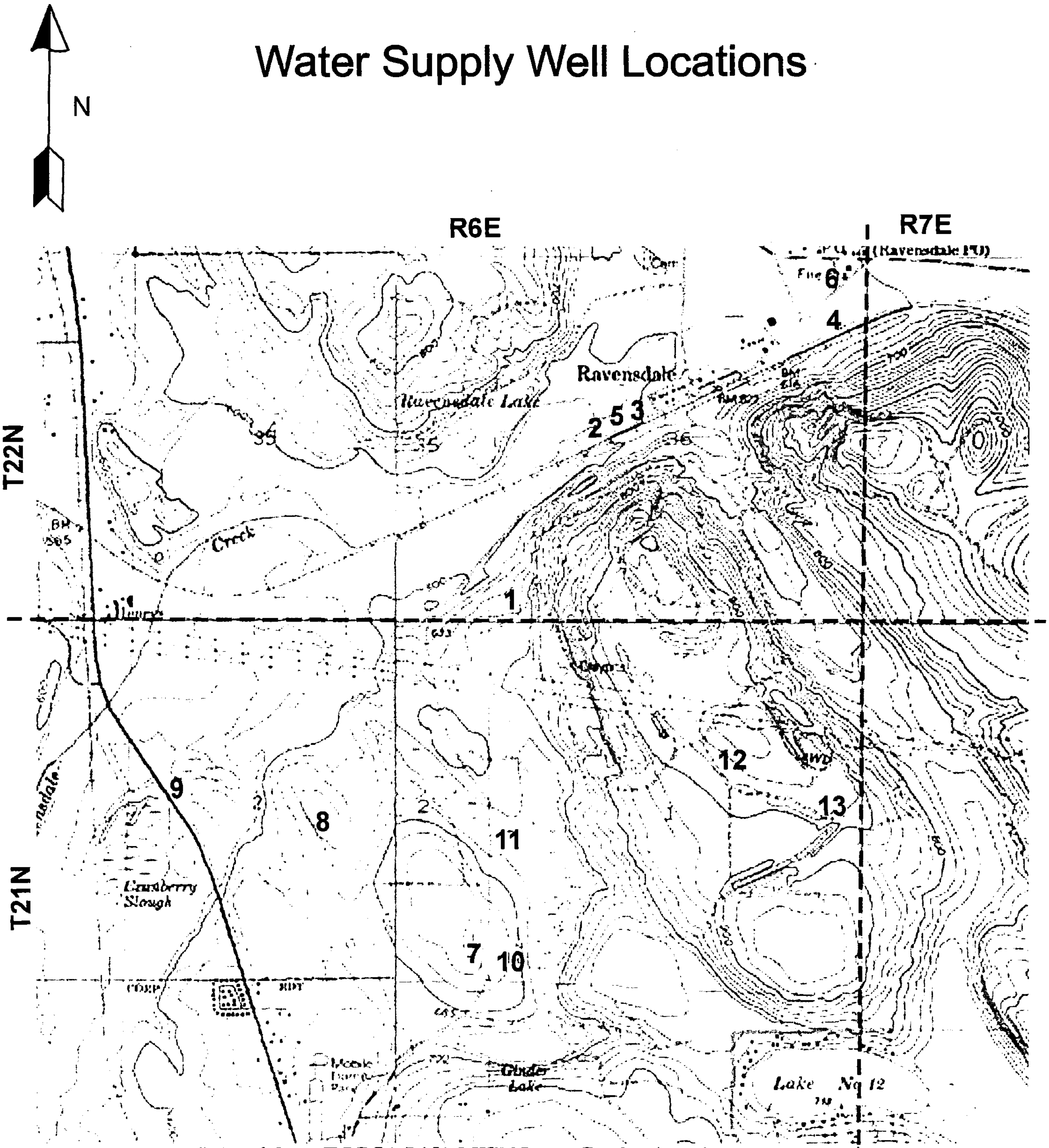
Sheet 3. Lower Road, South.

Sheet 4. Upper Road, North.


SEE SHEET 1 OF 2
TOPOGRAPHIC SURVEY FOR
PRESTON GATES AND ELLIS, LLP
UPPER ROAD SHEET 2 OF 2
MONITOR WELL #1
TOP CONC. PAD
ELEV.= 927.18
MONITOR WELL #2
TOP CONC. PAD
ELEV.= 928.65
GPR LINE A-A'
STATION 0+41
ELEV.= 926.01
42-D
GPR LINE A-A'
STATION 0+00
ELEV.= 912.68
42-G
GPR LINE A-A'
STATION 1+98
ELEV.= 921.11
39-F
GRAVEL HAUL ROAD
DENSE BRUSH
DENSE TREES
N 126000
APPROXIMATE PROPERTY LINE FROM AERIAL TOPO
SCALE: 1"=50 FEET
0 25 50 100
LEGEND
TESTPIT
GPR STATION
MONITORING WELL
SPOT ELEVATION
MERIDIAN
WASHINGTON STATE GRID NORTH ZONE
VERTICAL DATUM
NGVD 29
E. TRUE & ASSOC.
PROFESSIONAL LAND SURVEYORS
P.O. BOX 908
YELM, WASHINGTON 98597
(360) 458-2804
EDDIE M. TRUE
STATE OF WASHINGTON
24227
REGISTERED
PROFESSIONAL LAND SURVEYOR
EXPIRES 02/15/2002
March 7, 2000

Appendix 4: Water Supply Well Logs

Water Supply Well Locations



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LEGEND

1 Water Supply Well Location

Holnam
September 1999

Second Copy—Owner's Copy
Third Copy—Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No 01458

Water Right Permit No.

(1) OWNER: Name L-Bar Products Incorporated Address 26000 Ravensdale Black Diam

(2) LOCATION OF WELL: County King SW ¼ SW ¼ Sec 36 T 22 N., R 6 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address)

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☒ Municipal ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐ Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 36 feet. Depth of completed well 36 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6 " Diam. from 0 ft. to 36 ft.
Welded ☒ " Diam. from ft. to ft.
Liner installed ☐ " Diam. from ft. to ft.
Threaded ☐

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☐ No ☒
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel
Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal puddling clay
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 27 ft. below top of well Date 1-11-88
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Airtest 2-3 gal./min. with stem set at 23 ft. for 2 1/2 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Brown gravel & sand	0	9
Tan gravel & sand-clay	9	20
Brown gravel-sand-clay	20	25
Gray clay gravel-sand	25	30
Gray gravel & sand-water some clay	30	36
Gray clay-gravel	36	—

RECEIVED
JAN 25 1988
DEPARTMENT OF ECOLOGY
NORTHWEST REGION

Work started 1-11, 19. Completed 1-1, 19 8

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Johnson Drilling Co. Inc (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 19415 108th Ave SE Renton 98c
(Signed) [signature] (WELL DRILLER) License No. 0233
Contractor's Registration No. JOHNSDC207JM Date 1-12, 19 8

(USE ADDITIONAL SHEETS IF NECESSARY)

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. ____
Permit No. ____

(1) OWNER: Name Ralph V. Barnett Address 26726 SE Ravensdale Way Ra

(2) LOCATION OF WELL: County King par of SE ¼ NW ¼ Sec. 36 T 22 N., R. C
Bearing and distance from section or subdivision corner See attached

(3) PROPOSED USE: Domestic [X] Industrial [ ] Municipal [ ]
Irrigation [ ] Test Well [ ] Other [ ]

(4) TYPE OF WORK: Owner's number of well (if more than one) ____
New well [X] Method: Dug [ ] Bored [ ]
Deepened [ ] Cable [X] Driven [ ]
Reconditioned [ ] Rotary [ ] Jetted [ ]

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 37 ft. Depth of completed well 37 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from 0 ft. to 37 ft.
Threaded [ ] ____" Diam. from ____ ft. to ____ ft.
Welded [X] ____" Diam. from ____ ft. to ____ ft.

Perforations: Yes [ ] No [X]
Type of perforator used ____
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes [ ] No [X]
Manufacturer's Name ____
Type ____ Model No. ____
Diam. ____ Slot size ____ from ____ ft. to ____ ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes [ ] No [X] Size of gravel: ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes [X] No [ ] To what depth? 18 ft.
Material used in seal puddling clay
Did any strata contain unusable water? Yes [ ] No [X]
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

(7) PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ____ ft.
Static level 23 ft. below top of well Date 8-30-84
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes [ ] No [ ] If yes, by whom? ____

Yield: gal./min.	with ft. drawdown	after hrs.
25	4	2
Bailer		

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____
Bailer test 24 gal./min. with 4 ft. drawdown after 2 hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes [ ] No [ ]

(10) WELL LOG:
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Surface	0	
Brown hardpan gravel		
Brown water sand gravel		
Brown hardpacked gravel	33	

SEE REVERSE OF REPORT

RECEIVED SEP 0 1984 DEPARTMENT OF ECOLOGY NORTHWEST REGION

Work started 8-28, 1984 Completed 8-30, 19

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Johnson Drilling Co. Inc (Person, firm, or corporation) (Type or print)
Address 19415 108th Ave SE Renton 98
[Signed] Bud Johnson (Well Driller)
License No. 0233 Date 8-30, 19

USE ADDITIONAL SHEETS IF NECESSARY

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Application No ....
Permit No. ....

(1) OWNER: Name Ray C. Bennett Address 26733 SE Ravensdale Pl, Ravensdale

(2) LOCATION OF WELL: County King P.O. Rd OF – SE ¼ NW ¼ Sec 26 22 6

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)....
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 36 ft. Depth of completed well 36 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6" Diam. from 0 ft. to 36 ft.
Threaded ☐ ___" Diam. from ___ ft. to ___ ft.
Welded ☒ ___" Diam. from ___ ft. to ___ ft.

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations ___ in. by ___ in.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name
Type ___ Model No.
Diam. ___ Slot size ___ from ___ ft. to ___ ft.
Diam. ___ Slot size ___ from ___ ft. to ___ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel:
Gravel placed from ___ ft. to ___ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal puddling Clay
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ___ Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: ___ H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ft.
Static level 22 ft. below top of well Date 8-27-84
Artesian pressure ___ lbs. per square inch Date
Artesian water is controlled by ___ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom?

Yield: gal./min.	with ft. drawdown	after hrs.
25	4	2
	AIR JET	

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test ___ gal./min. with ___ ft. drawdown after ___ hrs.
Artesian flow ___ g.p.m. Date
Temperature of water ___ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Surface		
Tan sand & gravel	2	5
Brown hardpan gravel	5	22
Brown water sand & gravel	22	36
Brown solid rock	36	–

RECEIVED
SEP 04 1984
DEPARTMENT OF ECOLOGY
NORTHWEST REGION

* SEE REVERSE OF REPORT

Work started 8-27, 1984. Completed 8-27, 19

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Johnson Drilling Co., Inc (Person, firm, or corporation) (Type or print)

Address 19415 108th Ave SE Renton

[Signed] Brad Johnson (Well Driller)

License No. 0233 Date 8-27, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. ______
Permit No. ______

(1) OWNER: Name Fire District No. 43 Address 27401 SE Kent Kangley Rd.

(2) LOCATION OF WELL: County King NE ¼ NE ¼ Sec. 36 T. 22 N., R. 6
Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☒ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ______
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 40 ft. Depth of completed well 40 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from 0 ft. to 40 ft.
Threaded ☐ ______" Diam. from ______ ft. to ______ ft.
Welded ☒ ______" Diam. from ______ ft. to ______ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal puddling clay
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name ______
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ...... ft.
Static level 10 ft. below top of well Date 2/16/82
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ______
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test 50 gal./min. with 15 ft. drawdown after 2 hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG:
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Surface	0	
Brown hardpan	2	
Brown water gravel	18	

RECEIVED
1982
DEPARTMENT OF ECOLOGY
NORTHWEST REGION

Work started 2/15 1982 Completed 2/15 19__

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Johnson Drilling Co. Inc. (Person, firm, or corporation) (Type or print)
Address 19415 105th Ave SE Renton 980..
[Signed] Rod Johnson (Well Driller)
License No. 0233 Date 2/15 19__

(USE ADDITIONAL SHEETS IF NECESSARY)

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

22/6-36F

Application No

Permit No ...

(1) OWNER: Name Evor D Morgan Address 26707 S.E Ravensdale P...

(2) LOCATION OF WELL: County King POR OF — SE ¼ NW ¼ Sec. 36 T. 22 N...

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)....
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 37 ft. Depth of completed well 37 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6 " Diam. from 0 ft. to 37 ft.
Threaded ☐ ____ " Diam. from ____ ft. to ____ ft.
Welded ☒ ____ " Diam. from ____ ft. to ____ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ____
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ____
Type ____ Model No. ____
Diam. ____ Slot size ____ from ____ ft. to ____ ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal puddling clay
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

(7) PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ____ ft.
Static level ____ ft. below top of well Date ____
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? ____
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.
" 25 " 6 " 3 "
" " AIR JET "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____
Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and show thickness of aquifers and the kind and nature of the m... stratum penetrated, with at least one entry for each change...

MATERIAL	FR...
Surface:	...
Brown hardpan gravel	...
Brown water sand & gravel	...
Brown solid rock	...

RECEIVED
DEPT. OF ECOLOGY

[redacted]

Work started 8-24, 19 84 Completed 8-...

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and th... true to the best of my knowledge and belief.

NAME Johnson Drilling Co., I... (Person, firm, or corporation) (Type o...

Address 19415 108th Ave SE R...

[Signed] Brad John... (Well Driller)

License No. 0233 Date 8-2...

USE ADDITIONAL SHEETS IF NECESSARY

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON 22/6-36A

Application No.

Permit No.

(1) OWNER: Name KING COUNTY WATER DIST. 105 Address 30033 188th Ave. S.E., KENT

(2) LOCATION OF WELL: County KING — NE ¼ NE ¼ Sec 36 T 22 N., R 6E W.M.

Bearing and distance from section or subdivision corner APPROX 150' S. AND 300' E OF N.E. COR. OF SEC.

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☒ Irrigation ☐ Test Well ☒ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) RAVENSDALE [illegible]
New well ☒ Method: Dug ☐ Bored ☐ Deepened ☐ Cable ☒ Driven ☐ Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 16 inches. Drilled 43 ft. Depth of completed well 40.8 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 16" Diam. from +2.0 ft. to 28.6 ft.
Threaded ☐ ___" Diam. from ___ ft. to ___ ft.
Welded ☒ ___" Diam. from ___ ft. to ___ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ___
SIZE of perforations ___ in. by ___ in.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name JOHNSON — WATERMARK
Type STAINLESS Model No. ___
Diam. 14 P.S. Slot size 100 from 31.3 ft. to 38.3 ft.
Diam. ___ Slot size ___ from ___ ft. to ___ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: ___
Gravel placed from ___ ft. to ___ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal CONCRETE
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ___ Depth of strata ___
Method of sealing strata off ___

(7) PUMP: Manufacturer's Name N.A.
Type: ___ H.P. ___

(8) WATER LEVELS: Land-surface elevation above mean sea level ~620 ft.
Static level 22.21 ft. below top of well Date 7/12/84
Artesian pressure ___ lbs. per square inch Date ___
Artesian water is controlled by ___ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? ROBINSON + NOBLE
Yield: 1850 gal./min. with 2.26 ft. drawdown after 24 hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
0	24.47	75	22.76		
1½	22.94	150	22.72		
9½	22.88				

Date of test 7/12-13/84
Bailer test ___ gal./min. with ___ ft. drawdown after ___ hrs.
Artesian flow ___ g.p.m. Date ___
Temperature of water 48 °F Was a chemical analysis made? Yes ☒ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
BROWN [illegible]	[illegible]	[illegible]
GRAVEL & BOULDERS [illegible]		
GRAVEL COMMON [illegible]		
BROWN SILTY SAND AND GRAVEL	14	24
BROWN LARGE GRAVEL UP TO COBBLE SIZE WITH SOME SAND. LARGE BOULDER AT 23'	21	40
BROWN SAND AND GRAVEL WITH SOME BROWN CLAY	40	43

RECEIVED AUG 1984 DEPARTMENT OF ECOLOGY NORTHWEST REGION

PREPARED BY:
ROBINSON + NOBLE, INC.
MBS

Work started JULY 1, 1984 Completed JULY 13, 198[illegible]

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Holt Drilling and Pump Systems (Person, firm, or corporation) (Type or print)

Address 2405 41st Ave NE

[Signed] Randy Holt (Well Driller)

License No. 1099 Date 7-14 198[illegible]

(USE ADDITIONAL SHEETS IF NECESSARY)

ENTERED

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W064621
UNIQUE WELL I.D. # ABZ160
Water Right Permit No. 21-6E-2R

(1) OWNER: Name Y Bar S Water Co Address PO Box 43, Southworth, WA 983

(2) LOCATION OF WELL: County King SE 1/4 SE 1/4 Sec 2 T. 21 N., R. 6E W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) 397XX 258th SE, Enumclaw

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☒ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) #3
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 380 feet. Depth of completed well 235 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from 0 ft. to 246 ft.
Welded ☒ ___" Diam. from ___ ft. to ___ ft.
Liner installed ☐ ___" Diam. from ___ ft. to ___ ft.
Threaded ☐

Perforations: Yes ☒ No ☐
Type of perforator used star wheel
SIZE of perforations 1/8 in. by 2 in.
100 perforations from 162 ft. to 175 ft.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ___
Type ___ Model No. ___
Diam. ___ Slot size ___ from ___ ft. to ___ ft.
Diam. ___ Slot size ___ from ___ ft. to ___ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ___
Gravel placed from ___ ft. to ___ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ___ Depth of strata ___
Method of sealing strata off ___

(7) PUMP: Manufacturer's Name ___
Type: ___ H.P. ___

(8) WATER LEVELS: Land-surface elevation above mean sea level ___ ft.
Static level 35 ft. below top of well Date 2-27-97
Artesian pressure ___ lbs. per square inch Date ___
Artesian water is controlled by ___ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ___
Yield: ___ gal./min. with ___ ft. drawdown after ___ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ___
Bailer test ___ gal./min. with ___ ft. drawdown after ___ hrs.
Airtest 40-50 gal./min. with stem set at 150 ft. for 2 1/2 hrs.
Artesian flow ___ g.p.m. Date ___
Temperature of water ___ Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Surface	0	3
Brown sand	3	8
Brown sand-gravel	8	11
Brown hardpan	11	21
Brown sand-gravel	21	29
Gray sand-gravel	29	35
Gray hardpan	35	41
Gray sand-gravel	41	49
Gray clay-gravel	49	90
Gray sand	90	91
Gray clay-gravel	91	108
Gray clay	108	138
Gray water sand-gravel	138	175
Gray clay gravel	175	186
Gray silt	186	205
Gray clay gravel	205	226
Gray decayed rock-caving	226	380
Hole caved in below 255' - bentonite plug from 238-255'		

RECEIVED
MAR 03 1997
DEPT. OF ECOLOGY

Work Started 2-12 19__ Completed 2-27 1997

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Johnson Drilling Co, Inc (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 19415 108th Ave SE, Renton 980
(Signed) [signature] (WELL DRILLER) License No. 0233

Contractor's Registration No. JOHNSDC207QM Date 2-27 1997

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (206) 407-6600. The TDD number is (206) 407-6006.

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

ENTERED

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W063674
UNIQUE WELL I.D. # ACG-82
Water Right Permit No. 21-6E-2J

(1) OWNER: Name Mike Freeland Address 2231 "W" ST NW, Auburn, WA 9800

(2) LOCATION OF WELL: County King NE 1/4 SE 1/4 Sec 2 T. 21 N., R. 6E W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) 16130 SE 300th St, Kent, Wa.

(3) PROPOSED USE: ☑ Domestic ☐ Irrigation ☐ DeWater ☐ Industrial ☐ Test Well ☐ Municipal ☐ Other

(4) TYPE OF WORK: Owner's number of well (if more than one) ____
Abandoned ☐ New well ☑ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Cable ☐ Rotary ☑ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 155 feet. Depth of completed well 155 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6 " Diam. from 0 ft. to 155 ft.
Welded ☑ ____ " Diam. from ____ ft. to ____ ft.
Liner installed ☐ ____ " Diam. from ____ ft. to ____ ft.
Threaded ☐

Perforations: Yes ☐ No ☑
Type of perforator used ____
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☐ No ☑
Manufacturer's Name ____
Type ____ Model No. ____
Diam. ____ Slot size ____ from ____ ft. to ____ ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ☐ Size of gravel ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☑ No ☐ To what depth? 18 ft.
Material used in seal bentonite
Did any strata contain unusable water? Yes ☐ No ☑
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

(7) PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

(8) WATER LEVELS: Land-surface elevation above mean sea level ____ ft.
Static level 120 ft. below top of well Date 7-10-97
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☑ If yes, by whom? ____
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____
Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.
Airtest 18-20 gal./min. with stem set at 151 ft. for 2 1/2 hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☑

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Brown sand-gravel	0	12
Brown gravel-clay	12	50
Gray clay	50	93
Brown silty clay	93	143
Gray clay	143	146
Gray water sand-gravel	146	155

RECEIVED
JUL 17 1997
DEPT. OF ECOLOGY

Work Started 7-3, 19 ____ Completed 7-10, 1997

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Johnson Drilling Co., Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 19415 108th Ave SE, Renton 98055
(Signed) Brad Johnson (WELL DRILLER) License No. 0235
Contractor's Registration No. JOHNSDC207RM Date 7-10, 1997

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (206) 407-6600. The TDD number is (206) 407-6006.

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No [redacted]

11/612F

Water Right Permit No 98354

OWNER: Name Larry Strong Address 2309 Milton Way, #6, Milto

(2) LOCATION OF WELL: County King SE ¼ NW ¼ Sec 2 T 21 N., R 6 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) 246XX SE 392nd, Enumclaw

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☒ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐ Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) [illegible] Diameter of well 6 inches.
Drilled 116 feet. Depth of completed well 116 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from 0 ft. to 116 ft.
Welded ☒ ____" Diam. from ____ ft. to ____ ft.
Liner installed ☐
Threaded ☐ ____" Diam. from ____ ft. to ____ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ____
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ____
Type ____ Model No. ____
Diam. ____ Slot size ____ from ____ ft. to ____ ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal puddling clay
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

(7) PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

(8) WATER LEVELS: Land-surface elevation above mean sea level ____ ft.
Static level 85 ft. below top of well Date 7-14-92
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ____
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____
Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.
Airtest 25 gal./min. with stem set at 108 ft. for 2½ hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Brown sand gravel - silty	0	10
Gray clay	10	34
Tan sand gravel - clay	34	65
Brown sandy silt	65	111
Brown water sand - gravel	111	116
Brown sand silt	116	–

RECEIVED
JUL 20 1992
DEPT. OF ECOLOGY

Work started 7-10, 19__ Completed 7-14, 1992

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Johnson Drilling Co., Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT) 980

Address 19415 108th Ave SE Renton

(Signed) [signature] (WELL DRILLER) License No. 0273

Contractor's Registration No. JOHNSDC207GM Date 7-14, 1992

(USE ADDITIONAL SHEETS IF NECESSARY)

21/6E/1D

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. 204995

~~Unique~~ well I.D. # ~~[illegible]~~

1

(1) OWNER: Name HANSEN, JEFF Address 33607 S.E. 309TH PALMER, WA 98051-

(2) LOCATION OF WELL: County KING - SW 1/4 SW 1/4 Sec 01 T 21 N., R 06E WM

(2a) STREET ADDRESS OF WELL (or nearest address) 36207VEAZIE-CUMBERLAND RD

(3) PROPOSED USE: DOMESTIC

(4) TYPE OF WORK: Owner's number of well (if more than one)

NEW WELL Method: ROTARY

(5) DIMENSIONS: Diameter of well 6 inches

Drilled 79 ft. Depth of completed well 79 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6 " Dia. from +1 ft. to 79 ft.

WELDED " Dia. from ft. to ft.

" Dia. from ft. to ft.

Perforations: NO

Type of perforator used

SIZE of perforations in. by in.

perforations from ft. to ft.

perforations from ft. to ft.

perforations from ft. to ft.

Screens: NO

Manufacturer's Name JOHNSON

Type Model No.

Diam. slot size from ft. to ft.

Diam. slot size from ft. to ft.

Gravel packed: NO Size of gravel

Gravel placed from ft. to ft.

Surface seal: YES To what depth? 19 ft.

Material used in seal BENTONITE CLAY

Did any strata contain unusable water? NO

Type of water? Depth of strata ft.

Method of sealing strata off N/A

(7) PUMP: Manufacturer's Name N/A

Type N/A H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ... ft.

Static level 63 ft. below top of well Date 03/12/93

Artesian Pressure lbs. per square inch Date

Artesian water controlled by N/A

(10) WELL LOG

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change in formation.

MATERIAL	FROM	TO
BROWN SILTY SAND SMALL GRAVEL	0	9
MEDIUM ANGULAR GRAVEL	9	16
BROWN SILTY SAND SMALL TO MEDIUM	16	27
ROUNDED GRAVEL	16	27
SMALL GRAVEL BROWN SILTY SAND	27	37
SILTY TO COARSE	37	56
~~BROWN MEDIUM ROUNDED GRAVEL~~	37	56
~~BROWN COARSE SAND SMALL~~	56	63
ROUNDED GRAVEL DAMP	56	63
BROWN COARSE SAND DAMP	63	74
SOME SMALL ROUNDED GRAVEL	63	74
WET	63	74
MEDIUM ROUNDED GRAVEL BROWN	74	79
COARSE SAND LOOSE WATER BEARING	74	79

RECEIVED
MAR 24 1993
DEPT. OF ECOLOGY

Work started 03/12/93 Completed 03/12/93

(9) WELL TESTS: Drawdown is amount water level is lowered below static level.

Was a pump test made? NO If yes, by whom?

Yield: gal./min with ft. drawdown after hrs.

Recovery data

Time Water Level Time Water Level Time Water Level

Date of test / /

Bailer test gal/min. ft. drawdown after hrs.

Air test 23 gal/min. w/ stem set at 79 ft. for 1 hrs.

Artesian flow g.p.m. Date

Temperature of water Was a chemical analysis made? NO

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME OBLKE DRILLING, INC.
(Person, firm, or corporation) (Type or print)

ADDRESS 4312 166AV E.SUMNER 98390

[SIGNED] Lee Turner License No. 1983 LEE TURNER

Contractor's Registration No. OBLKEDI 136QC Date 03/20/93

21/06/01

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No .....
Permit No. .....

(1) OWNER: Name Bob Bradley Address 25802 West Valley Hwy. Kent, Wa. 9

(2) LOCATION OF WELL: County King — NW ¼ SW ¼ Sec 1 T. 21 N., R. 6E

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) 1
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 160 ft. Depth of completed well 160 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6" Diam. from 0 ft. to 160 ft.
PVC Threaded ☐ 4" Diam. from 0 ft. to 160 ft.
Welded ☒ " Diam. from ft. to ft.

Perforations: Yes ☒ No ☐
Type of perforator used Saw
SIZE of perforations ⅛ in. by 4 in.
4 around every 1' perforations from 120 ft. to 160 ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☐ No ☒
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel:
Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ft.
Static level 50 ft. below top of well Date 7-8-85
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test 20 gal./min. with 50 ft. drawdown after 1 hrs.
Artesian flow g.p.m. Date 7-8-85
Temperature of water Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG:

Formation: Describe by color, character, size of material and structur show thickness of aquifers and the kind and nature of the material t stratum penetrated, with at least one entry for each change of form

MATERIAL	FROM	TO
Top soil & clay	0	2
Clay & some gravel	2	7
Boulders, clay & gravel	7	9
Soft sandstone	9	17
Hardpan & rock	17	42
Soft brownish sandstone	42	91
Coal	91	12
Hard gray sandstone	125	14
Watere & sandstone	140	16

RECEIVED
FEB 27 1986
DEPARTMENT OF ECOLOGY
NORTHWEST REGION

Work started 7-8- 19 85 Completed 7-8 19..

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report true to the best of my knowledge and belief.

NAME Richardson Well Drilling Co. (Person, firm, or corporation) (Type or print)

Address P.O. Box 44427 Tacoma, Wa. 98444

[Signed] [signature] (Well Driller)

License No. 0419 Date 1-21, 19..

USE ADDITIONAL SHEETS IF NECESSARY

File Original and First Copy with Department of Ecology
Second Copy—Owner's Copy
Third Copy—Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. [redacted]
21/6/1G
Water Right Permit No. ______ 12

(1) OWNER: Name John Konecny Address 39007 272nd S.E. Enumclaw

(2) LOCATION OF WELL: County King SW ¼ NE ¼ Sec. 1 T. 21 N., R. 6E W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) 39007 272nd SE. Enumclaw, WA. 98022

(3) PROPOSED USE: ☒ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ______
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 340 feet. Depth of completed well 340 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from +1 ft. to 176 ft.
Welded ☐ PVC 4.5" Diam. from +1 ft. to 340 ft.
Liner installed ☒
Threaded ☐ ______" Diam. from ______ ft. to ______ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☐ No ☒
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal Bentonite slurry + chips
Did any strata contain unusable water? Yes ☒ No ☐
Type of water? TANNIC Acid Depth of strata 170'
Method of sealing strata off Casing into claystone + 4"x6" shale trap seals (2) installed on 4.5" liner below the claystone

(7) PUMP: Manufacturer's Name N/A
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level N/A ft. below top of well Date ______
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ______
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest 40+ gal./min. with stem set at 320 ft. for 1 hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Loose Sand & gravel with water 100+ gpm	0	165
grey silty sand & gravel	165	170
claystone	170	230
Black & grey clay stone	230	240
claystone	240	310
Black & grey claystone	310	312
claystone	312	320
claystone with layers of coarse sand & water	320	340

RECEIVED
FEB - 9 1993
DEPT. OF ECOLOGY

Work started 2/2, 19__. Completed 2/5, 1993

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Geoboring & Development Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 9415 S.R. 162 E. Puyallup.
(Signed) Dale J. Smith (WELL DRILLER) License No. 1229
Contractor's Registration No. Geobodi 1170Z Date 2/8/, 1993

(USE ADDITIONAL SHEETS IF NECESSARY)

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

Jernagin

STATE OF WASHINGTON

Application No. 2106-01A
Permit No. ....

(1) OWNER: Name Jerry Jernagin Address 38850-276th S.E., Enumclaw

(2) LOCATION OF WELL: County King / Tax Lot 23 — SE ¼ NE ¼ Sec. 1 T. 21 N., R. 6E W.M.

Bearing and distance from section or subdivision corner: Approximately 5 acres

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ....
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 5 & 6 inches.
Drilled 200 ft. Depth of completed well 177 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6" Diam. from 0 ft. to 35 ft.
Threaded ☐ 5" Diam. from 0 ft. to 81 ft.
Welded ☒ " Diam. from ft. to ft.

Perforations: Yes ☒ No ☐
Type of perforator used Torch
SIZE of perforations 1/8 in. by 3 in.
perforations from 51 ft. to 81 ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☐ No ☒
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☒ No ☐ Size of gravel: Cement
Gravel placed from 177 ft. to 200 ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal puddling sandstone
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ft.
Static level 95 ft. below top of well Date 4/18/77
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test 15 gal./min. with 80 ft. drawdown after 2 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Surface	0	1
Brown hardpan rocks	1	15
Gray clay chocked with gravel	15	23
Gray hardpan gravel	23	27
Coal	27	32
Sandstone (soft) Gray	32	35
Sandstone (hard) Gray	35	40
Coal	40	68
Sandstone (soft) Gray	68	125
Sandstone (hard) Gray	125	180
Coal	180	200

Work started 4/14 1977 Completed 4/18 1977

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Johnson Drilling Co., Inc (Person, firm, or corporation) (Type or print)

Address 19415 108th Ave SE Renton 98055

[Signed] Brad Johnson (Well Driller)

License No. 0233 Date 4/18 1977

(USE ADDITIONAL SHEETS IF NECESSARY)

Appendix 5:
Robinson & Noble Groundwater Studies

ROBINSON & NOBLE, INCORPORATED
GROUND WATER & ENVIRONMENTAL GEOLOGISTS
5915 ORCHARD STREET WEST
TACOMA, WASHINGTON 98467
(206) 475-7711

HYDROGEOLOGY AND GEOCHEMISTRY OF INDUSTRIAL MINERAL PRODUCTS DALE #4 STRIP PIT

April, 1985

This report is provided separately

ROBINSON & NOBLE, INCORPORATED
GROUND WATER & ENVIRONMENTAL GEOLOGISTS
5915 ORCHARD STREET WEST
TACOMA, WASHINGTON 98467
(206) 475-7711

RESULTS OF DRILLING TEST WELLS 3 & 4 AT THE DALE #4 STRIP PIT

June, 1986

This report is provided separately

Appendix 6:
Test Pit Logs & Unified Soil Classification System

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE - GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVEL MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVEL	GW	WELL-GRADED GRAVEL, FINE TO COARSE GRAVEL
			GP	POORLY-GRADED GRAVEL
		GRAVEL WITH FINES	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	SAND MORE THAN 50% OF COARSE FRACTION PASSES NO. 4 SIEVE	CLEAN SAND	SW	WELL-GRADED SAND, FINE TO COARSE SAND
			SP	POORLY-GRADED SAND
		SAND WITH FINES	SM	SILTY SAND
			SC	CLAYEY SAND
FINE - GRAINED SOILS MORE THAN 50% PASSES NO. 200 SIEVE	SILT AND CLAY LIQUID LIMIT LESS THAN 50%	INORGANIC	ML	SILT
			CL	CLAY
		ORGANIC	OL	ORGANIC SILT, ORGANIC CLAY
	SILT AND CLAY LIQUID LIMIT 50% OR MORE	INORGANIC	MH	SILT OF HIGH PLASTICITY, ELASTIC SILT
			CH	CLAY OF HIGH PLASTICITY, FAT CLAY
		ORGANIC	OH	ORGANIC CLAY, ORGANIC SILT
HIGHLY ORGANIC SOILS			PT	PEAT

NOTES:

1) Field classification is based on visual examination of soil in general accordance with ASTM D 2488-83.
2) Soil classification using laboratory tests is based on ASTM D 2487-83.
3) Descriptions of soil density or consistency are based on interpretation of blowcount data, visual appearance of soils, and/or test data.

SOIL MOISTURE MODIFIERS

Dry- Absence of moisture, dusty, dry to the touch

Moist- Damp, but no visible water

Wet- Visible free water or saturated, usually soil is obtained from below water table

NELSON-COUVRETTE & ASSOCIATES, INC.
CONSULTING GEOTECHNICAL ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

UNIFIED SOIL CLASSIFICATION SYSTEM

FIGURE 1

LOG OF EXPLORATION

DEPTH	USC	SOIL DESCRIPTION
TEST PIT ONE		
0.0 – 1.5		BROWN SILTY FINE SAND WITH GRAVEL AND COBBLES (LOOSE, MOIST) (FILL)
1.5 – 6.0		LIGHT BROWNISH-ORANGE FINE TO MEDIUM SAND WITH TRACE SILT IRON OXIDE STAINED (DENSE, MOIST) **(WEATHERED SANDSTONE)**
		SAMPLES WERE COLLECTED AT 1.0, 2.0 AND 4.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 6.0 FEET ON 8/5/99
TEST PIT TWO		
0.0 – 4.0		LIGHT TO DARK BROWN SILTY FINE SAND WITH GRAVEL, COBBLES, ROOTS AND IRON OXIDE STAINING (LOOSE, MOIST) (FILL)
4.0 – 7.9		LIGHT BROWNISH-ORANGE FINE TO MEDIUM SAND WITH TRACE SILT IRON OXIDE STAINED (MEDIUM DENSE TO ENSE, MOIST) **(WEATHERED SANDSTONE)**
		SAMPLES WERE NOT COLLECTED GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 7.9 FEET ON 8/5/99
TEST PIT THREE		
0.0 – 6.5		GRAY AND BROWN SILTY FINE SAND WITH GLASS PIECES, PLASTIC, GLOVES, BOTTLE CAPS, CEMENT KILN DUST AND BRICK CEMENTED (MEDIUM DENSE TO DENSE, DRY TO MOIST) (FILL)
6.5 – 11.0		GRAY, SILTY FINE SAND WITH GRAVEL, GLASS AND COAL PIECES (MEDIUM DENSE TO DENSE, MOIST) (FILL)
		SAMPLES WERE COLLECTED AT 2.0, 2.5, 5.0 AND 8.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 11.0 FEET ON 8/5/99
TEST PIT FOUR		
0.0 – 3.0		BROWN FINE SANDY SILT (LOOSE, MOIST TO WET) (FILL)
3.0 – 8.0		LIGHT BROWNISH-ORANGE DARK BROWN AND GRAY SILTY FINE TO COARSE SAND WITH GRAVEL AND COBBLES, DECAYING ORGANICS, GLASS AND BRICK (LOOSE, MOIST) (FILL)
8.0 – 11.0	SM	DARK BROWN SILTY FINE SAND (LOOSE, MOIST) (TOPSOIL)
11.0 – 12.8		LIGHT BROWNISH-ORANGE FINE TO MEDIUM SAND WITH TRACE SILT IRON OXIDE STAINED (MEDIUM DENSE TO DENSE, MOIST) **(WEATHERED SANDSTONE)**
		SAMPLES WERE COLLECTED AT 1.5, 4.0, 9.0 AND 12.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 12.8 FEET ON 8/5/99

LOG OF EXPLORATION

DEPTH	USC	SOIL DESCRIPTION
TEST PIT FIVE		
0.0 – 0.5		BROWN FINE SANDY SILT (LOOSE, MOIST TO WET) (FILL)
0.5 – 6.3		LIGHT BROWNISH-ORANGE TO DARK BROWN SILTY FINE SAND WITH GRAVEL, COBBLES AND WOOD (LOOSE, MOIST) (FILL)
6.3 – 8.5	SM	LIGHT BROWNISH-ORANGE SILTY FINE TO COARSE SAND WITH GRAVEL AND TRACE COBBLES IRON OXIDE STAINED (MEDIUM DENSE TO DENSE, MOIST TO WET) **(WEATHERED DRIFT)**
		SAMPLES WERE COLLECTED AT 4.0 AND 8.0 FEET SLIGHT GROUND WATER SEEPAGE WAS ENCOUNTERED AT 8.3 FEET TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 8.5 FEET ON 8/5/99
TEST PIT SIX		
0.0 – 7.0		BROWN SILTY FINE TO COARSE SAND WITH GRAVEL, COBBLES AND ROOTS TO DARK BROWN SILTY FINE SAND WITH ORGANICS, ROOTS AND TRACE GRAVEL (LOOSE TO MEDIUM DENSE, MOIST) (FILL)
7.0 – 8.0	SM	BROWN SILTY FINE SAND (MEDIUM DENSE, MOIST) **(TOPSOIL)**
8.0 – 9.0	SM	LIGHT BROWN SILTY FINE SAND WITH GRAVEL AND TRACE COBBLES IRON OXIDE STAINED (MEDIUM DENSE, MOIST) **(WEATHERED DRIFT)**
9.0 – 11.8	SM	BLUE-GRAY SILTY FINE SAND WITH FINE SAND SEAMS, GRAVEL, IRON OXIDE STAINING AND TRACE COBBLES (DENSE TO VERY DENSE, MOIST) **(DRIFT)**
		SAMPLES WERE COLLECTED AT 5.0, 8.5 AND 11.8 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 11.8 FEET ON 8/5/99
TEST PIT SEVEN		
0.0 – 7.8		BROWN AND DARK BROWN SILTY FINE TO COARSE SAND WITH GRAVEL, COBBLES, LARGE WOOD PIECES, TRACE ROOTS AND BOULDERS (MEDIUM DENSE, MOIST) (FILL)
7.8 – 9.9	SM	BLUE-GRAY SILTY FINE TO COARSE SAND WITH FINE SAND SEAMS, GRAVEL, TRACE COBBLES AND IRON OXIDE STAINED (DENSE, MOIST TO WET) **(DRIFT)**
		SAMPLES WERE COLLECTED AT 9.9 FEET SLIGHT GROUND WATER SEEPAGE WAS ENCOUNTERED AT 9.9 FEET TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 9.9 FEET ON 8/5/99
TEST PIT EIGHT		
0.0 – 5.5		BROWN AND LIGHT BROWN SILTY FINE SAND WITH GRAVEL, TRACE COBBLES, AND WOOD DEBRIS (LOOSE TO MEDIUM DENSE, MOIST) (FILL)
5.5 – 7.0	SM	BROWN SILTY FINE SAND WITH TRACE ROOTS (MEDIUM DENSE, MOIST) **(TOPSOIL)**
7.0 – 10.5	SM	BLUE-GRAY SILTY FINE TO COARSE SAND WITH FINE TO MEDIUM SAND LENSES, GRAVEL, IRON OXIDE STAINING AND TRACE COBBLES (DENSE, MOIST TO WET) **(WEATHERED DRIFT)**
		SAMPLES WERE COLLECTED AT 9.0 AND 10.5 FEET SLIGHT GROUND WATER SEEPAGE WAS ENCOUNTERED AT 9.5 FEET TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 10.5 FEET ON 8/5/99

LOG OF EXPLORATION

DEPTH	USC	SOIL DESCRIPTION
TEST PIT NINE		
0.0 – 5.0		BROWN AND LIGHT BROWN SILTY FINE SAND WITH GRAVEL, TRACE COBBLES, ROOTS AND COAL PIECES (LOOSE, MOIST) **(FILL)**
5.0 – 6.5	SM	RUST-BROWN SILTY FINE SAND WITH GRAVEL AND ROOTS (MEDIUM DENSE, MOIST) **(TOPSOIL)**
6.5 – 10.4	SM	LIGHT BROWN SILTY FINE TO COARSE SAND WITH FINE TO MEDIUM SAND LENSES, GRAVEL, IRON OXIDE STAINING AND TRACE COBBLES (MEDIUM DENSE TO DENSE, MOIST TO WET) **(WEATHERED DRIFT)**
		SAMPLES WERE COLLECTED AT 6.0, 8.0 AND 10.4 FEET SLIGHT GROUND WATER SEEPAGE WAS ENCOUNTERED AT 10.0 FEET TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 10.4 FEET ON 8/5/99
TEST PIT TEN		
0.0 – 4.0		BROWN AND LIGHT BROWN SILTY FINE SAND WITH GRAVEL, TRACE COBBLES, COAL PIECES AND WOOD (LOOSE, MOIST) **(FILL)**
4.0 – 6.0	SM	RUST-BROWN SILTY FINE SAND WITH GRAVEL AND TRACE ROOTS (MEDIUM DENSE, MOIST) **(TOPSOIL)**
6.0 – 8.0	SM	LIGHT BROWN SILTY FINE TO COARSE SAND WITH FINE TO MEDIUM SAND LENSES, GRAVEL, IRON OXIDE STAINING AND TRACE COBBLES (MEDIUM DENSE TO DENSE, MOIST TO WET) **(WEATHERED DRIFT)**
		SAMPLE COLLECTED AT 8.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 8.0 FEET ON 8/5/99
TEST PIT ELEVEN		
0.0 – 6.0		LIGHT BROWN AND DARK BROWN SILTY FINE SAND WITH GRAVEL, ORGANICS AND TRACE COBBLES (MEDIUM DENSE, MOIST) **(FILL)**
6.0 – 7.5	SM	LIGHT BROWN SILTY FINE TO COARSE SAND WITH GRAVEL (MEDIUM DENSE, MOIST) **(WEATHERED DRIFT)**
7.5 – 9.0	SM	BLUE-GRAY SILTY FINE TO COARSE SAND WITH IRON OXIDE STAINING, GRAVEL, FINE TO MEDIUM SAND LENSES AND TRACE COBBLES (DENSE TO VERY DENSE, MOIST TO WET) **(DRIFT)**
		SAMPLE COLLECTED AT 9.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 9.0 FEET ON 8/5/99

LOG OF EXPLORATION

DEPTH	USC	SOIL DESCRIPTION
TEST PIT TWELVE		
0.0 – 3.8		LIGHT BROWN SILTY FINE SAND WITH GRAVEL, WOOD AND TRACE COBBLES (MEDIUM DENSE, MOIST) (FILL)
3.8 – 5.9	SM	RUST-BROWN SILTY FINE TO COARSE SAND WITH GRAVEL (MEDIUM DENSE, MOIST) **(TOPSOIL)**
5.9 – 7.5	SM	LIGHT BROWN SILTY FINE TO COARSE SAND WITH GRAVEL, FINE TO MEDIUM SAND LENSES, IRON OXIDE STAINING AND TRACE COBBLES (DENSE, MOIST) **(WEATHERED DRIFT)**
		SAMPLE COLLECTED AT 7.5 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 7.5 FEET ON 8/5/99
TEST PIT THIRTEEN		
0.0 – 2.4		LIGHT BROWN SILTY FINE SAND WITH GRAVEL, TRACE COBBLES AND ROOTS (LOOSE, MOIST) (FILL)
2.4 – 4.0	SM	RUST-BROWN SILTY FINE SAND WITH GRAVEL, TRACE COBBLES AND ROOTS (MEDIUM DENSE, MOIST) **(TOPSOIL)**
4.0 – 5.8	SM	LIGHT BROWN SILTY FINE TO COARSE SAND WITH FINE TO MEDIUM SAND LENSES, GRAVEL, IRON OXIDE STAINING AND TRACE COBBLES (MEDIUM DENSE, MOIST TO WET) **(WEATHERED DRIFT)**
5.8 – 8.4	SM	GRAY IRON OXIDE STAINED SILTY FINE TO COARSE SAND WITH FINE TO MEDIUM SAND LENSES, GRAVEL AND TRACE COBBLES (DENSE TO VERY DENSE, MOIST) **(DRIFT)**
		SAMPLES WERE COLLECTED AT 5.0 AND 8.4 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 8.4 FEET ON 8/5/99
TEST PIT FOURTEEN		
0.0 – 0.5		LIGHT BROWN SILTY FINE SAND WITH GRAVEL AND ROOTS (LOOSE, MOIST) (FILL)
0.5 – 3.0	SM	RUST-BROWN SILTY FINE SAND WITH TRACE GRAVEL AND ROOTS (LOOSE, MOIST) **(TOPSOIL)**
3.0 – 6.5		LIGHT BROWNISH-ORANGE FINE TO MEDIUM SAND WITH TRACE SILT IRON OXIDE STAINED (DENSE TO VERY DENSE, MOIST) **(WEATHERED SANDSTONE)**
		SAMPLE COLLECTED AT 6.5 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 6.5 FEET ON 8/5/99
TEST PIT FIFTEEN		
0.0 – 1.0	SM	RUST-BROWN SILTY FINE SAND WITH TRACE GRAVEL AND ROOTS (LOOSE, MOIST) **(TOPSOIL)**
1.0 – 5.0		LIGHT BROWNISH-ORANGE FINE TO MEDIUM SAND WITH TRACE SILT IRON OXIDE STAINED (DENSE, MOIST) **(WEATHERED SANDSTONE)**
		SAMPLES WERE COLLECTED AT 2.0 AND 5.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 5.0 FEET ON 8/5/99

LOG OF EXPLORATION

DEPTH	USC	SOIL DESCRIPTION
TEST PIT SIXTEEN		
0.0 – 2.5		BROWN AND DARK BROWN SILTY FINE SAND WITH GRAVEL AND ROOTS (LOOSE, MOIST) **(FILL/TOPSOIL)**
2.5 – 6.0		LIGHT BROWNISH-ORANGE FINE TO MEDIUM SAND WITH TRACE SILT IRON OXIDE STAINED (DENSE, MOIST) **(WEATHERED SANDSTONE)**
		SAMPLE COLLECTED AT 6.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 6.0 FEET ON 8/5/99
TEST PIT SEVENTEEN		
0.0 – 1.0		LIGHT BROWN SILTY FINE SAND WITH GRAVEL AND ROOTS (LOOSE, MOIST) **(FILL)**
1.0 – 5.0		LIGHT BROWNISH-ORANGE FINE TO MEDIUM SAND WITH TRACE SILT IRON OXIDE STAINED (DENSE, MOIST) **(WEATHERED SANDSTONE)**
		SAMPLE COLLECTED AT 5.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 5.0 FEET ON 8/5/99
TEST PIT EIGHTEEN		
0.0 – 7.0		BROWN SILTY FINE SAND WITH GRAVEL, COAL PIECES, WOOD, ROOTS AND TRACE COBBLES (LOOSE, MOIST) **(FILL)**
7.0 – 8.0	SM	DARK BROWN SILTY FINE SAND WITH ROOTS (LOOSE, MOIST) **(TOPSOIL)**
8.0 – 13.5	SM	LIGHT BROWN SILTY FINE TO COARSE SAND WITH FINE TO MEDIUM SAND LENSES, GRAVEL, IRON OXIDE STAINING AND TRACE COBBLES (DENSE TO VERY DENSE, MOIST TO WET) **(WEATHERED DRIFT)**
		SAMPLES WERE COLLECTED AT 9.0 AND 13.5 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 13.5 FEET ON 8/5/99
TEST PIT NINETEEN		
0.0 – 3.0		BROWN SILTY FINE SAND WITH GRAVEL, ROOTS AND COAL PIECES (LOOSE, MOIST) **(FILL)**
3.0 – 6.0		LIGHT BROWNISH ORANGE FINE SAND (MEDIUM DENSE TO DENSE, MOIST) **(WEATHERED SANDSTONE)**
		SAMPLE COLLECTED AT 6.0 FEET GROUND WATER SEEPAGE WAS NOT ENCOUNTERED TEST PIT CAVING WAS NOT ENCOUNTERED TEST PIT WAS COMPLETED AT 6.0 FEET ON 8/5/99

Appendix 7:
Geophysical Report, Apollo Geophysics, Inc.

APOLLO GEOPHYSICS CORPORATION
Engineering, Geology, Environmental, Construction & Mining

Thursday, November 18, 1999

Steve High
TESI
4909 North 13th Street
Tacoma, Washington 98406

AGC's File No.: **99.227**

Re: **GPR and 1D Electrical Resistivity Study**
Ravensdale Mine
Ravensdale, Washington

Dear Mr. High,

This report presents the results of geophysical exploration for potential mine workings and non-native fill delineation at the above referenced site. The site is located at the Reserve Silica Corporation Ravensdale Mine in Ravensdale, Washington. The geophysical field program was completed between August 3 and August 13, and on October 26 and 28, 1999 by a three-person field crew from APOLLO GEOPHYSICS.

INTRODUCTION

This site is speculated to be the result of non-native fill wasting in the remnants of trenches produced by Silica Sand and Coal mining. The non-native fill was apparently end-dumped into the trenches, which were 80 to 100 feet wide and in excess of 80 feet deep. The non-native fill was then purportedly capped with locally derived semi-impermeable soils.

The use of multiple near-surface geophysical tools has been shown to provide an excellent exploration approach on similar sites. Based upon the premise that the non-native fill would be relatively low in electrical resistivity as compared to the surrounding soils, several 1D vertical electrical resistivity soundings were completed to establish a basis by which to "discover" the potential mining trench and non-native fill areas. In addition, Ground Penetrating Radar transects were also completed to provide continuous data for super imposing upon the electrical and geological data.

GEOPHYSICAL METHODS

In this study, we utilized two different geophysical approaches. The primary approach, used in both the upper and lower area of the site, was Ground Penetrating Radar (GPR). GPR uses a pulsed electromagnetic signal, which is reflected from interfaces with differing dielectric properties. The method used in the lower non-native fill disposal area was direct contact vertical electrical soundings (VES), I-D Electrical Resistivity. The VES measures the volumetric resistance, of soils, beneath a linear electrode array. Thus the unit of measurement is in terms of ohm-meters, or the resistance of a one-meter cube of soil.

Several other geophysical methods, such as electromagnetic profiling, were considered for exploration at this project. The use of these approaches was eliminated primarily due to the presence of significant cultural interference, such as overhead high voltage power lines.

GROUND PENETRATING RADAR

The Ground Penetrating Radar was completed using a PE 1000 system with both a 450 MHz and a 100 MHz antenna. Each antenna required a separate traverse across the GPR alignment. Location control for each traverse was based upon an integrated survey, which triggered the radar pulse at 0.05 and .1 meters for the 450 MHz and 100 MHz antennas respectively. Location from the survey wheel was normalized to established survey control stakes.

Ground penetrating radar (GPR) is an electro-magnetic (EM) device used to acquire subsurface information. The device operates in the radar bandwidths or more specifically in the electro-magnetic frequency spectrum from 16 to 2000 MHz. It is commonly applied for mapping soil layers, depth to bedrock, buried stream channels, rock fracture zones and cavities; to detect and delineate buried waste materials (both bulk and drummed); to locate buried utilities (both metallic and nonmetallic); to locate buried structural components; and in cultural resource management, to locate buried cultural features. GPR instrumentation is operated on 12 VDC, and is backpack portable for access to difficult locations.

Large advances in solid state circuitry and embedded system technology (i.e., digital signal processor (DSP)) have lead to micro-computer controlled ground penetrating radar systems of relatively small physical size and power consumption. Collection of GPR data has evolved allowing the data to be recorded directly onto magnetic media for later filtering and processing on PC size office computers. Not only have the recording methods improved, advanced processing capabilities have lead to the reduction of the amount of time required to produce a useable image.

Ground Penetrating Radar is a technique that involves the transmission of a short burst of electro-magnetic (EM) energy (at radar frequencies, i.e. from 10 MHz to 2000 MHz) into the ground and recording the reflections that may occur from the materials in the path of the radar beam. GPR reflections are created by changes in the dielectric constant of the materials through which the EM energy passes. The dielectric constant of a material is a measure of the ability of the material to conduct electricity, and is expressed as the electric permittivity, or the relative permittivity, ε_r, of the material times the permittivity of space, e_0 (10^{-9} / 36p Farad/meter).

A GPR system can be either "impulse" radar or "pulse" radar. "Impulse" radar operates at a wide-band width with a center frequency, whereas "pulse" radar operates at a single frequency, where the transmission is generally one "pulse" or wavelength. Electromagnetic pulses of short duration (1 to 5 nanoseconds) are transmitted from an antenna, which is moved across the ground surface. The energy radiates down through the subsurface and is reflected back to the receiving antenna from various interfaces within the subsurface. The reflections occur from subsurface electrical discontinuities. Variations in the continuously recorded signals are sent to the control unit for processing and display. The record produced by the GPR may be a continuous, cross-sectional picture or profile of subsurface conditions within the depth of penetration, or it may resemble a seismic reflection "wiggly trace" record. For both type of records the reflections from interfaces between two layers or materials having sufficiently different electrical properties are graphically displayed. These reflections may be associated with natural geologic conditions as well as man-made objects. Radar reflections from a single interface generally result in a set of multiple colored bands. The location of each interface is picked at one of the contrasting lines shown on the continuous or "wiggly trace" records. Occasionally, multiple bands, of energy arrival, obscure information when two interfaces are close together, although special processing techniques have been developed to alleviate this problem.

The time the electromagnetic pulse takes to travel from the transmitting antenna to the buried object or interface and back to the receiving antenna is proportional to the depth of the buried object or interface. This time is a two-way travel time and is dependent on the dielectric properties of the media through which the pulse travels. The dielectric properties (electrical permeability and conductivity) are a function of the composition and moisture content of the subsurface soil and rock materials.

Depth of penetration is highly site-specific and is limited in depth by attenuation of the outgoing pulse. The GPR system prefers to look through insulators to conductors. Greater penetration is obtained in dry, sandy, or rocky soils or concrete and little penetration is obtained from moist, clayey conductive soils. Depth of penetration for the EM energy is determined by the energy loss of the transmitted wave. The energy loss mechanism is attenuation due to the conductivity of the intervening material (spreading loss plus absorption loss by conversion of the energy to heat), and is also a function of the frequency of the energy transmission. The attenuation may be expressed in terms of "skin depth" of the material at a particular frequency. The skin depth is the depth at which the radar signal is attenuated by 4.34 dB or to 37% of its original amplitude (or to 1/e, where e = 2.71828...).

The output power levels of the transmitted energy are optimized for each system and antenna design. An increase in the output power level of the GPR energy does not necessarily increase the depth of the signal penetration. The reflected radar energy is dominated more by coherent scattering than by random noise generated in the subsurface materials. Thus, at increased power levels, the records become "cluttered" with undesired "noise", which may hide the desired subsurface interface being sought. Additionally, the system noise (inherent in the electronics) limits detection of the deeper signal levels, which attenuate to very low signal levels (usually greater than an attenuation of 60 to 80 dB).

The resolution, or the ability to separate two closely spaced reflections, is inversely proportional to frequency and is frequently quoted as being equal to half the pulse length, which may be greater than a single wave length. For radar systems, the resolution is approximately equal to the wave length divided by 2. If the frequency, f, is in MHz, the wave length, λ, in meters, is given by:

$$\lambda = \frac{300}{f\sqrt{\varepsilon_r}}$$

In air ($\varepsilon_r = 1$), for a 500 MHz antenna, the wavelength is approximately 0.6 meters (1.96 feet); for a 300 MHz antenna the wavelength is approximately 1 meter (3.28 feet). For the 500 MHz antenna, the wave length in a dry sand ($\varepsilon_r = 5$) is approximately 0.26 meters (0.88 feet), for marshy, forested flat land ($\varepsilon_r = 12$) the wave length becomes 0.17 meters (0.56 feet). The calculated wave length for concrete (ε_r=6) using the 2000 MHz antenna is 0.02 meters (2.4 inches) making this antenna a valuable high-resolution tool to locate structural steel within walls and floors.

For subsurface interface depths within 2 to 3 meters (6.5 to 10 feet) of the surface a 500 MHz antenna is generally preferable. As the depth of interest increases, the antenna frequency should decrease. Antenna frequencies range from 12.5 to 2000 MHz. The potential, maximum penetration depth for a given radar frequency can be related to the "skin depth" by the conductivity or resistivity of the material (the resistivity being the inverse of the conductivity). Skin depth in meters can be estimated as:

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$$

δ = Skin Depth
ω = 2pf
σ = Conductivity in Siemens per meter
μ = (1.26×10^{-6} Henries/Meter) Permeability

The relationship of radar loss or attenuation, α, and conductivity, σ, of a sample is given by:

$$\alpha \approx \frac{1.63\sigma}{\sqrt{\varepsilon_r}}$$

where ε_r is the relative permittivity. GPR systems can detect signals up to approximately 60 to 80 dB of attenuation. The maximum penetration can be estimated for a particular frequency as 9.22 times the Skin Depth.

Increasing pulse frequency can increase the resolution of a profile, however, the increased frequency seriously decreases the penetration. Resolution of GPR profiles ranges from a few centimeters to several meters, depending on the output frequency. Simply changing antennas and minor adjustments to the data collection software driven computer changes frequencies. The project requirements and site conditions must be considered when deciding which frequency to use.

GPR reflections are recorded in two-way travel time depths, that is, from the start of the pulse, or "0" time, down to the interface, and then back to the surface where the reflection is recorded. The recording time is generally is in nano-seconds (ns). The depth of the reflection, or found interface, can then be estimated from the measured two-way time interval and an estimation of the velocity of the wave in the materials. It should be pointed out that the velocity of the EM wave in a material may vary across a site both horizontally and vertically. A vertical velocity, for example, will change drastically when the EM wave encounters the water table or the percentage of moisture changes with depth. GPR material velocities are generally expressed as the rate of wave propagation in terms of "nano-seconds per foot" rather than as a velocity of "feet per second". Typical material conductivity's, permittivity's and two-way travel times are shown in Table I.

TABLE I.

MATERIAL ELECTROMAGNETIC PARAMETERS

MATERIAL	CONDUCTIVITY SIEMENS/METER	PERMITTIVITY Ns/FOOT	APPROXIMATE VELOCITY
AIR	0	1	2
FRESH WATER	10^{-3} TO $3X10^{-2}$	81	18
DRY SAND	10^{-7} TO 10^{-3}	4 TO 6	4 TO 4.9
WET SAND	10^{-4} TO 10^{-2}	30	11
CLAY, SATURATED	10^{-1} TO 1	8 TO 12	5.7 TO 7
CLAY, DRY	$2.7x10^{-4}$	2.4	5.3
SILT, SATURATED	10^{-3} TO 10^{-2}	10	6.4
PEAT	$8X10^{-3}$ TO $3X10^{-2}$	43 TO 71	4 TO 17
CONCRETE	$12x10^{-4}$	6	8.2

Note: Nanoseconds per foot is approximate velocity.

Some of the data are shown as a range of values, which reflects the percentage of moisture contained in the material. There are several techniques by which the propagation rates can be measured directly. The simplest of the techniques is to cross a reflector with a known depth. A second technique is to cross a point source reflector, for example a pipe with a small diameter. The radar wave sees the point source reflector before the antenna passes over the source. The resulting image is a hyperbola that defines the location of the point source at the closest point of the hyperbola to the surface. Using the distance at which the point source is first seen to the top of the hyperbola and the two corresponding time depths, a calculation can be made to define the depth to the source.

As water has a relative permittivity of 81, the velocity of the EM wave will be greatly affected by the percentage of contained water. Calibration of the velocity over areas with varying soil moisture may be especially difficult.

Knowing the soil permittivity, ε_r, the two-way travel time may be computed directly by:

$$t = \frac{2d\sqrt{\varepsilon_r}}{3x\,10^8}$$

where **t** = two-way time in seconds and **d** = target depth. If **t** is in nano-seconds, the equation then becomes: $t = 6.67d\sqrt{\varepsilon_r}$

Depth interpretation is made by (1) field measurements of the EM signal velocity (by making direct measurements over a known reflector at a known depth); (2) estimating the velocity knowing the resistivity or conductivity of the subsurface materials; or (3) by utilizing the geometry of the parabola produced by a single point reflector. For any of these methods, the depth interpretations can only be an estimate of the depth of the recorded reflectors, due to the vertical and horizontal inhomogenities inherent in subsurface soils. Target identification is through the application of geometric optics similar in acoustic profiling, knowledge of expected geologic conditions and most importantly through operator experience. Due to expected velocity variations and inherent noise, which may produce false targets, extreme care must be exercised in target identification.

An advantage of Ground Penetrating Radar is the continuity of acquired data; it provides a continuous vertical profile. Data is also acquired at a relatively high speed. In some areas, work can be accomplished by using a vehicle to tow the radar antenna. GPR may be affected by signal noise. Sources of noise include system noise; above the surface (overhead) reflections from power lines, tunnel ceilings, light fixtures, etc.; noise from surface features such as metal, ditches, etc.; and noise due to natural subsurface features and buried conductors. However, shielded antennas reduce the effect of overhead objects.

1D VERTICAL ELECTRICAL RESISTIVITY METHOD

The electrical resistivity method is an excellent way to determine the configuration of subsurface materials based upon differences in their electrical properties (i.e., electrical resistivity).

The resistivity of a geologic unit is a function determined by the amount of contained water, the quantity of total dissolved salts in the water and the distribution of the water within the unit, e.g. the amount of void space which may contain water. Thus, the resistivity of most granular soils and rocks are controlled more by porosity, water content and water quality than by the conductivity of matrix materials. The capacity of a stratum to conduct electricity is affected by the number of interconnected spaces (permeability) and the water content. Void spaces must be interconnected and filled with water in order to conduct electricity. The pore volumes consist of two parts; larger voids that serve as storage locations and finer interconnecting zones. Much of the resistance, to current flow, is due to the connecting of small sized pores, because of their smaller cross section. Thus, a rock with a higher ratio of storage pore volume to connecting pore volume will have a higher resistivity.

Clay minerals such as kaolinite, halloysite, montmorillonite, etc., have the property of absorbing ions in an exchangeable state. Thus, when clay is mixed with water, the exchangeable ions may separate from the clay minerals in a process resembling ionization. These ions render the water in a pore structure conductive, even when the water has no salinity. These types of materials are called ionic conductors. Most earth materials possess some ionic exchange capacity. Therefore, the conductivity of an electrolyte in a pore structure will always be increased by ions supplied by desorption.

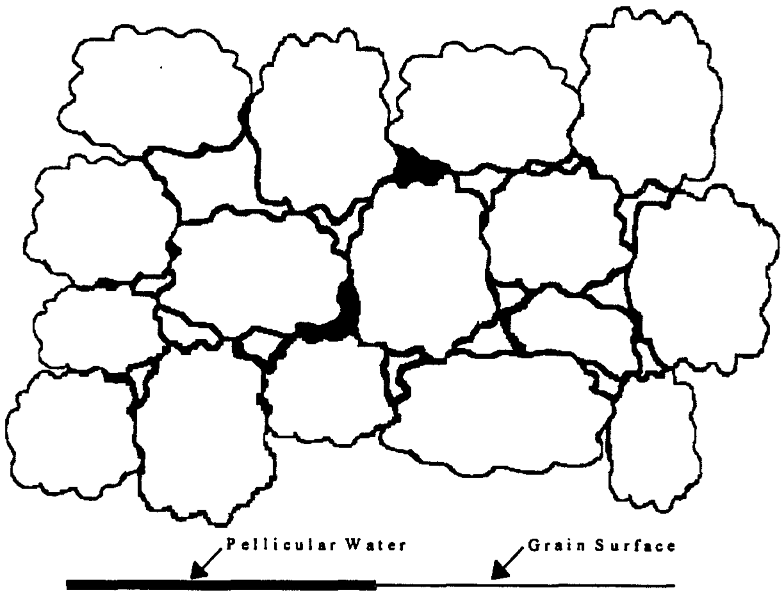


Figure 1. Relationship of Pellicular Water.

The pore structure of a geologic material need not necessarily be filled with an electrolyte, as is usually found in strata lying above the regional groundwater table. Most of the pore space is generally filled with air and only the granular surfaces potentially are coated with water, termed pellicular water, as indicated in Figure 1. The resistivity of a material with only a partial fraction of saturation will generally exhibit a resistivity much higher than the same material fully saturated. Studies showing the effect desaturation has on the resistivity of various types of oil reservoir rocks, containing saline water, allow recognition of an empirical expression termed Archie's Law;

$$\rho = a\rho_w \psi^{-m} \tag{1}$$

where ρ is the bulk resistivity of the geologic unit, ρ_w is the resistivity of the water contained in the pore structure, and ψ is the porosity expressed as a fraction per unit volume of rock. The terms a and m are parameters whose values are assigned to allow the equation to fit practical field measurements. Generally, it is found that a is slightly greater than one, and m is slightly less than two for granular materials. Thus, as the above equation indicates, the resistivity increases approximately as the square of the volumetric reduction in water content. We suggest that Resistivity Measurements are an effective method to determine the degree of saturation and porosity (i.e., grain size distribution).

Field and Interpretive Methods

Vertical Electrical Soundings (VES) are accomplished by applying a direct current or very low frequency synchronous alternating current to the ground, through a pair of electrodes (A & B). The corresponding resistivity is calculated according to Ohm's Law as follows;

$$\rho_a = K\frac{E}{I} \qquad (2)$$

where the generic form of K is;

$$K = \frac{2\Pi}{\frac{1}{\overline{AM}} - \frac{1}{\overline{BM}} - \frac{1}{\overline{AN}} + \frac{1}{\overline{BN}}} \qquad (3)$$

K is a geometric factor depending only upon the relative position of the four electrodes.

In order to study the variation of resistivity with depth, the spacing between the current electrodes is gradually increased. The effect of materials at depth becomes more pronounced with the increased electrode spacing and corresponding set of potential measurements.

The methodology used to reduce the field collected data to solution layering is more rigorous than curve matching or other empirical techniques. We normally use these more rigorous procedures to reduce the number of possible solutions for any single set of field data and provide a more definitive description of the geophysical regime at exploration sites. Interpretation of the data obtained during an electrical resistivity study has evolved tremendously, since the work of the Schlumberger brothers in the early 1930's. This evolution follows a sequence consisting of solution by empirical techniques (circa 1940 -1960 to present). The empirical methods involve the assumption of a direct relationship of depth to electrode spacing and in many instances appear to produce reasonable results, when the underlying substratum is non-conductive. Current curve matching techniques achieve much better results, but are however, rather limited by the number of published theoretical curves, and the complexity of the field curve. Generally, the analysis of a field curve is limited to no more than four layers. There were additional techniques by which a curve can be matched to allow five or more layers. Although due to the tedium and inaccuracies introduced by these solutions, such solutions were utilized very infrequently with less than desirable results. During the early to mid-1970's, several investigators began to use high speed digital computers for the analysis of electrical resistivity data. The most predominant interpretive method, to evolve, consists of deconvoling the electrical field by the application of a series of filter coefficients. The filter coefficients are applied for the direct solution of the integral defining the resistivity of a solid earth. Thus, it is possible to develop an electrical model from the field curve with no further input. Currently, it is possible by utilization of computer techniques to easily solve field curves for electrical models in excess of five layers.

The vertical electrical soundings (VES) are accomplished by applying a D.C. current to the ground through a pair of electrodes and measuring the potential established by this current across a second set of electrodes. In order to study the variation of resistivity with depth, the spacing between the current and potential electrodes is increased according to the array used. The depth of penetration of the current through the electrode array is a function of the spacing of the inner (potential) and outer (current) electrodes and the layer resistivities, and probably not in a 1 to 1 ratio of vertical depth to the horizontal separation between the outer, current electrodes.

We, at APOLLO GEOPHYSICS, utilize an industry standard Earth Resistivity Meter. This system applies two current pulses (D.C.) of opposite polarity (150V at 20mA) during a 3.5 second interval. The resultant potential differences are arithmetically subtracted, and the corresponding resistance for the remaining potential is calculated by internal microprocessors. The resistance is displayed for the operator to record at the end of each cycle. During most studies, we generally use averages of up to 64 cycles.

The Schlumberger electrode array was used to obtain the VES data in this report. In the Schlumberger array, four electrodes are spaced so that the ratio of the distance between the current (outside) electrodes to the distance between the potential (inner) electrodes is greater than 3. The electrodes are designated as the points on a line, AMNB, where A and B are the current electrodes, and M and N are the potential electrodes.

The electrode array was expanded from an AB/2 of 1 meter to a maximum of 30 to 60 meters, depending on the space available to expand the array. The measured resistance values were converted to apparent resistivities in the field with the use of a laptop computer. The resistivity curve was displayed by the computer in order to check for interference from cultural effect and to correct invalid data if possible. At some locations it was necessary to re-occupy a sounding location several times in order to gather sufficiently adequate data.

The VES data was interpreted with a computer program, developed by APOLLO GEOPHYSICS Corporation personnel, for automatic inversion of VES curves. Each VES point, for all data considered valid, was adjusted to a continuous fit, smoothed and digitized at 6 points per decade (i.e., 1, 10, 100, 1000, etc. on a Log-Log graph). The curve was adjusted to the data in the last MN spacing (3 meters) prior to the digitizing process. The data obtained is interpreted by use of a computer program, based upon the mathematical methodology described above, for the inversion of VES curves. The interpretation program is an automatic, one-dimensional inversion of the Schlumberger sounding curve. This method assumes the digitized VES to represent the points on a modified DAR Zarrouk (MDZ) curve as a fast approximation. These points are then solved for layer thickness and resistivities. The total Kernel Function curve for this layering is calculated using Sunde's Recursion Formula, and the VES curve is calculated by convolution using Ghosh's Coefficients. This curve is compared to the field VES curve and iteratively adjusted until both curves fit within a prescribed tolerance. In certain cases (e.g., VES curves with steeply descending branches), a modification of numerical integration techniques is likely necessary to establish a better relationship for an interpretation. The field data was adjusted to the data gathered at the last MN spacing (3 meters). The obvious data errors were removed, and the resulting curve was digitized at 6 points per decade with a Cubic Spline function. The digitized data was solved for layer resistivities using an auto-interpretation computer program. The digitized field data is listed in the computer solution as the "Observed VES."

This methodology allows the data points to affect the solution and does not force the solution to fit a predetermined solution layering. No adjustments of the data points are made, except for eliminating those data that are obviously in error.

The interpreted thickness, depths and resistivity values for each sounding are computed as the Detailed Solution to Smoothed VES Curve. The Detailed Solution is the interpreted resistivity solution for an initial estimation of 1 layer per data point.

RESULTS AND DISCUSSION

Ground Penetrating Radar Data

The results of the Ground Penetrating Radar traverses are shown in Figures A-1 through A-7; Figures B-1 through B-7 and C-1 through C-6. The prefix A, (upper road) B (middle road) or C (lower road) correspond to transect identification. Each figure has been normalized with respect to vertical scale utilizing 4.5 nano-seconds per foot. With regard to the estimated vertical scale, the normal relationship between radar time and actual depth for the Northwest Region, based upon our experience, is approximately 4 to 4.5 nanoseconds per foot. It should be noted that this relationship holds true in a general sense. Variations of water content, silt content and other factors may also change this relationship. Therefore it should be expected that the vertical scale is an estimate only and may vary from the shown scale.

Transect A begins at hub 42-G and progresses in a northerly direction along the upper road. Transect ~~B~~ C begins at hub 40-A and progresses in a southerly direction along the lower road. Transect ~~C~~ B begins at 43-I and progresses in a northerly direction along the middle road.

The GPR data basically defines three primary units along each transect. In comparison with backhoe test pit data, we expect the uppermost unit to represent a near surface road fill. The middle unit may represent a surficial topsoil or weather bedrock unit lying directly above the glacial drift or sandstone found on the site. Direct correlation with electrical resistivity units are shown along GPR section B-B' and C-C'.

COMMENTS AND RECOMMENDATIONS

We recommend that APOLLO GEOPHYSICS be retained to provide any further geophysical services necessary on the site. APOLLO GEOPHYSICS has first hand knowledge of site conditions, logistics, and we can further assist in evaluating the geologic conditions.

To further refine the local geologic interpretations, we recommend that Two Dimensional Electrical Resistivity Profiles be completed on the site. The data collected from 2D Electrical Resistivity Profiles are nearly continuous. This data will produce high detail geophysical/geologic cross-sections, which should provide fairly accurately the bounds of the trench locations. We have completed several 2D Electrical Resistivity projects in the Pacific Northwest for slope stability, groundwater studies, directional drilling feasibility studies, and various other applications. 2D Electrical Resistivity is a very cost-effective tool. Should further detail be required in specific localized areas, 3D electrical resistivity technique is the most viable exploration approach for high detail. 3D electrical resistivity is extremely cost effective for high detail exploration and resolving complex geological environments.

WARRANTY OF SERVICES

All geophysical information presented is based upon geophysical measurements made by generally accepted methods and field procedures and APOLLO GEOPHYSICS' interpretation of these data. The geophysical results are, therefore, interpretative in nature and are considered to be a reasonably accurate presentation of existing conditions within the limitations of the methods employed. Services performed by APOLLO GEOPHYSICS under this agreement are conducted in a manner consistent with, but no less than, that level of care skill ordinarily exercised by members of the profession currently practicing under similar conditions. We cannot guarantee the accuracy or correctness of any interpretation, and we shall not be liable or responsible for any loss, cost, damages or expenses incurred or sustained by the Client resulting from any interpretation made by any of our officers, agents or employees. No other warranty, expressed or implied, is made. APOLLO GEOPHYSICS recognizes that subsurface conditions may vary from those encountered at the location where geophysical or other explorations are made. The data interpretations and recommendations made by APOLLO GEOPHYSICS are based solely on the information available to them at the time of performance; and APOLLO GEOPHYSICS shall not be responsible for the interpretation, by others, of the information developed.

We trust this will complete your requirements for this project and look forward to working with you on future projects. If you have any further questions or need further assistance, please don't hesitate to call.

Sincerely,

APOLLO GEOPHYSICS CORPORATION

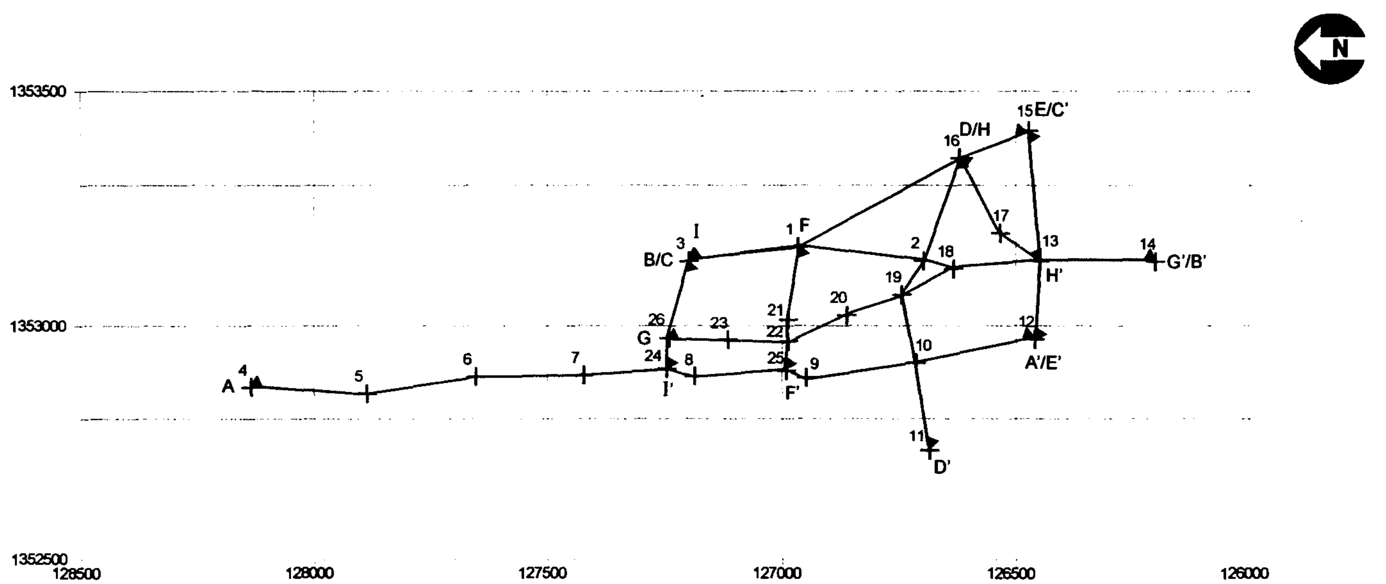
Lynn M. Ringstad

Lynn M. Ringstad
Project Geologist/Geophysicist

Clyde A. R

Clyde A. Ringstad
Senior Geophysicist

VES Orientation Map



LEGEND

4 + APPROXIMATE LOCATION OF VERTICAL ELECTRICAL SOUNDING (VES)

A — A' GEO-ELECTRICAL CROSS-SECTION A-A'

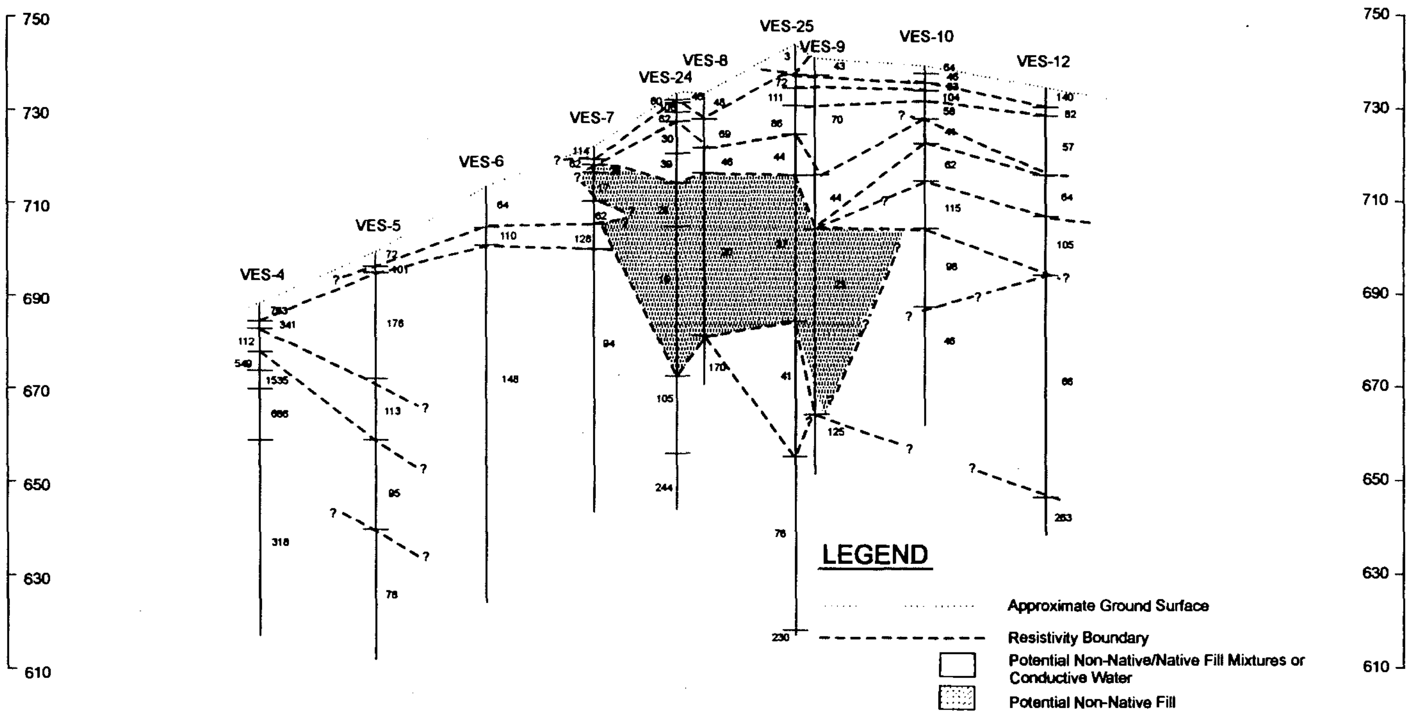
0 200 400

Approximate Scale 1" = 200'

Note: VES location data provided by E. True & Associates Land Surveying.

APOLLO GEOPHYSICS CORPORATION ENGINEERING, GEOLOGY, ENVIRONMENTAL CONSTRUCTION & MINING	Lower Disposal Area Ravensdale, Washington	FIGURE 1
	FILE NO. 99.227	DATE November 1999

Geo-Electrical Cross-Section A-A'



Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

APOLLO GEOPHYSICS CORPORATION ENGINEERING, GEOLOGY, ENVIRONMENTAL CONSTRUCTION & MINING	Lower Disposal Area Ravensdale, Washington	FIGURE 2
	FILE NO. 99.227	DATE November 1999

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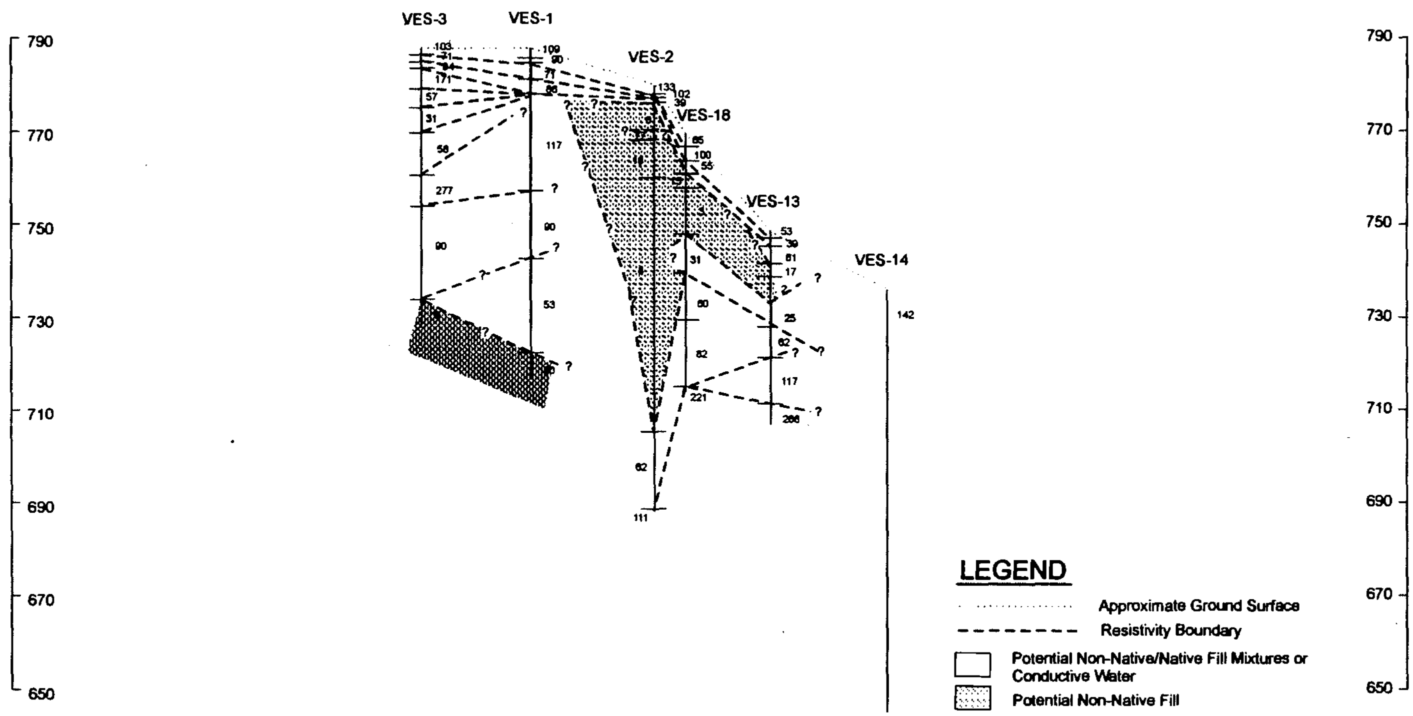
Geo-Electrical Cross-Section B-B'



Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

APOLLO GEOPHYSICS CORPORATION Engineering, Geology, Environmental Construction & Mining	Lower Disposal Area Ravensdale, Washington	FIGURE 3
	FILE NO. 99.227	DATE November 1999

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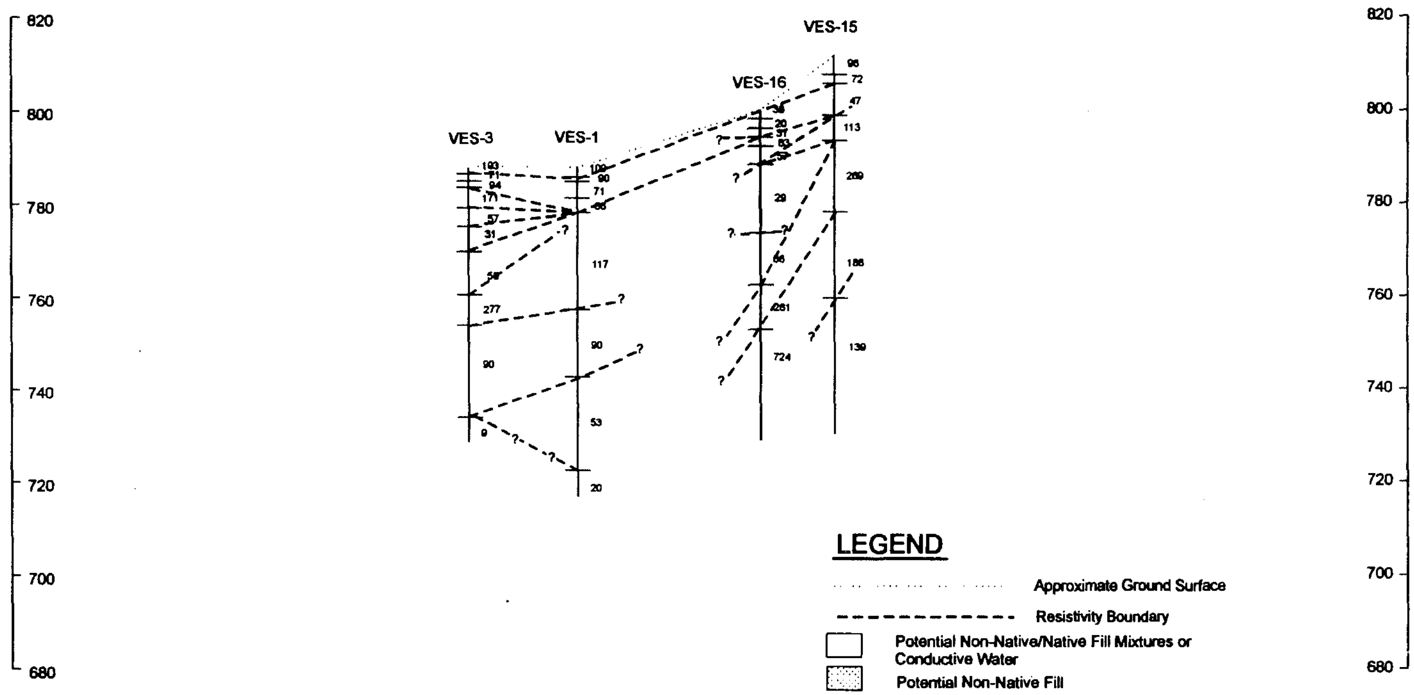
Geo-Electrical Cross-Section C-C'



Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

APOLLO GEOPHYSICS CORPORATION ENGINEERING, GEOLOGY, ENVIRONMENTAL CONSTRUCTION & MINING	Lower Disposal Area Ravensdale, Washington		FIGURE 4
	FILE NO. 99.227	DATE November 1999	

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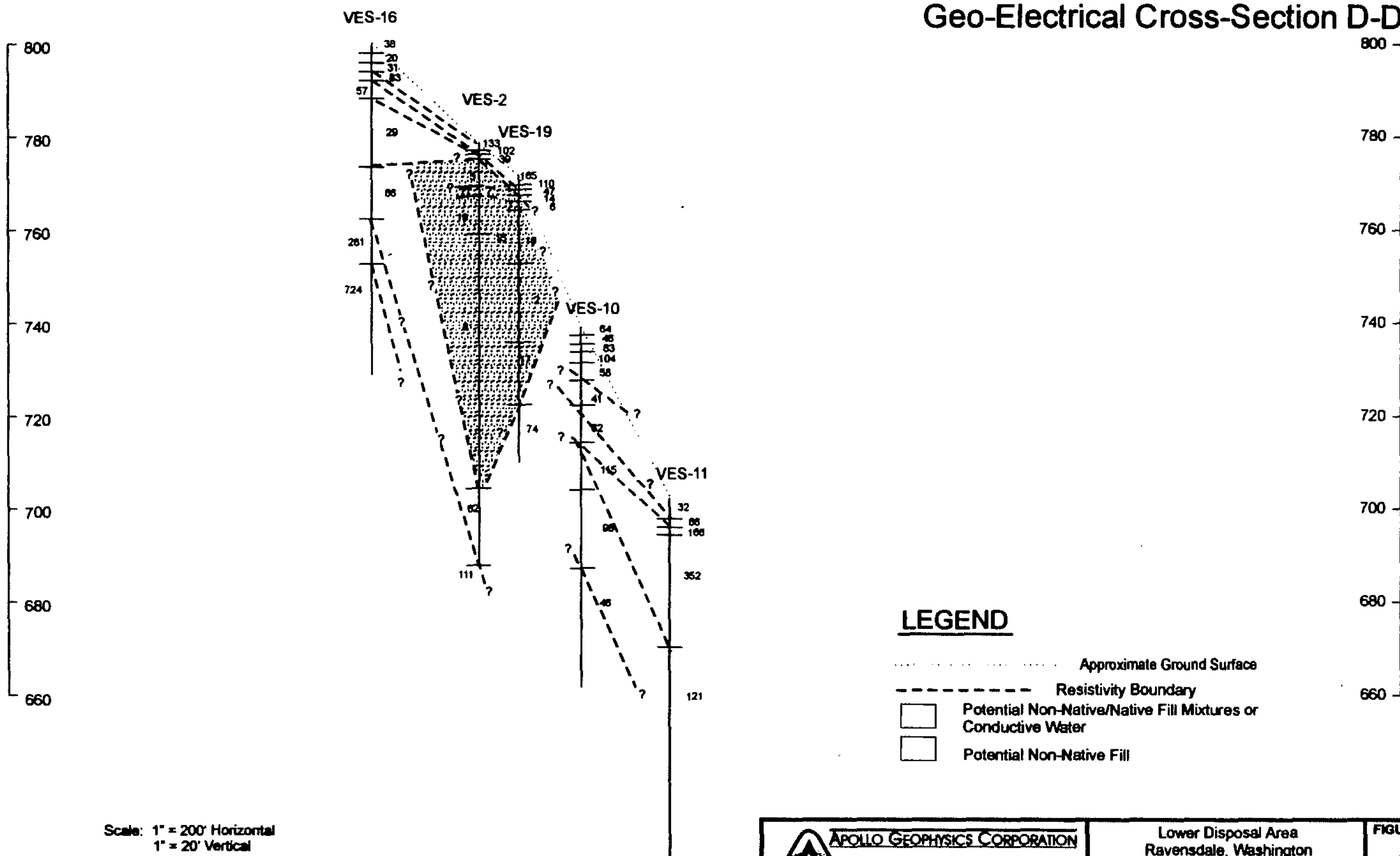
Geo-Electrical Cross-Section D-D'



Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

APOLLO GEOPHYSICS CORPORATION ENGINEERING, GEOLOGY, ENVIRONMENTAL CONSTRUCTION & MINING	Lower Disposal Area Ravensdale, Washington	FIGURE 5
	FILE NO. 99.227	DATE November 1999

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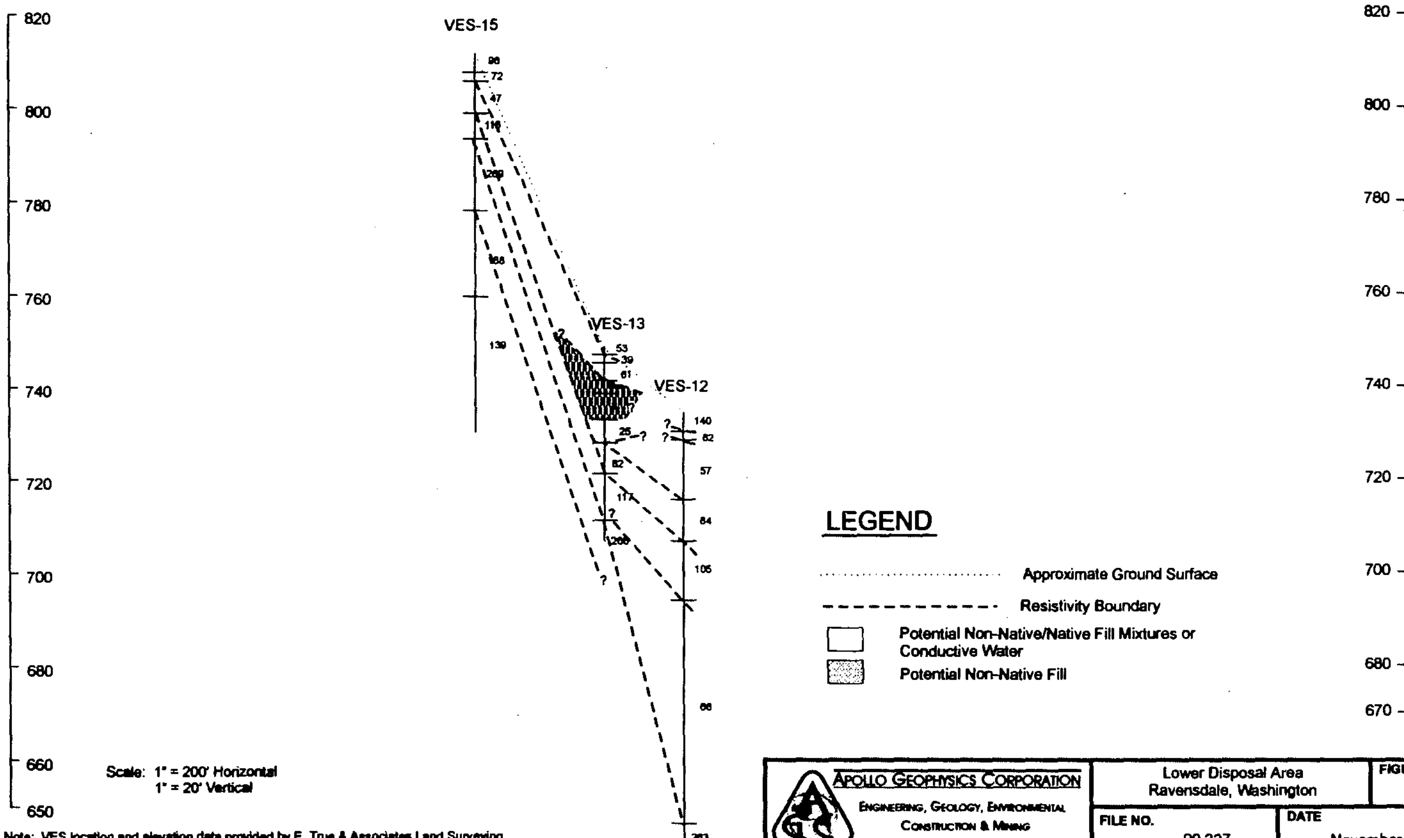
Geo-Electrical Cross-Section E-E'



Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

APOLLO GEOPHYSICS CORPORATION ENGINEERING, GEOLOGY, ENVIRONMENTAL CONSTRUCTION & MINING	Lower Disposal Area Ravensdale, Washington	FIGURE 6
	FILE NO. 99.227	DATE November 1999

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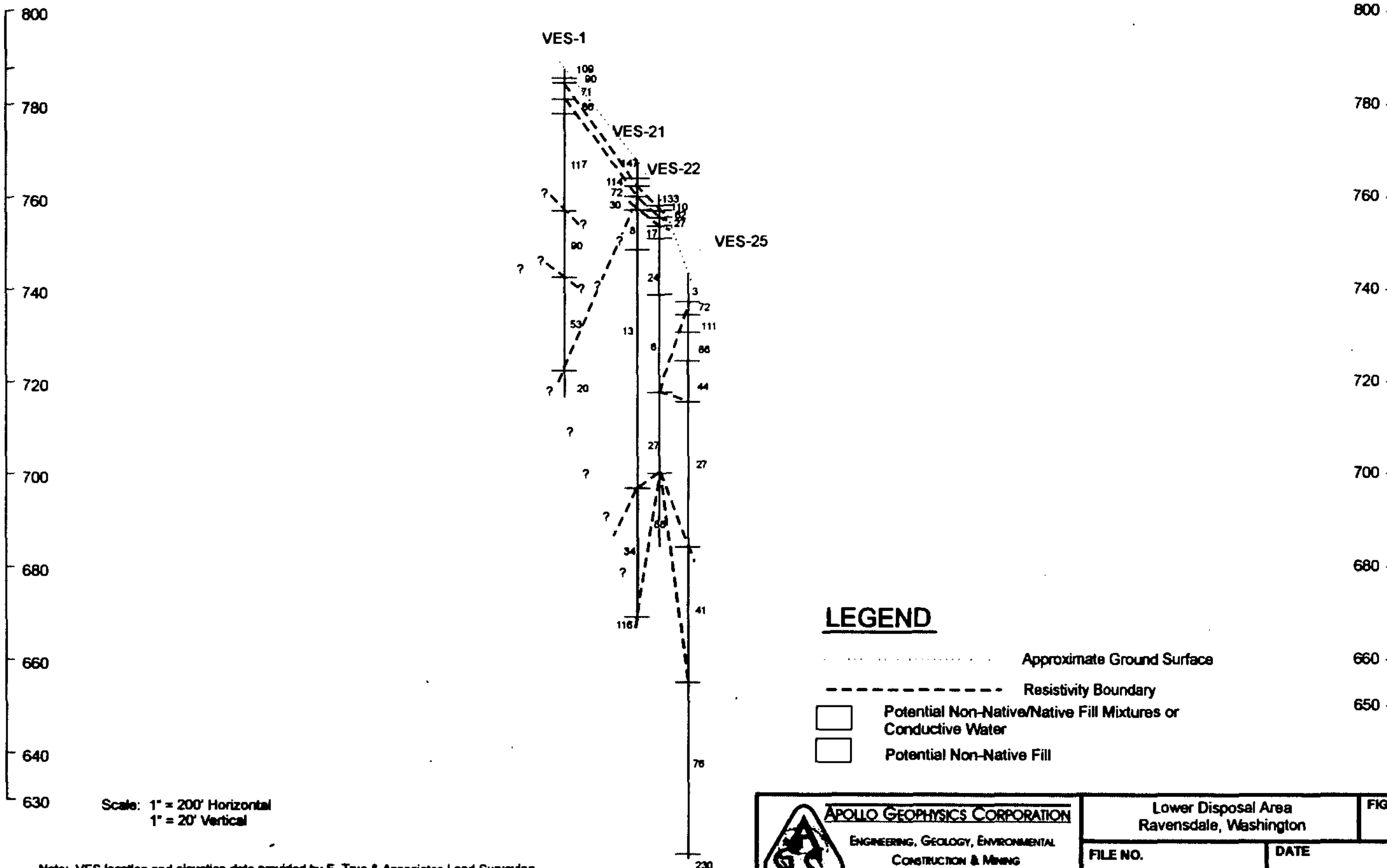
Geo-Electrical Cross-Section F-F'



LEGEND

Approximate Ground Surface

Resistivity Boundary

Potential Non-Native/Native Fill Mixtures or Conductive Water

Potential Non-Native Fill

Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

APOLLO GEOPHYSICS CORPORATION ENGINEERING, GEOLOGY, ENVIRONMENTAL CONSTRUCTION & MINING	Lower Disposal Area Ravensdale, Washington	FIGURE 7
	FILE NO. 99.227	DATE November 1999

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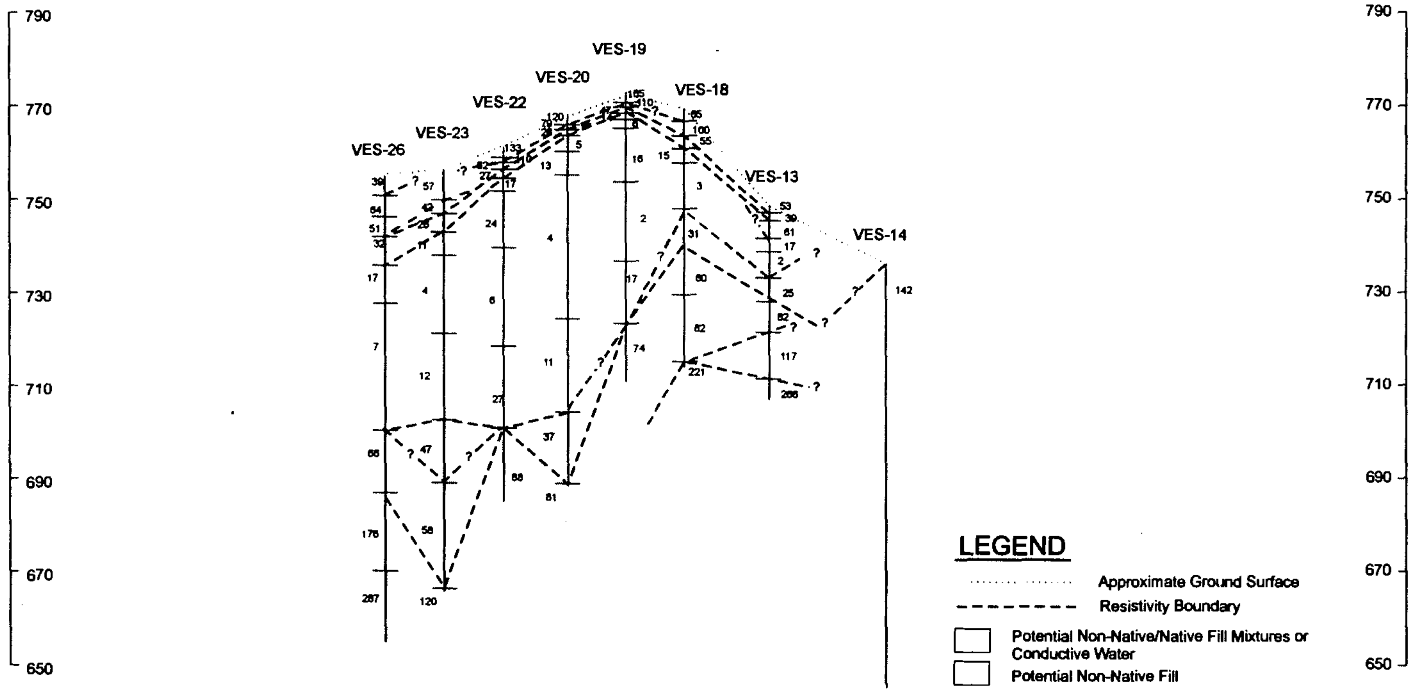
Geo-Electrical Cross-Section G-G'



Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

Apollo Geophysics Corporation Engineering, Geology, Environmental Construction & Mining	Lower Disposal Area Ravensdale, Washington	FIGURE 8
	FILE NO. 99.227	DATE November 1999

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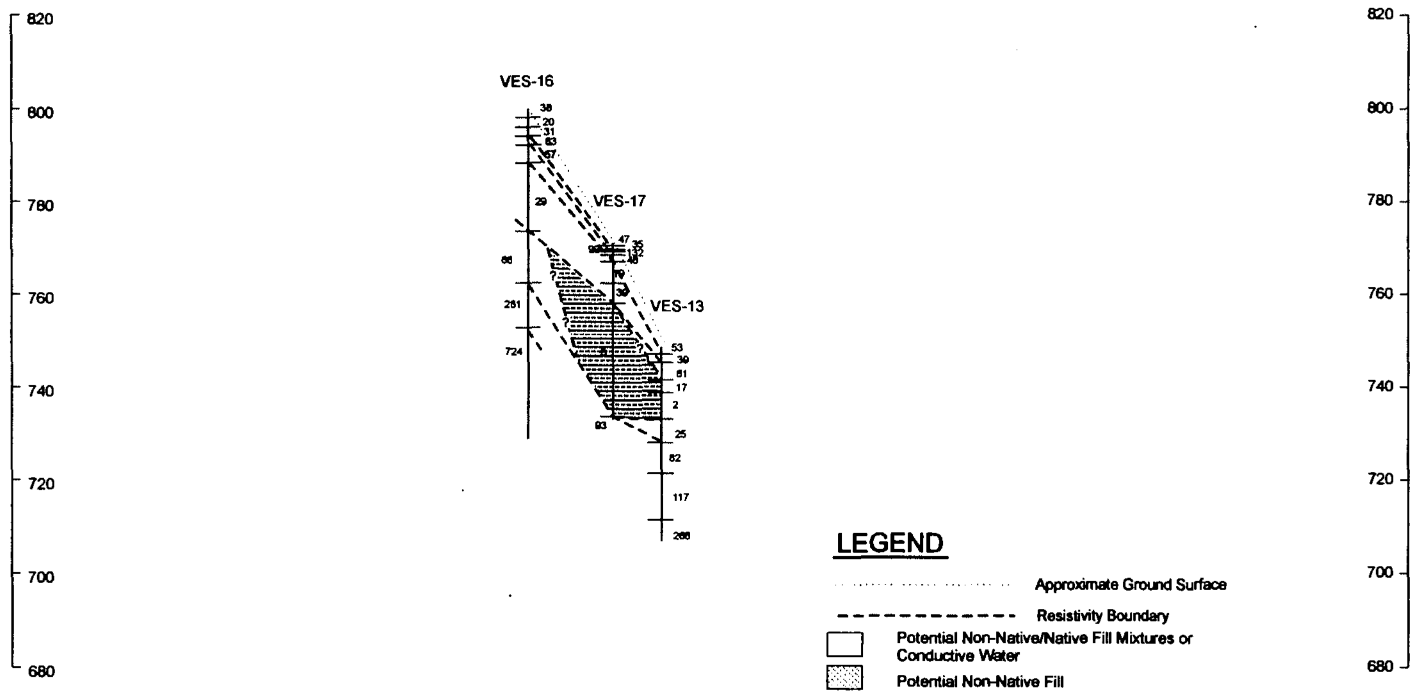
Geo-Electrical Cross-Section H-H'



Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

Apollo Geophysics Corporation Engineering, Geology, Environmental Construction & Mining	Lower Disposal Area Ravensdale, Washington	FIGURE 9
	FILE NO. 99.227	DATE November 1999

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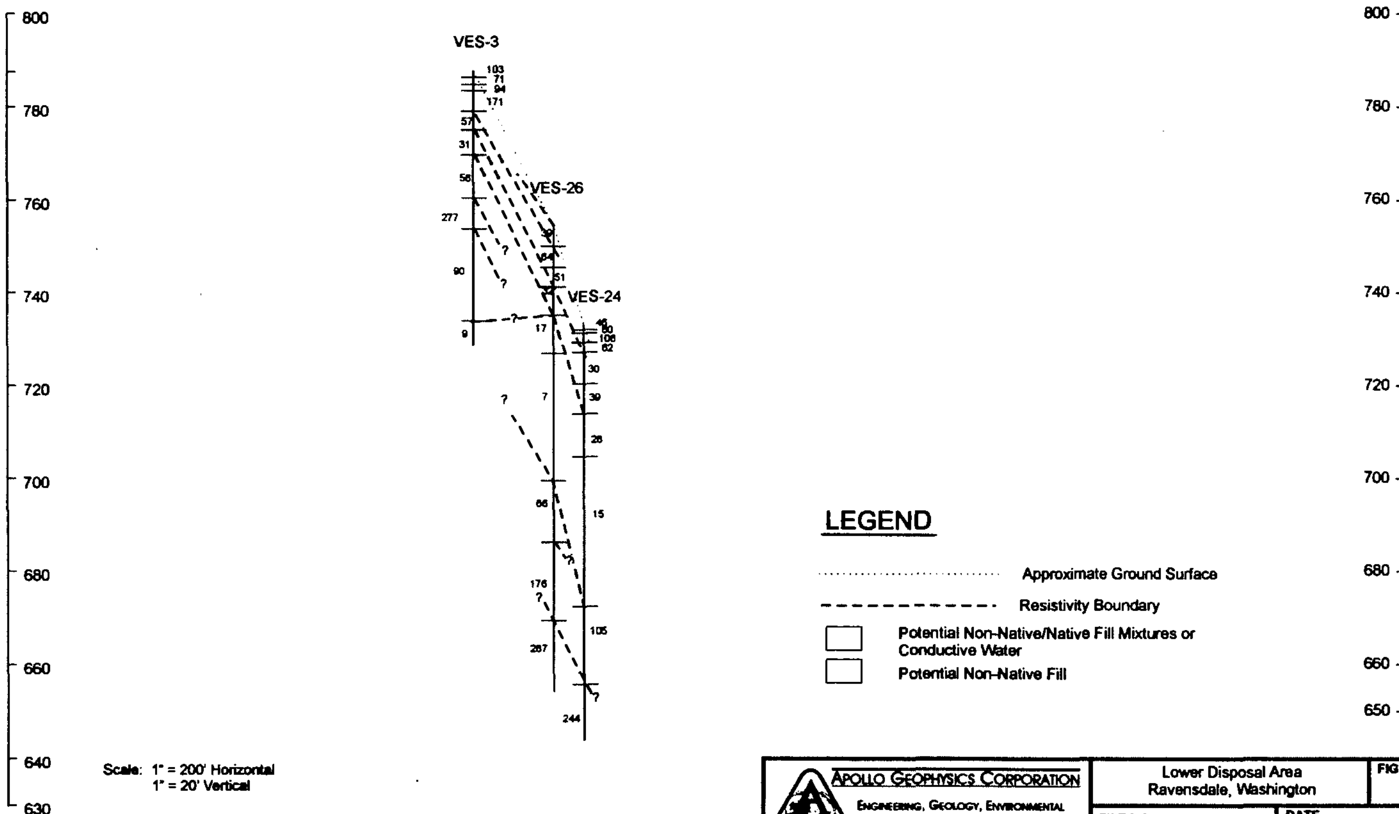
Geo-Electrical Cross-Section I-I'



Scale: 1" = 200' Horizontal
1" = 20' Vertical

Note: VES location and elevation data provided by E. True & Associates Land Surveying.

Apollo Geophysics Corporation Engineering, Geology, Environmental Construction & Mining	Lower Disposal Area Ravensdale, Washington	FIGURE 10
	FILE NO. 99.227	DATE November 1999

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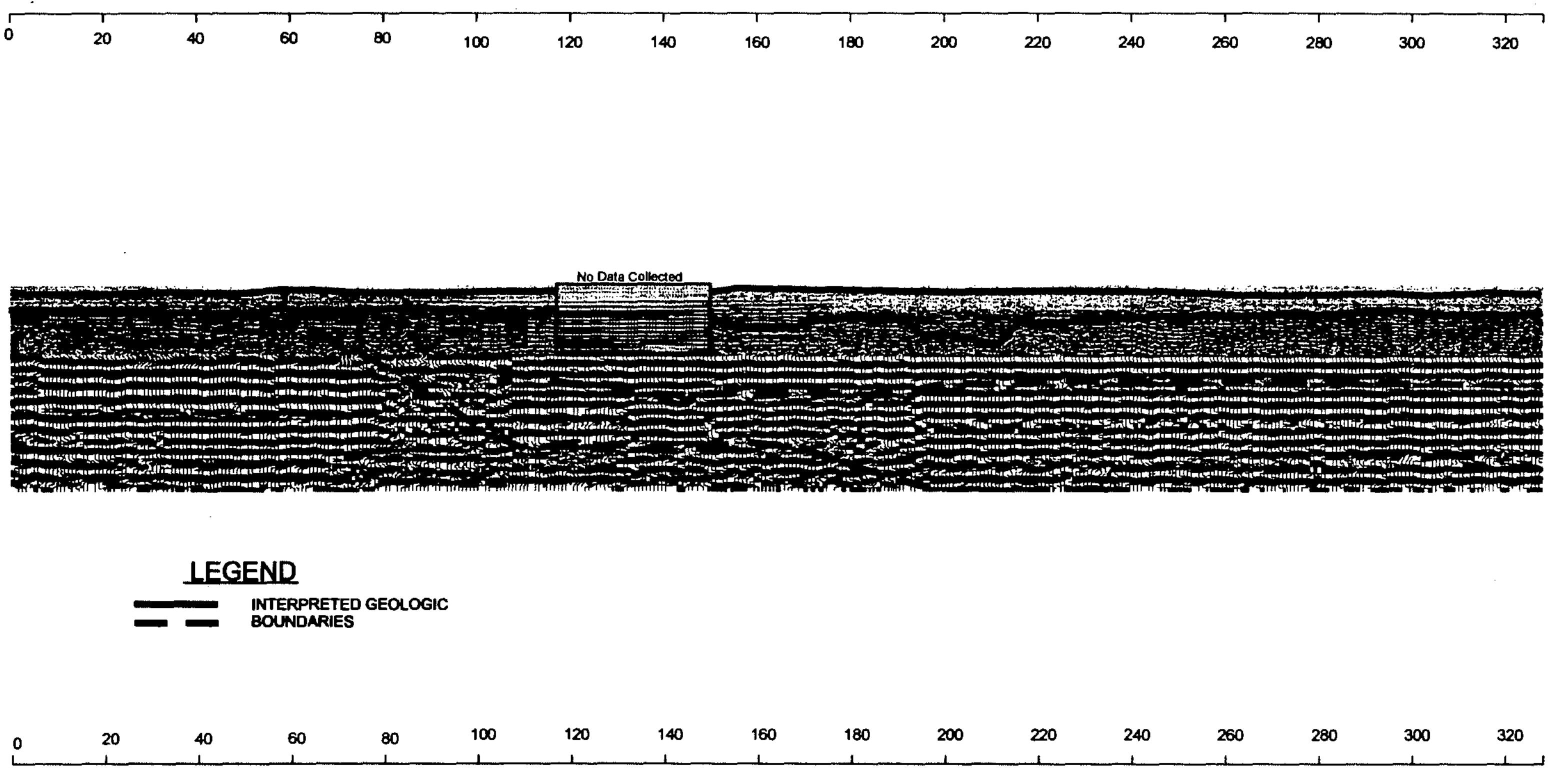
Ground Penetrating Radar Cross-Section A-A'



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Davis Pit #4 Ravensdale, Washington	A-1	99.227	November 1999

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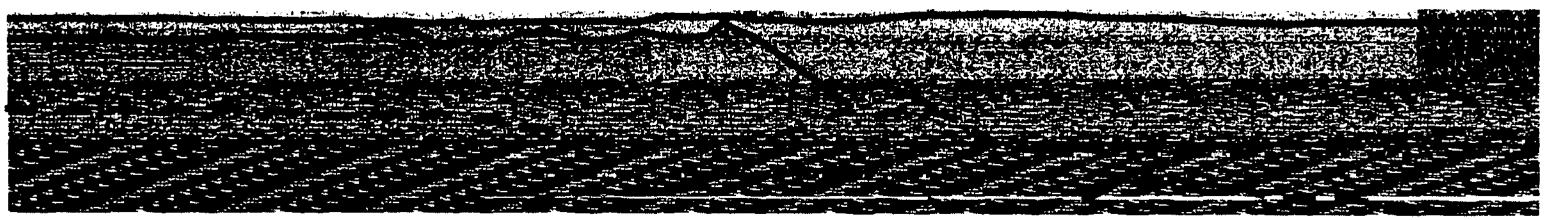
Ground Penetrating Radar Cross-Section A-A' (cont.)

328 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 656



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

328 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 656

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Davis Pit #4 Ravensdale, Washington	FIGURE A-2	FILE NO. 99.227	DATE November 1999

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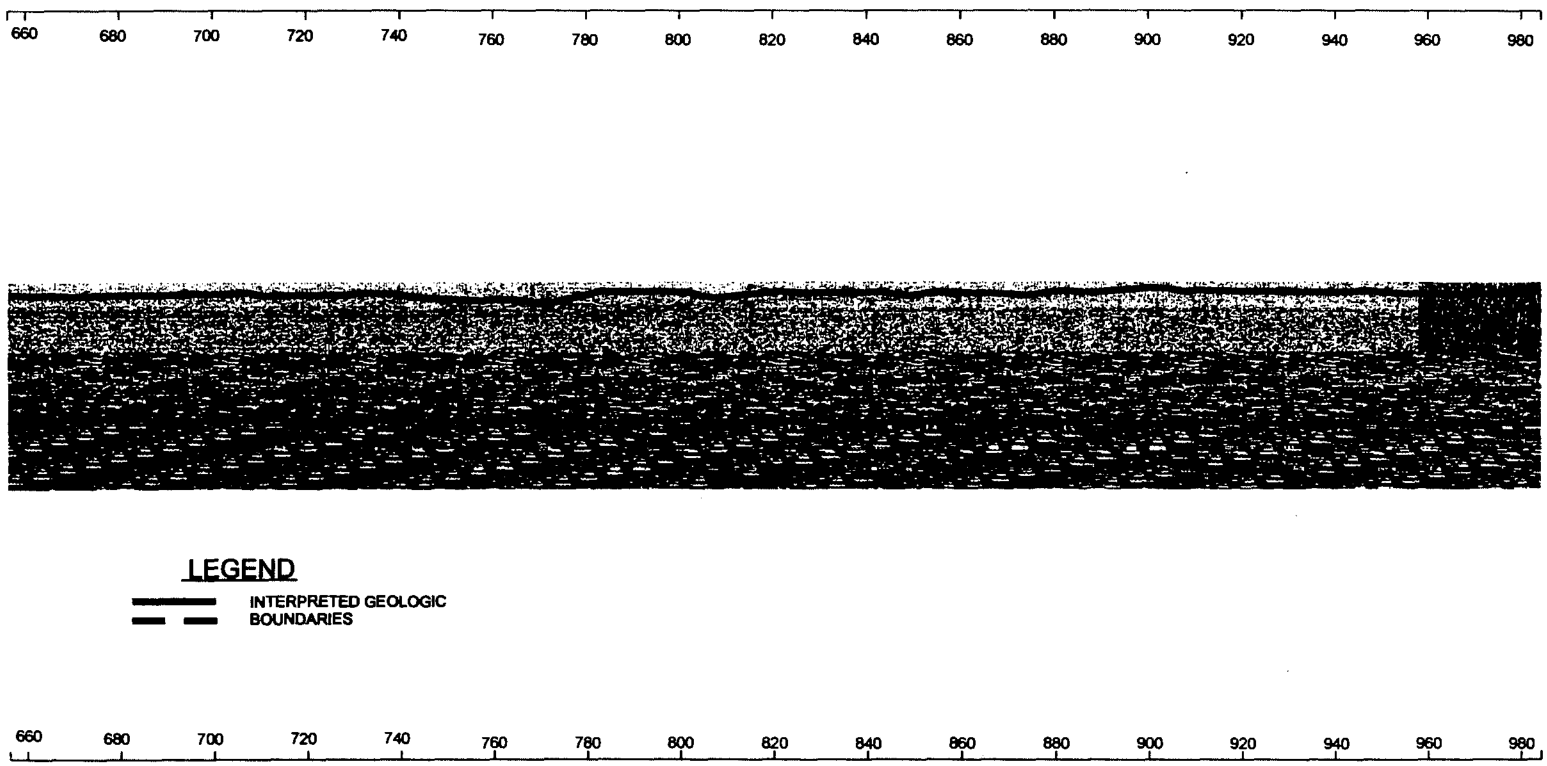
Ground Penetrating Radar Cross-Section A-A' (cont.)



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Davis Pit #4 Ravensdale, Washington	FIGURE A-3	FILE NO. 99.227	DATE November 1999

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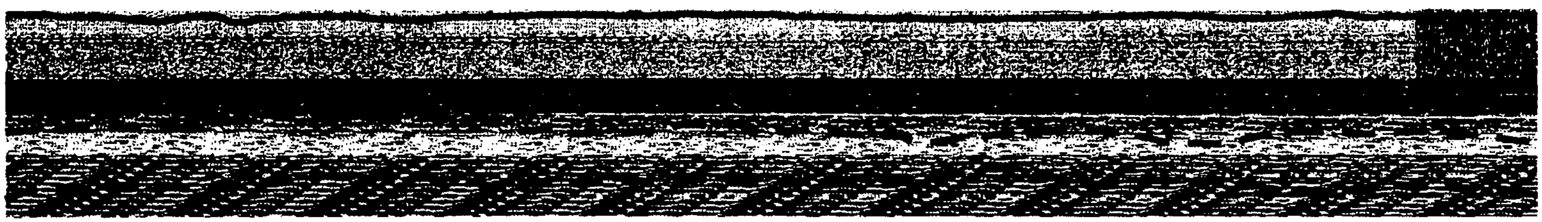
Ground Penetrating Radar Cross-Section A-A' (cont.)

1000 1020 1040 1060 1080 1100 1120 1140 1160 1180 1200 1220 1240 1260 1280 1300



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

1000 1020 1040 1060 1080 1100 1120 1140 1160 1180 1200 1220 1240 1260 1280 1300

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Davis Pit #4 Ravensdale, Washington	A-4	99.227	November 1999

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Ground Penetrating Radar Cross-Section A-A' (cont.)

1320 1340 1360 1380 1400 1420 1440 1460 1480 1500 1520 1540 1560 1580 1600 1620 1640

LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

1320 1340 1360 1380 1400 1420 1440 1460 1480 1500 1520 1540 1560 1580 1600 1620 1640

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Davis Pit #4 Ravensdale, Washington	A-5	99.227	November 1999

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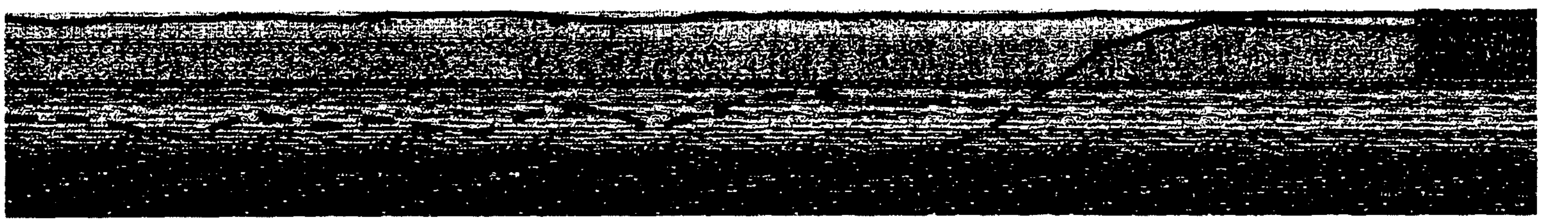
Ground Penetrating Radar Cross-Section A-A' (cont.)

1660 1680 1700 1720 1740 1760 1780 1800 1820 1840 1860 1880 1900 1920 1940 1960



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

1660 1680 1700 1720 1740 1760 1780 1800 1820 1840 1860 1880 1900 1920 1940 1960

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Davis Pit #4 Ravensdale, Washington	A-6	99.227	November 1999

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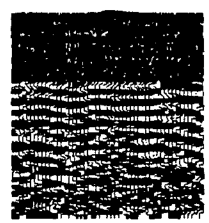
Ground Penetrating Radar Cross-Section A-A' (cont.)

1980 2000



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

Scale: 1" = 20'
Horizontal & Vertical

1980 2000

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Davis Pit #4 Ravensdale, Washington	A-7	99.227	November 1999

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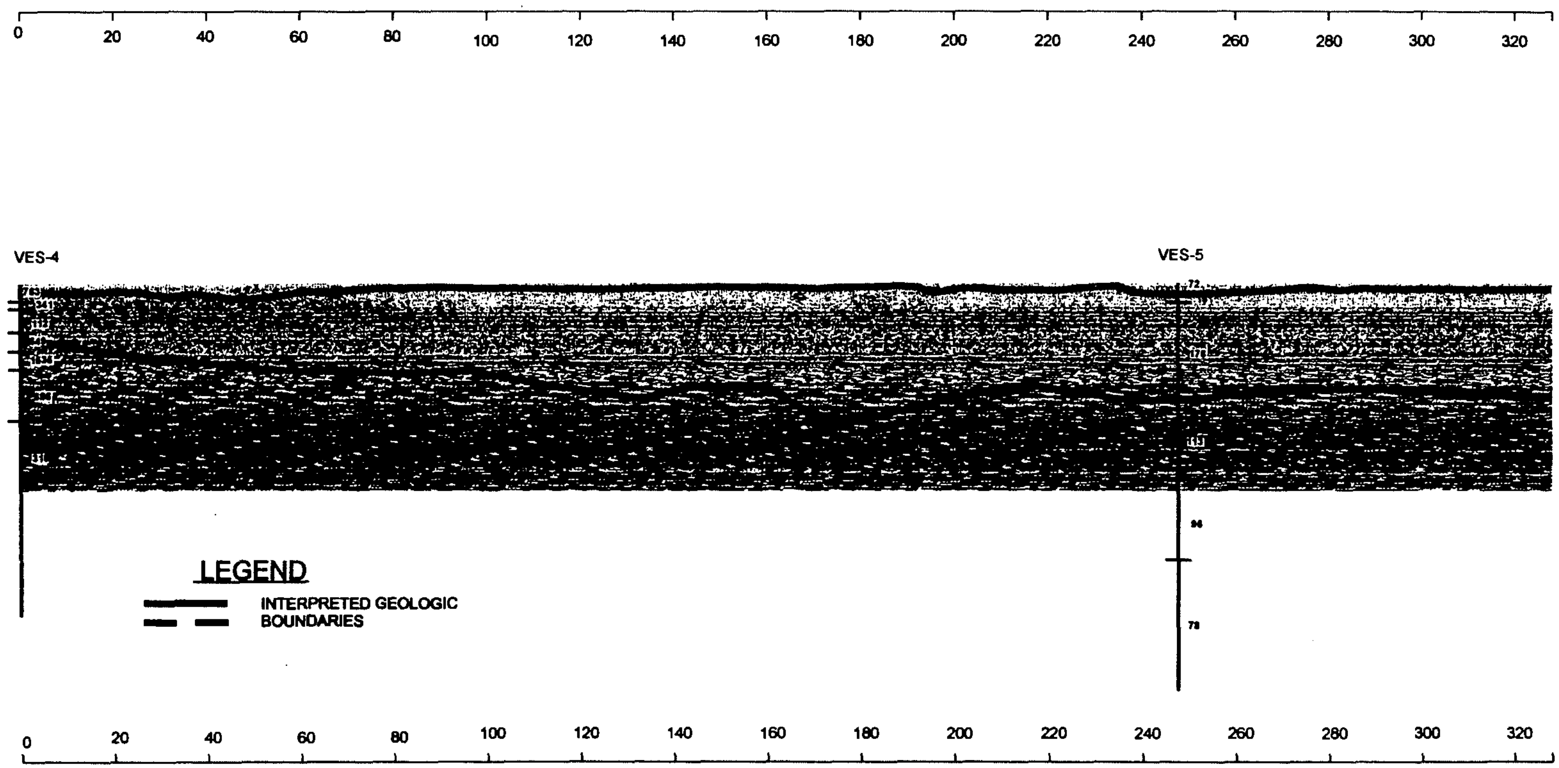
Ground Penetrating Radar Cross-Section B-B'



Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Lower Disposal Area Ravensdale, Washington	B-1	99.227	November 1999

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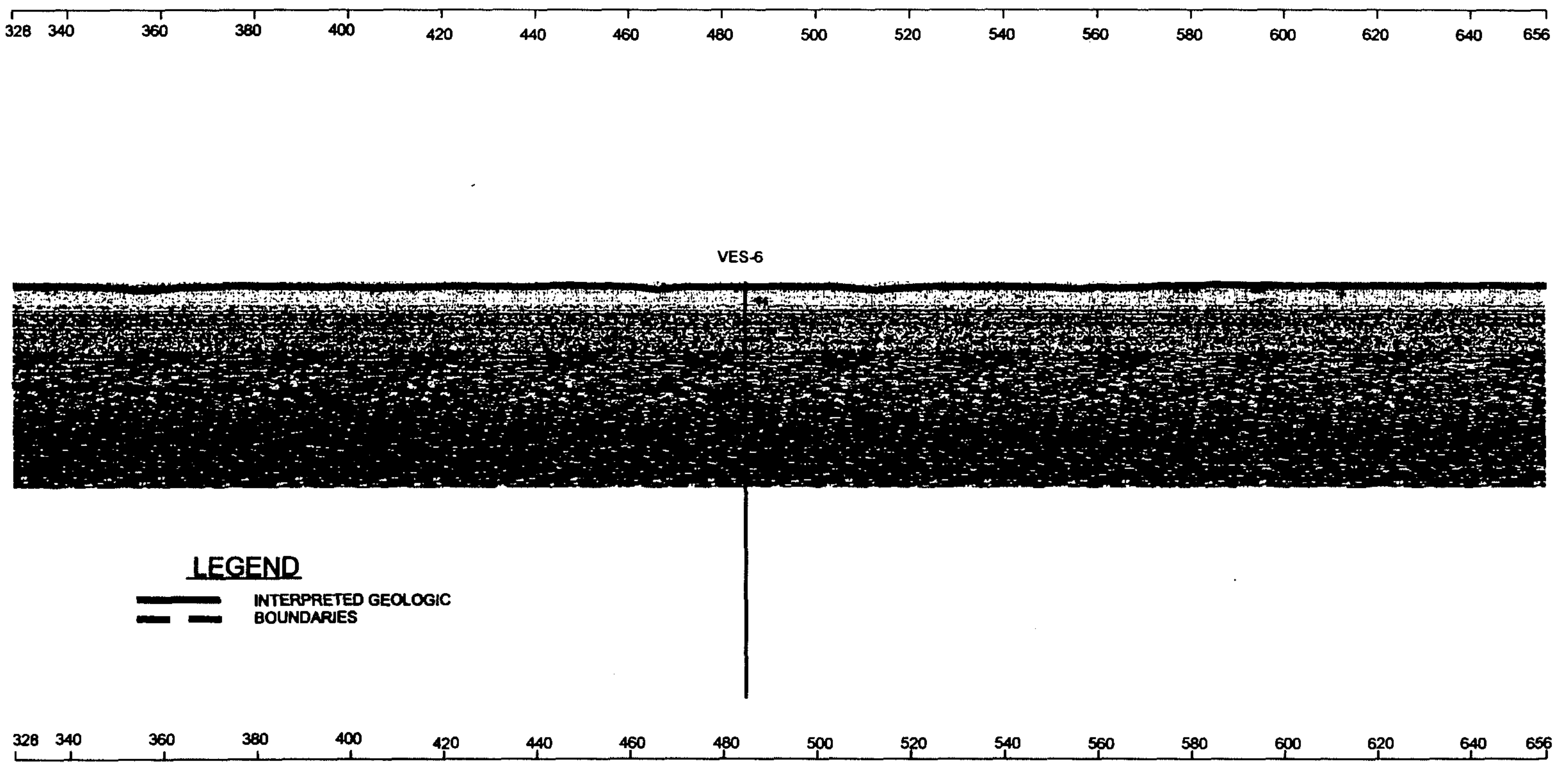
Ground Penetrating Radar Cross-Section B-B' (cont.)



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Lower Disposal Area Ravensdale, Washington	B-2	99.227	November 1999

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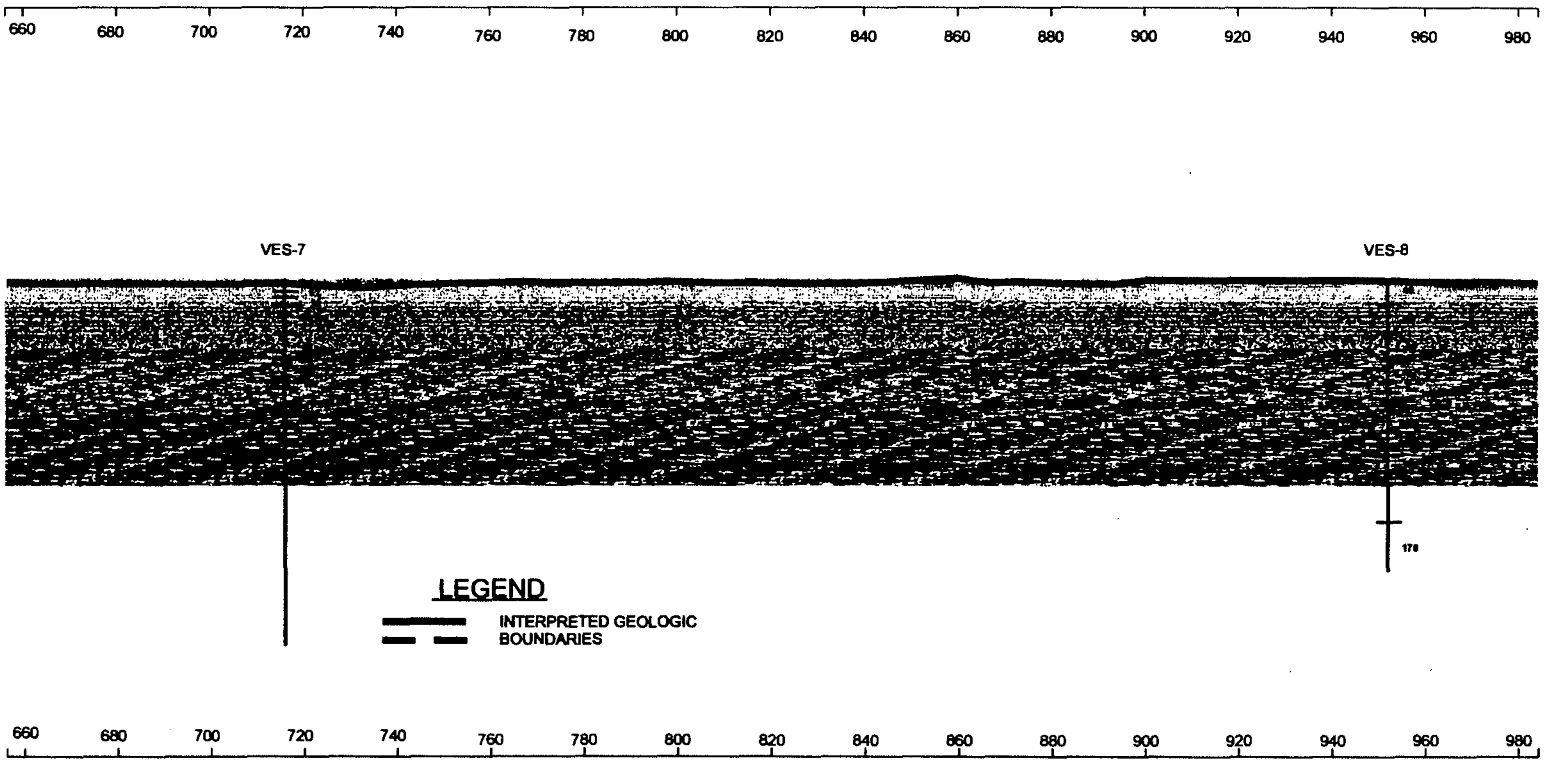
Ground Penetrating Radar Cross-Section B-B' (cont.)



Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Lower Disposal Area Ravensdale, Washington	FIGURE B-3	FILE NO. 99.227	DATE November 1999

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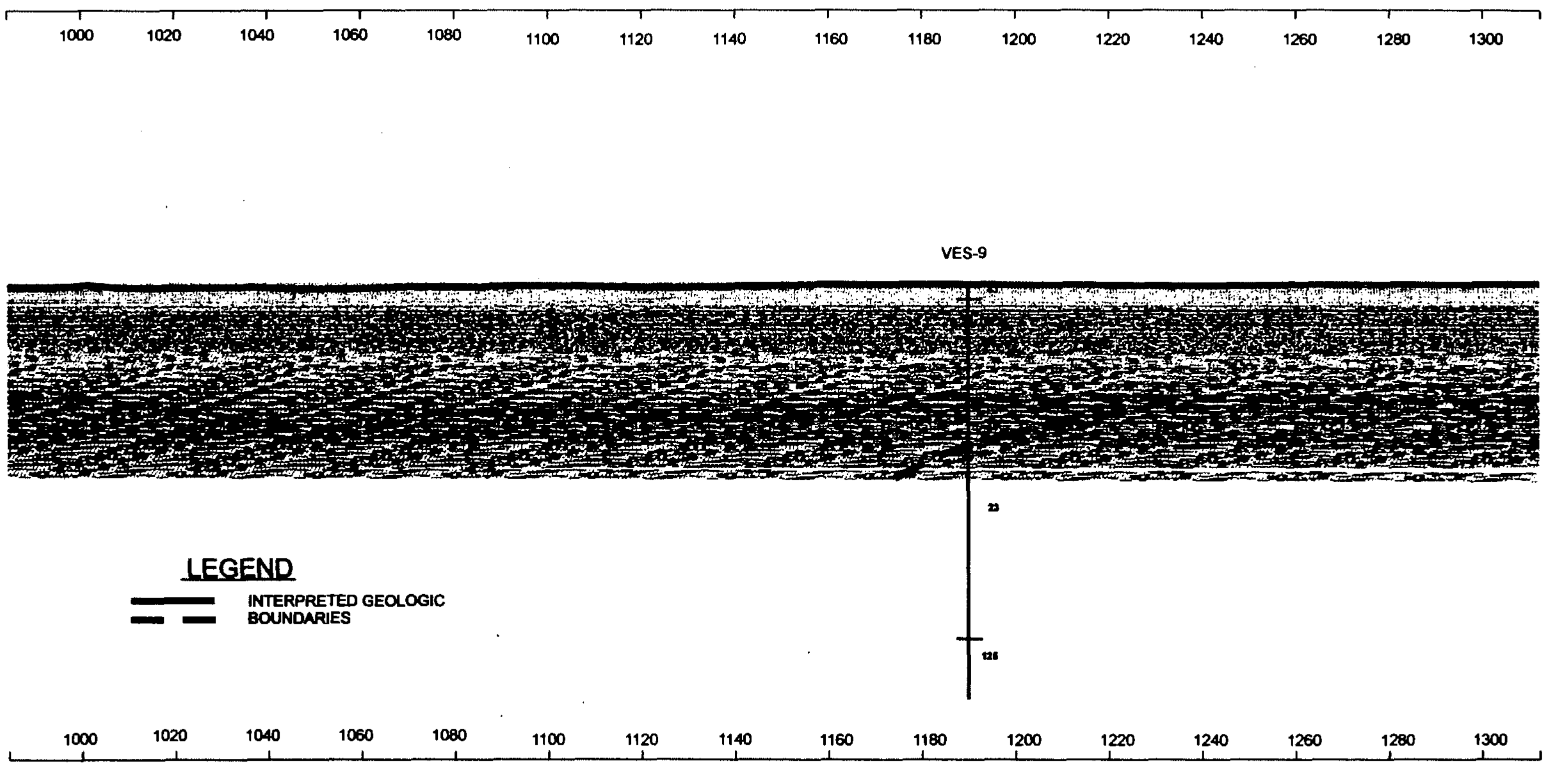
Ground Penetrating Radar Cross-Section B-B' (cont.)



Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Lower Disposal Area Ravensdale, Washington	FIGURE B-4	FILE NO. 99.227	DATE November 1999

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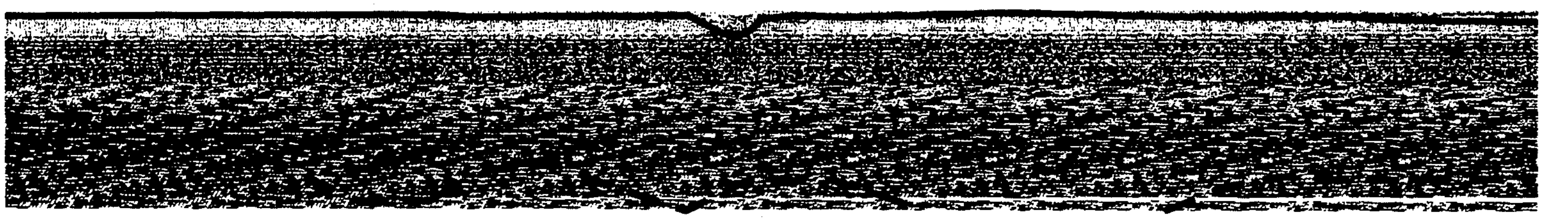
CONSTRUCTION & MINING

Ground Penetrating Radar Cross-Section B-B' (cont.)

1320 1340 1360 1380 1400 1420 1440 1460 1480 1500 1520 1540 1560 1580 1600 1620 1640



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

1320 1340 1360 1380 1400 1420 1440 1460 1480 1500 1520 1540 1560 1580 1600 1620 1640

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Lower Disposal Area Ravensdale, Washington	FIGURE B-5	FILE NO. 99.227	DATE November 1999

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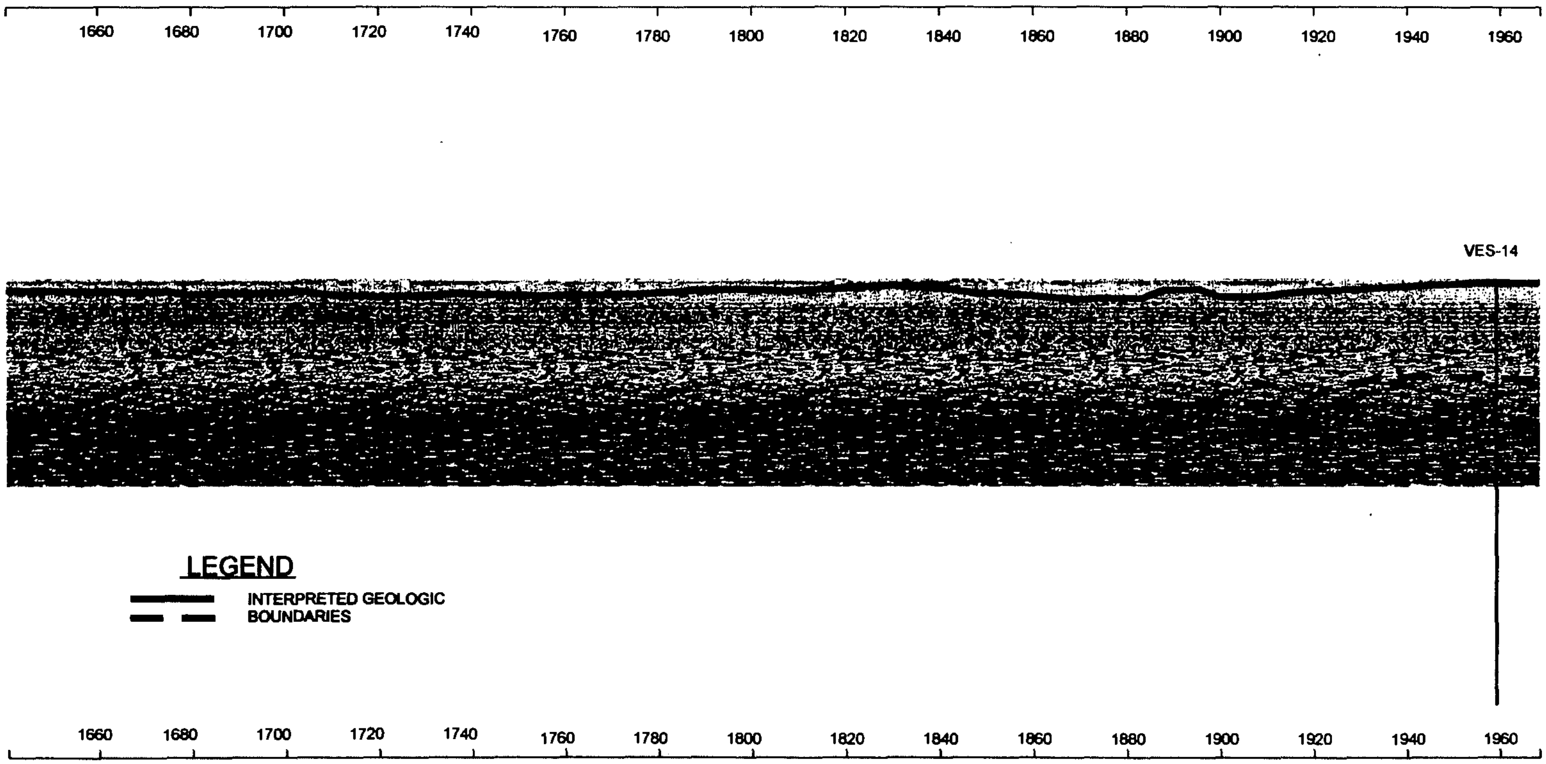
Ground Penetrating Radar Cross-Section B-B' (cont.)



Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Lower Disposal Area Ravensdale, Washington	B-6	99.227	November 1999

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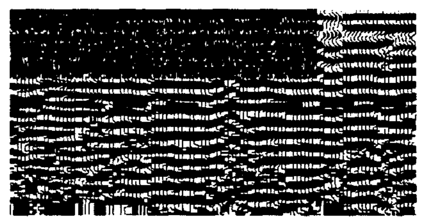
Ground Penetrating Radar Cross-Section B-B' (cont.)

1980 2000 2020 2040



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

Scale: 1" = 20'
Horizontal & Vertical

1980 2000 2020 2040

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Davis Pit #4 Ravensdale, Washington	B-7	99.227	November 1999

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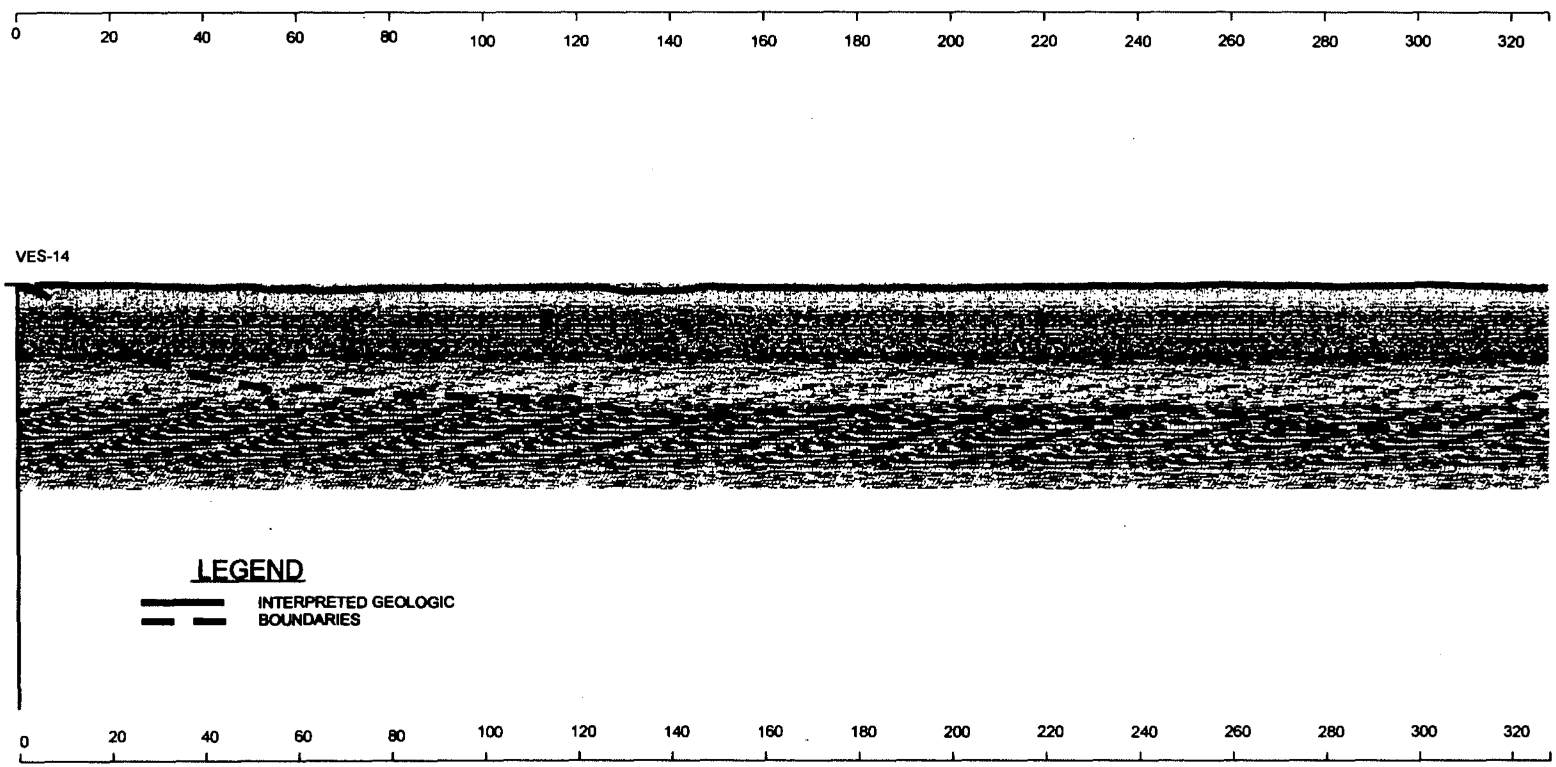
Ground Penetrating Radar Cross-Section C-C'



Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Lower Disposal Area Ravensdale, Washington	C-1	99.227	November 1999

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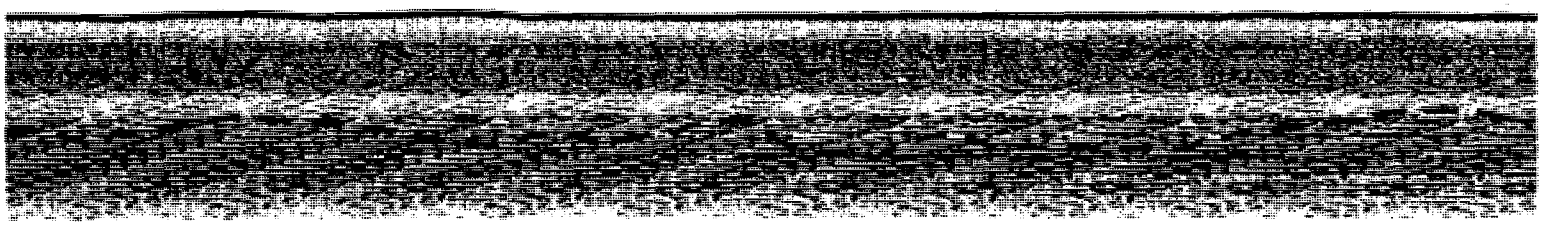
Ground Penetrating Radar Cross-Section C-C' (cont.)

328 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 656



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

328 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 656

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Lower Disposal Area Ravensdale, Washington	FIGURE C-2	FILE NO. 99.227	DATE November 1999

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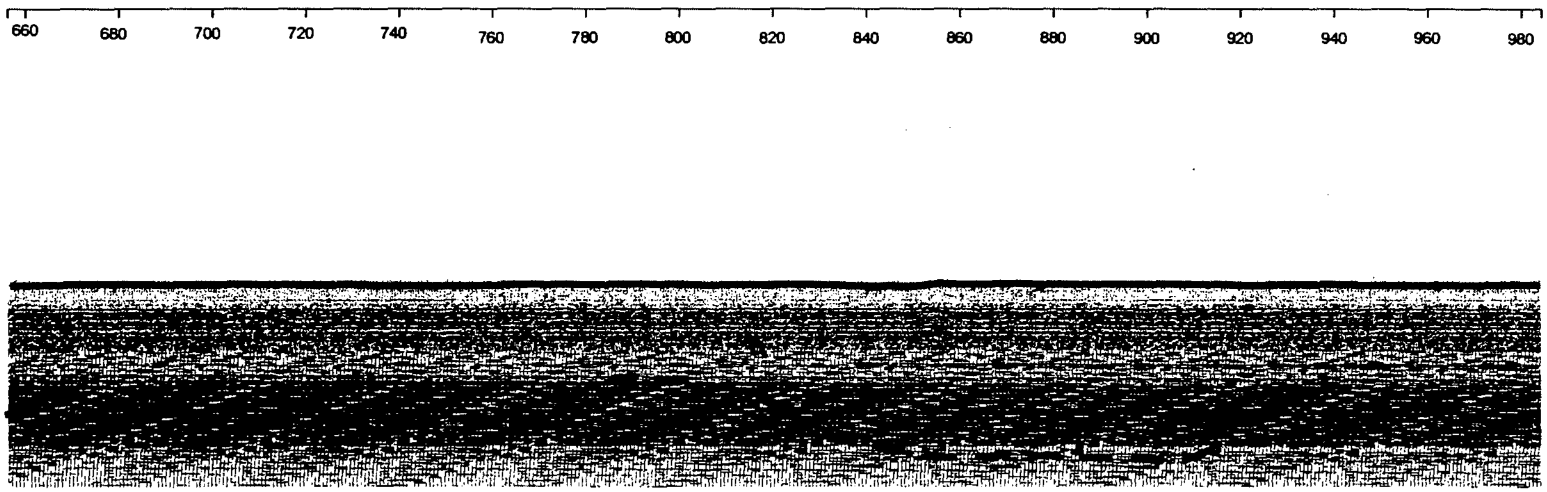
Ground Penetrating Radar Cross-Section C-C' (cont.)



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

660 680 700 720 740 760 780 800 820 840 860 880 900 920 940 960 980

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Lower Disposal Area Ravensdale, Washington	FIGURE C-3	FILE NO. 99.227	DATE November 1999

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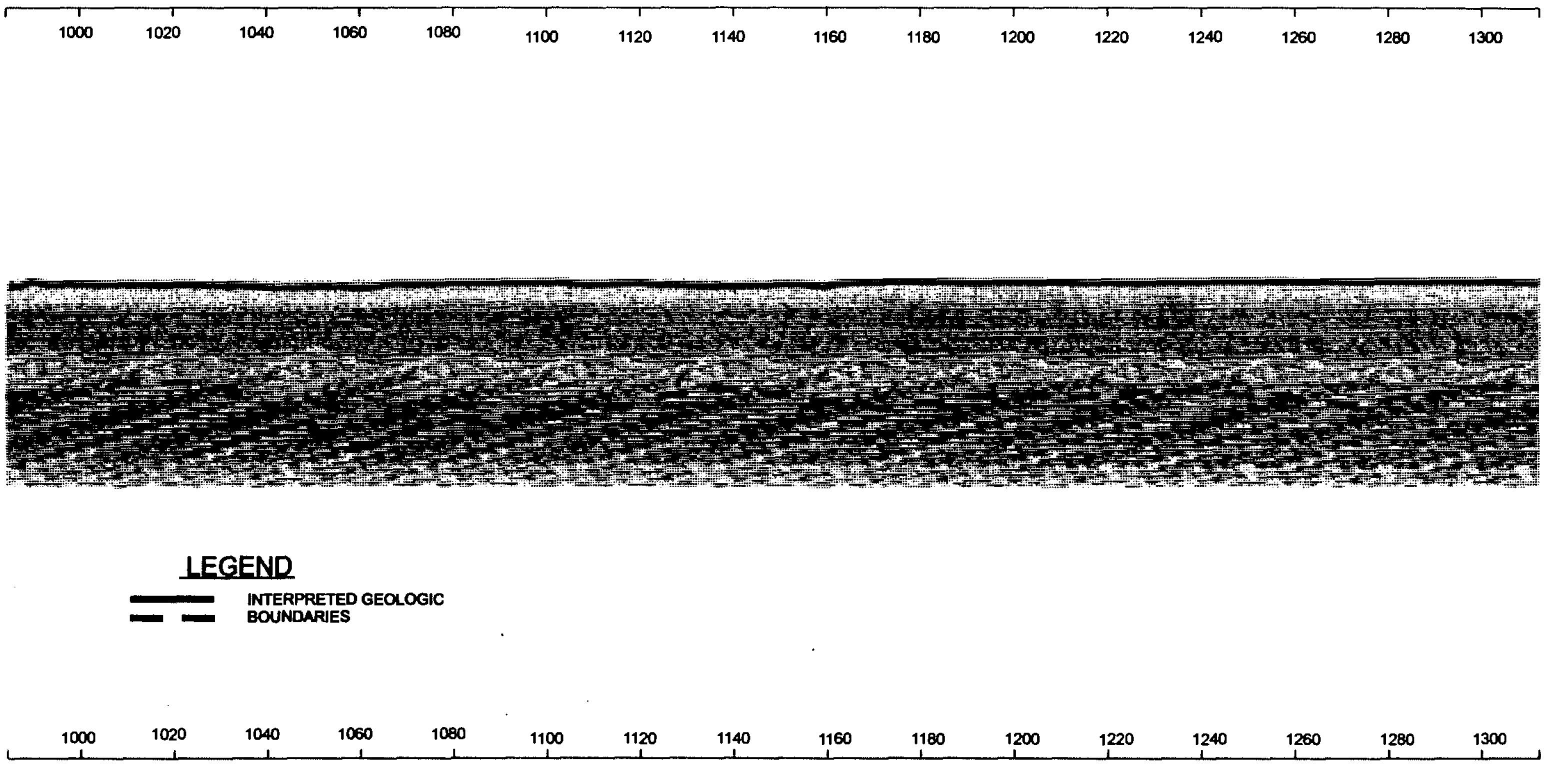
Ground Penetrating Radar Cross-Section C-C' (cont.)



Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

	FIGURE	FILE NO.	DATE
Lower Disposal Area Ravensdale, Washington	C-4	99.227	November 1999

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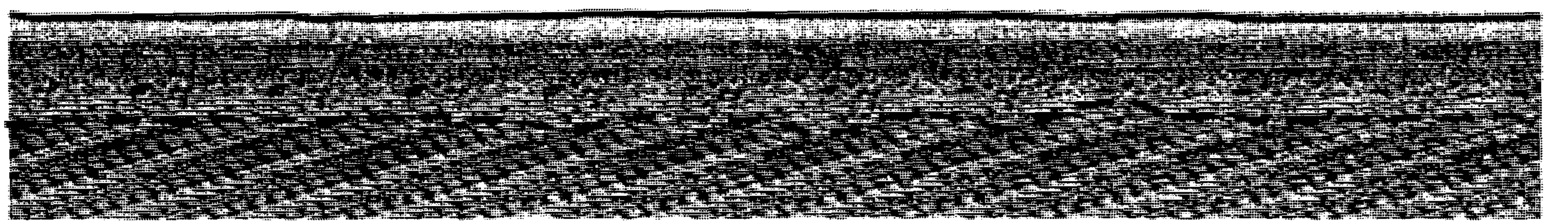
Ground Penetrating Radar Cross-Section C-C' (cont.)

1320 1340 1360 1380 1400 1420 1440 1460 1480 1500 1520 1540 1560 1580 1600 1620 1640



LEGEND

INTERPRETED GEOLOGIC BOUNDARIES

1320 1340 1360 1380 1400 1420 1440 1460 1480 1500 1520 1540 1560 1580 1600 1620 1640

Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Lower Disposal Area Ravensdale, Washington	FIGURE C-5	FILE NO. 99.227	DATE November 1999

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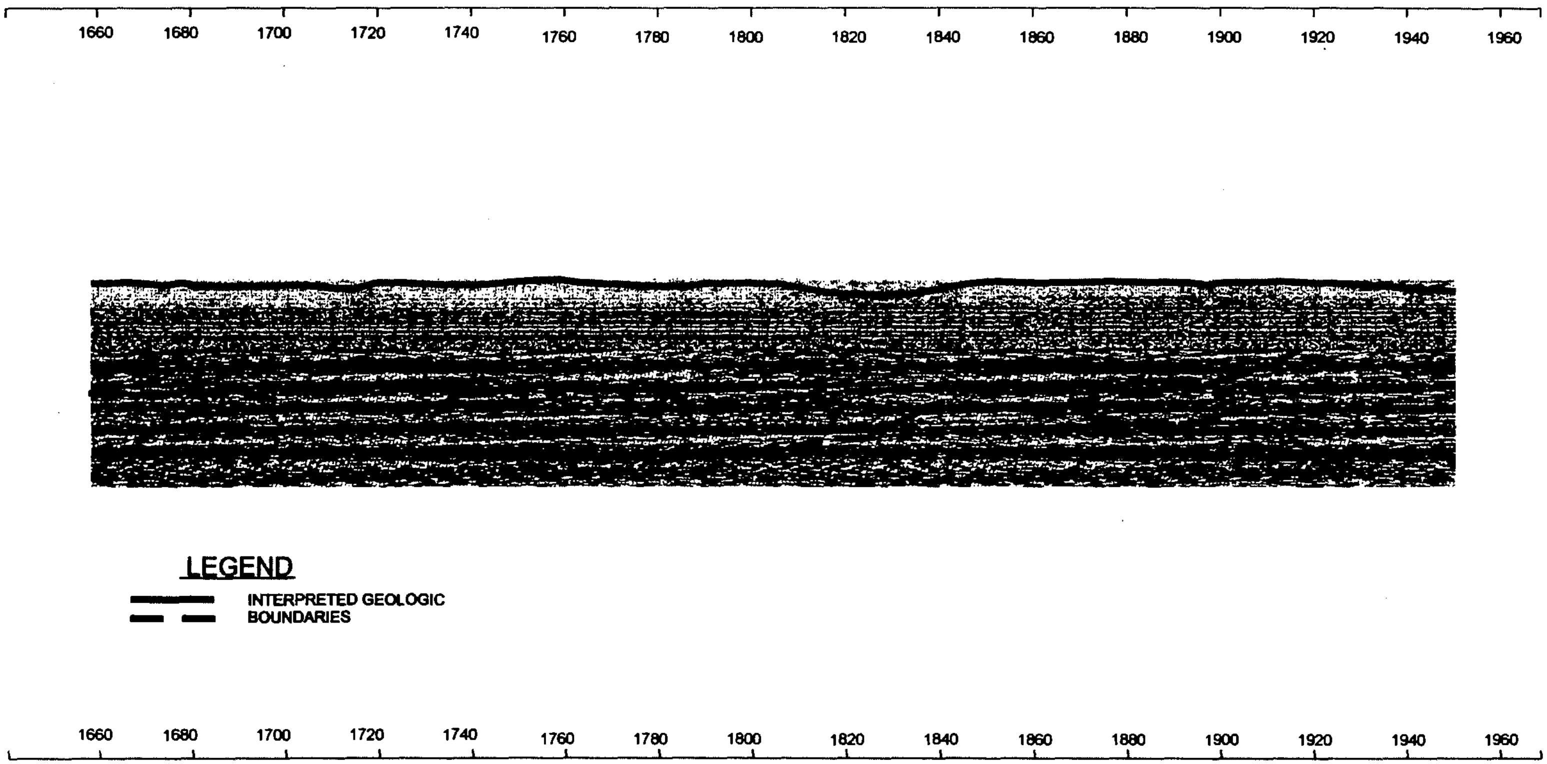
Ground Penetrating Radar Cross-Section C-C' (cont.)



Scale: 1" = 20'
Horizontal & Vertical

Note: From 0 to a depth of 15 feet, data was acquired with a 450 mHz antenna. From 15 feet to a depth of 44 feet, data was acquired with a 110mHz antenna. The locations of all features shown are approximate.

Lower Disposal Area Ravensdale, Washington	FIGURE C-6	FILE NO. 99.227	DATE November 1999

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Appendix 8:
Groundwater Monitoring Requirements & Sample DMRs

GROUNDWATER MONITORING PROCEDURES AND REPORTING

This Appendix contains the following documents:

1) Sample copy of groundwater reporting format currently used for monitoring at the Dale Strip Pit (DSP) resource protection wells. The documents provided consist of: Cover letter with distribution list; Field Data Form which reports sampling parameters in effect at the time groundwater samples were collected; and Data Summary Form which summarizes the laboratory results, together with pertinent field data.

2) The most current Standard Operating Procedure in effect for groundwater monitoring at the DSP, effective November, 1998.

3) A copy of an internal Department of Ecology memorandum, dated February 21, 1996, from Ecology groundwater specialist, Mr. Dennis Erickson, to Ecology project manager, Mr. Robert Stone. The memo contains a summary of Department's expectations for groundwater monitoring at the DSP, together with a graphic summary and interpretation of data collected in 1996 by TESI at the DSP.

Mr. Robert Stone, Hazardous Waste Specialist
Department of Ecology
Hazardous Waste Program
Northwest Regional Office
3190 160th Avenue SE
Bellevue, WA 98008-5452

April 18, 2000

Subject: Ravensdale CKD Pit: Transmittal of Groundwater Monitoring Data
First Quarter, 2000

Mr. Stone:

I am transmitting the Ravensdale groundwater monitoring results for the first quarter, 2000. If you have any questions concerning these matters, please do not hesitate giving me a call at 253.381.TESI (8374).

Sincerely Yours,

Steven D. High, IH/Environmental Scientist
Tacoma Environmental Sciences, Inc.

Attachment

cf.:

Ms. Jodie Earle, Corporate Environmental Affairs
Holnam, Inc.
P.O. Box 122
Dundee, MI 48131

Mr. John Melfi, Plant Manager
Reserve Silica Corporation
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Ravensdale, WA 98051

Mr. David C. Hickock
Senior Environmental Specialist
Seattle-King County Dept. of Public Health
999 3rd Avenue
Suite 700
Seattle, WA 98104

Mr. Bill Chapman, Attorney at Law
Preston Gates & Ellis
5000 Columbia Center
701 Fifth Avenue
Seattle, WA 98104-7078

Mr. Nick Ferris, Ph.D.
Vice President, Exploration
Reserve Industries
9555 Ralston Rd.
Arvada, CO 80002

Mr. Dennis Erickson, Hazardous Waste Spec.
Department of Ecology
Toxics Investigations Section
P.O. Box 4770
Olympia, WA 98504-7710

Letter 000418 DMRs

COPY

HOLNAM-RAVENSDALE
DATE: March 19, 2000

FIELD DATA FORM

Sampling Location	Sample Identification Numbers:	Field Duplicate ID Number	Rinsate Sample ID Number	TOC Elevation (ft)	BOC Elevation (ft)	Static Water Level (ft)	Purge Volume (ga, each)	pH (pH units)	Conductivity (mS)	Temp., (°C)
MW-1 Shallow	000319-MW1 Shallow			928.58	826.59	901.58 (-27.00)	12	7.328 7.301 7.311	0.775 0.813 0.922 1.042	9.9 10.7 11.0 11.3
MW-1 Deep	000319-MW1 Deep			928.83	680.02	853.75 (-75.08)	28	7.274 7.303 7.284	1.291 1.302 1.297	10.4 10.7 10.7
MW-2 Deep	000319-MW2			927.50	664.92	741.75 (-185.75)	12	7.422 7.299 7.255	0.185 0.428 0.455	11.2 10.2 10.9
MW-3 Shallow MW-3 Middle MW-3 Deep				927.00 927.00 927.00	883.88 819.76 677.46					
MW-4 Shallow MW-4 Middle				937.00 937.00	895.45 829.79					
MW-4 Deep	000319-MW4	000319-MW4 Dupe		937.00	706.55	911.29 (-25.71)	33	7.379 7.375 7.372	0.489 0.489 0.505 0.533	9.6 10.2 10.4 10.7
Mine Portal	000319-Portal			650 (est.)				7.375	0.682	9.3
Duplicate Rinsate										

ANALYTES: As, Ba, Cd, Pb, Zn (250 ml) ☐ Total Dissolved Solids (250 ml) ✓ Ca, Mg, Na (500 ml) ✓
(Dissolved; Sampled Annually, Analyze by ICP-MS, Collect rinsate sample also) Cl, Bicarb (500 ml) ✓

HOLNAM-RAVENSDALE
March18/19, 2000 (1st Quarter, 2000)

DATA SUMMARY FORM

Sampling Location	Sample ID	Rinsate Sample ID	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	** As (mg/L)	Ba (mg/L)	Cd (mg/L)	Pb (mg/L)	Zn (mg/L)	Bicarb. as $CaCO_3$ (mg/L)	Chloride (mg/L)	pH (su)	Cond. (mS)	Total Dissolved Solids (mg/L)
MW-1 Shallow	000319-MW1 Shallow		31	80	170						510	6.2	7.31	1.042	1,000
MW-1 Deep	000319-MW1 Deep		56	97	220						480	22	7.28	1.297	1,400
MW-2 Deep	000319-MW2		16	27	65						300	1.8	7.26	0.455	360
MW-3 Shallow	ns														
MW-3 Middle	ns														
MW-3 Deep	ns														
MW-4 Shallow	ns														
MW-4 Middle	ns														
MW-4 Deep	000319-MW4		14	37	82						390	1.4	7.37	0.533	450
MW-4 Deep/Dupe	000319-MW4 Dupe		15	37	84						390	1.4	7.37	0.533	450
Mine Portal	000319-Portal		41	39	62						380	6.7	7.38	0.682	630

ND = Not Detected at PQL

**NOTE: As, Ba, Cd, Pb and Zn are analyzed by ICP-MS
ns = Not Sampled This Round

COPY

Resource Protection Well & Surface Water Sampling

STANDARD OPERATING PROCEDURE
Effective: November 1998 (revision 3.0)

Prepared By: Tacoma Environmental Sciences, Inc.
109 Tacoma Avenue North, Tacoma, WA 98403

1.0 Purpose

The purpose of this standard operating procedure (SOP) is to provide uniform guidance for the collection of groundwater samples from resource protection wells at the Reserve Silica Corporation, Ravensdale, WA. The following chemical and physical analyses will be performed on groundwater samples during well purging or monitoring:

Depth of water
Depth of well measuring point
Volume of water
Purge volumes
pH
Temperature
Specific conductivity
Total dissolved solids
Calcium
Magnesium
Sodium
Chloride
Bicarbonate

The following dissolved metals will be sampled annually by ICP-MS:

Arsenic
Barium
Cadmium
Lead
Zinc

This SOP is applicable to groundwater samples collected in resource protection wells located at the Reserve Silica Corporation Dale Pit No. 4 at the Reserve Silica Sand Quarry at, Ravensdale, WA. The following wells will be sampled under this SOP:

MW-1S
MW-1D
MW-2 (background)
MW-4D

The following four additional wells were sampled in 1995 and will only be sampled under the present SOP on request by Ecology and with prior approval of Holnam, Inc.

MW-3S
MW-3M
MW-4S
MW-4M

Effluent from the former mine portal will be sampled for the same analytes and physical parameters as the groundwater (including annual sampling for dissolved metals). Applicable QA/QC protocols and procedures will be followed for the portal grab samples, including those for decontamination, sample handling and data recordation. Dissolved metals samples shall be filtered in the field.

The objective of the groundwater sampling methodology provided in this SOP is to deliver sample media, together with analytical results collected in the field, to the contract laboratory (Sound Analytical Services, Inc., Fife, WA) which are as representative of groundwater from the respective zone of influence at each of the specified wells as is practicable, given the current state of knowledge and limitations imposed by project constraints.

2.0 Requirements/Equipment

The following sampling equipment is approved for this sampling procedure:

Solinist, Keck or Slope Indicator water level indicator
PVC or Teflon bailer, hand-operated
Stainless-steel/Teflon well pump, 2 inch diameter (e.g. Grundfos RediFlo-2)
110 volt, 2500 Watt (min), 16 amp (min), generator
Teflon-coated pump leads and PVC tubing
Orion pH and Temperature meter
Corning or YSI Conductivity meter
Pre-cleaned, pre-labeled sample containers provided by the laboratory

Corning hand-operated vacuum pump
Eagle-Pitcher pre-cleaned, pre-labeled 0.45 micron nitrocellulose filter system
Engineering tape rule, marked in hundredths of feet
Deionized water supplied by contract laboratory
Alconox detergent; decontamination containers (5 Ga); decontamination brushes
Pre-printed, pre-labeled field sampling forms
Steel wastewater storage drums, 55 ga

3.0Procedure

3.1 Health & Safety

Prior to conducting the sampling procedures outlined in this section field monitoring personnel shall have read and discussed the Site Health and Safety Plan (the Plan) for this project. All field personnel will be equipped with Modified Level D personal protective equipment, as set forth in the Plan. This Plan requires persons conducting groundwater monitoring to wear cotton or Tyvek coveralls, eye protection and steel-toe safety shoes/boots.

3.2 Training

All personnel participating in field activities will have completed training consistent with the Occupational Safety and Health Act of 1970 (29 U.S.C. Sec. 651 et seq.) and the Washington Industrial Safety and Health Act (chapter 49.17 RCW) and regulations and guidelines promulgated by OSHA and Washington State Department of Labor and Industries pursuant to these acts. At least one person engaged in onsite work will be required to have had first aid and CPR training. The training shall cover the following topics, in addition to prescribed in-the-field experience:

- ❑ hazardous waste health & safety procedures
- ❑ hazardous waste primer
- ❑ toxicology
- ❑ medical surveillance
- ❑ physical and chemical properties of hazardous materials
- ❑ risk assessment & hazard control
- ❑ site health & safety planning
- ❑ safety & fire protection
- ❑ respiratory protection
- ❑ instrumentation
- ❑ respirator fit testing
- ❑ protective clothing
- ❑ levels of contamination
- ❑ field training exercise

3.3 Maintaining Well and Aquifer Integrity

All sampling and monitoring equipment will be decontaminated in accordance with Section 3.7 prior to conducting sampling/monitoring activities at a well. This procedure is intended to minimize the risk of cross contamination between wells as well as contamination introduced due to loading/unloading of equipment and transit between wells.

3.4 Well Purging & Determination of Stable Conditions

The depth to water and well depth will be measured to the nearest 0.01 feet. Water levels will be measured and recorded at all wells in each well cluster. The water column volume will be calculated at each well before pumping commences. A minimum of three well volumes will be removed (purged) prior to sampling. Temperature, pH and specific conductivity measurements will be recorded from pump water collected following the third purge and recorded. Additional purges will be made if post-purge measurements vary by more than ten (10%) from sample measurements for these parameters.

3.5 Sampling & Field Measurement

Sampling for chemical analytes that will be analyzed by the contracting laboratories and field measurement of temperature, pH, and specific conductivity will commence following the determination that stable aquifer conditions are being measured. Sample volumes for chemical analytes will be withdrawn using a stainless-steel/Teflon submersible pump, re-usable Teflon bailer or disposable PVC bailer. One set of samples will be collected for each analyte to be determined. Samples will be collected in pre-cleaned, pre-labeled sample bottles.

3.6 Documentation & Chain-Of-Custody

All data will be recorded on pre-printed field data forms, Attachment 1. Chain-of-custody forms will be completed in the field, as samples are collected. Additional notes will be recorded in the TESI field logs which have pre-numbered pagination. Original documentation will be kept in a project file at TESI.

3.7 Decontamination

All sampling equipment will be decontaminated using Alconox® in a deionized water solution, followed by double rinse with deionized water. Decontamination of equipment will be completed following the completion of sampling at each well and prior to commencing sampling at each subsequent well (see Section 3.3, above). The submersible pump (and attached lines); the mechanical bailer (and attached lines) and the containers used to temporarily hold sampling apparatus at each well, will be decontaminated by these procedures before moving to the next well location, and prior to initiating sampling at the next well.

4.0 Related Information

Site Health & Safety Plan, 1992, TESI

Compendium of ERT Groundwater Sampling Procedures. 1991. U.S. EPA, Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/P-91/007

5.0 Specific QC Requirements

Equipment decontamination procedures are designed to eliminate the introduction of contaminants that may arise from contaminated equipment and work surfaces by sampling team personnel. Rinsate samples are collected and analyzed to demonstrate that procedures yield rinsate free from contamination. Rinsate samples shall be collected only for those sampling events where heavy metals (As, Ba, Cd, Pb and Zn) are being sampled. Procedures are designed to show that the decontamination methods are acceptable. One rinsate sample will be collected from each set of samples for heavy metals (= per year, randomly selected). One field duplicate sample set (i.e. for one monitoring well or portal sampling event) will be selected at random every quarter. Thus, field duplicate samples will be collected at a 20 percent frequency rate.

6.0 Responsibilities and Qualifications

The principal investigator, TESI, is responsible for assuring that equipment decontamination and health and safety protocol are conducted according to this procedure and other procedures referenced herein. The principal investigator may designate qualified project personnel to complete this procedure. Staff members are responsible for understanding the activities assigned to them, including any quality assurance requirements associated with field activities.

7.0 Approvals

I have personally read and do understand this Standard Operating Procedure. A copy has been provided to me as evidence that I am trained and competent to implement this SOP.

Signature	Printed Name	Date
Signature	Printed Name	Date
Signature	Printed Name	Date

DEPARTMENT OF ECOLOGY

February 21, 1996

FEB 26 1996

TO: Bob Stone
Hazardous Waste and Toxics
Reduction Program
NWRO

FROM: Denis Erickson
Environmental Investigations and
Laboratory Services Program

SUBJECT: **Holnam Pit Groundwater Monitoring Data**

At your request I have added the most recent groundwater monitoring results (December 1995) from the Holnam Pit at Ravensdale to our ENVIS database. These are the first samples obtained using the new sampling plan and the sampling services of Tacoma Environmental Services, Inc.

Indicator Parameters

The results for total dissolved solids (TDS), specific conductance, calcium and chloride for February 1985 through December 1995 are shown in Figures 1 through 8. Figures 1, 3, 5, and 7 show the results for the deep wells (MW1D, MW2, MW3D, MW4D) and the portal. Figures 2, 4, 6, and 8 show the results for the shallow (MW1S, MW3S, MW4S) and intermediate (MW3M and MW4M) wells. The results are discussed below.

TDS (Figures 1 and 2) had not been tested at site wells since May 1989. Based on the December results, TDS concentrations have increased substantially at MW1D, MW1S, and the portal since 1989 and now exceed the Secondary Maximum Contaminant Level (MCL) of 500 mg/L. Secondary MCLs are based on aesthetics such as taste, odor, or discoloration rather than potential adverse human health effects. TDS concentrations in the other wells appear to be similar to pre-1989 levels.

Specific conductance readings (Figures 3 and 4), and calcium (Figures 5 and 6) and chloride (Figures 7 and 8) concentrations have increased substantially since 1985 in wells MW1D, MW1S, and the portal. As described in previous memoranda, these increases are due to leakage from the pit. Specific conductance readings continue to exceed the Secondary MCL (900 micromhos/cm) at MW1D, MW1S, and the portal. The Secondary MCL for chloride is 250 mg/L and all concentrations from the monitoring network are well below 250 mg/L. There is no Secondary MCL for calcium.

COPY

Note the abrupt increases of specific conductance, calcium, and chloride in most of the wells compared to the last sampling round in July 1995. Because these parameters did not increase similarly at the portal, I believe the increases are probably related to sampling procedures, possibly due to more thorough purging prior to obtaining the well samples.

Trace Metals

The trace metals results are listed in Table 1. Barium was detected in all wells at concentrations ranging from 0.032 to 0.170 mg/L. The highest concentration (0.170 mg/L) was detected at three wells, one of which was MW2, the well used to define ambient groundwater quality. The occurrence of barium is probably natural and not related to leaching from the pit. Zinc was detected in one well but the measurement is qualified ("B") due to laboratory blank contamination.

The reporting limits for Holnam's trace metals results are listed in Table 2 and seem to be high. For comparison, I have listed in Table 2 the reporting limits routinely attained at Ecology's Manchester Laboratory using the same test method (Inductively Coupled Argon Plasma) as Holnam's contract laboratory. With the exception of barium, the Manchester Laboratory reporting limits are substantially lower than the reporting limits for the December samples. Lower reporting limits are desired because they will provide early detection of metals migration to groundwater, were it to occur.

Table 2. Trace metals reporting limits.

Analyte	Holnam December 1995	Manchester Laboratory
Arsenic	0.150	0.030
Barium	0.005	0.005
Cadmium	0.020	0.002
Lead	0.050	0.020
Zinc	0.020	0.003

I agree JCP 2/25

Recommendations

1. Quarterly monitoring as described in the Holnam's sampling plan should be implemented at the portal and wells MW1S, MW1D, MW2, and MW4D.

2. Trace metals reporting limits for subsequent sampling events should be equal to or less than those listed in Table 2 under the column heading "Manchester Laboratory".

If you have questions about these data or this memorandum, please call me at (360) 407-6767.

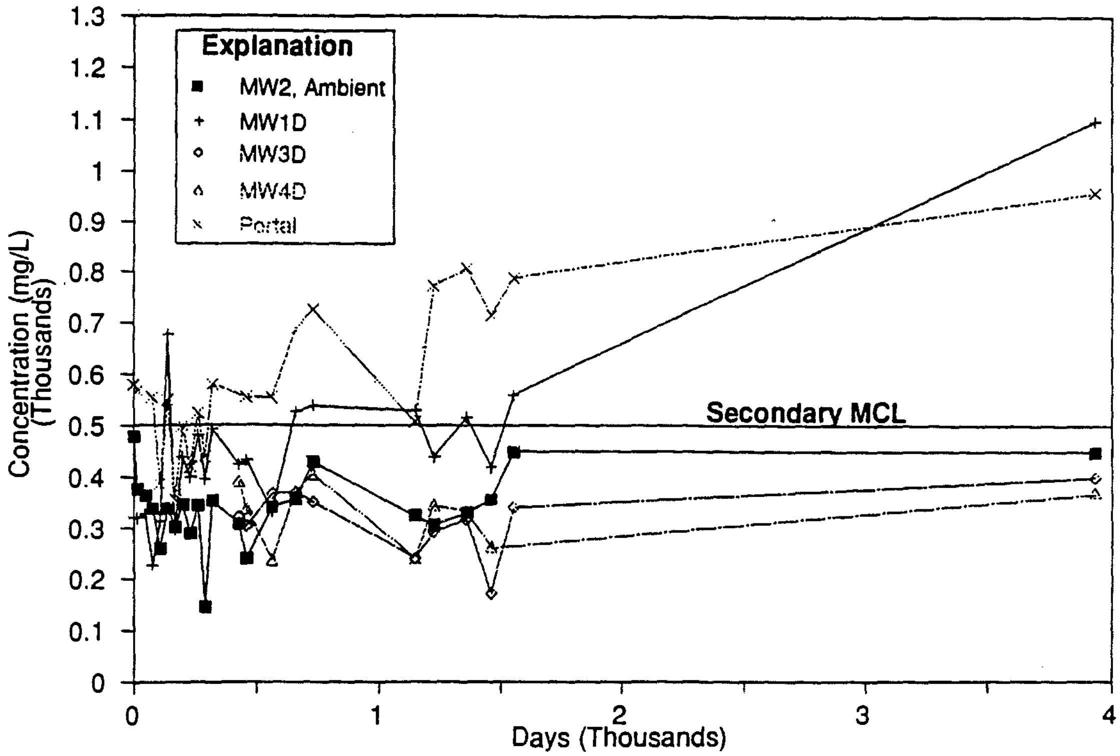

Figure 1. Total Dissolved Solids, Deep Wells and Portal.

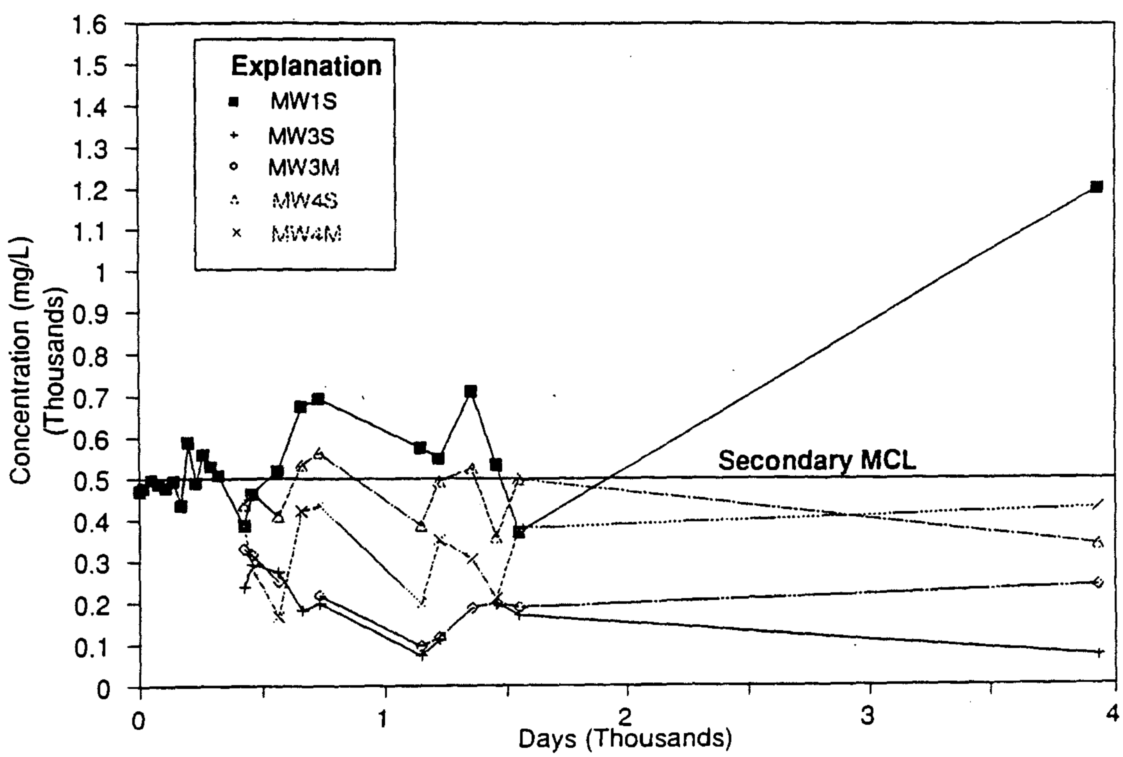

Figure 2. Total Dissolved Solids, "S" and "M" Wells.

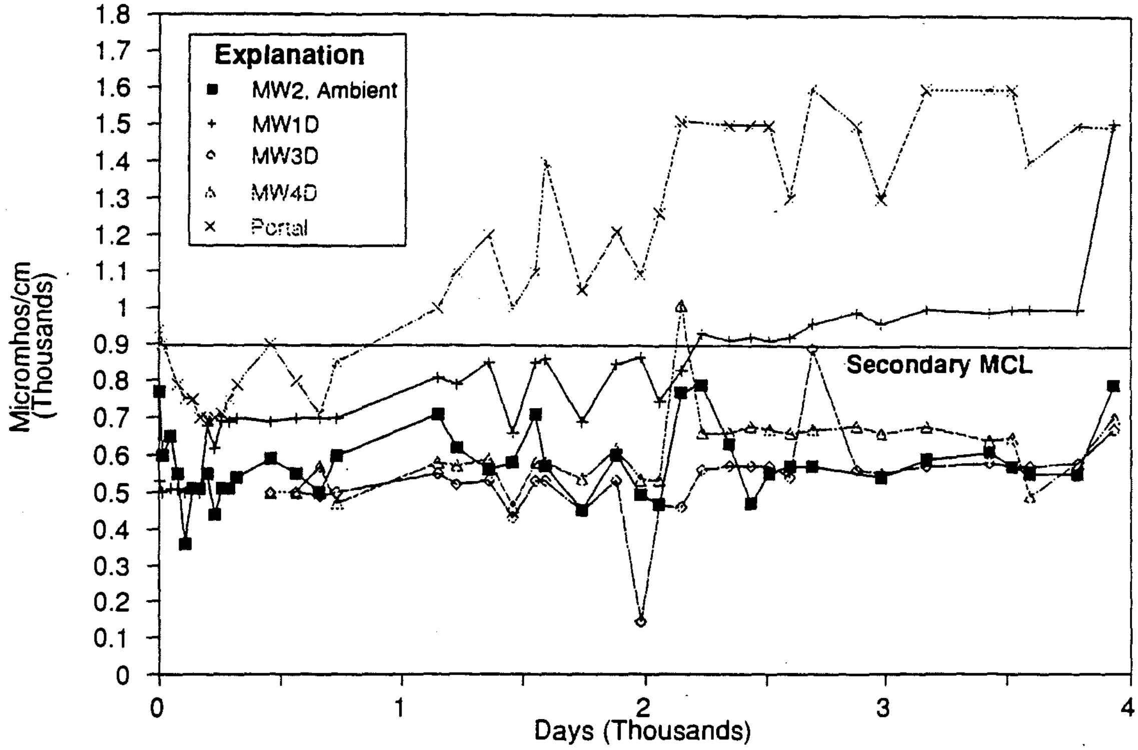

Figure 3. Specific Conductance, Deep Wells and Portal.

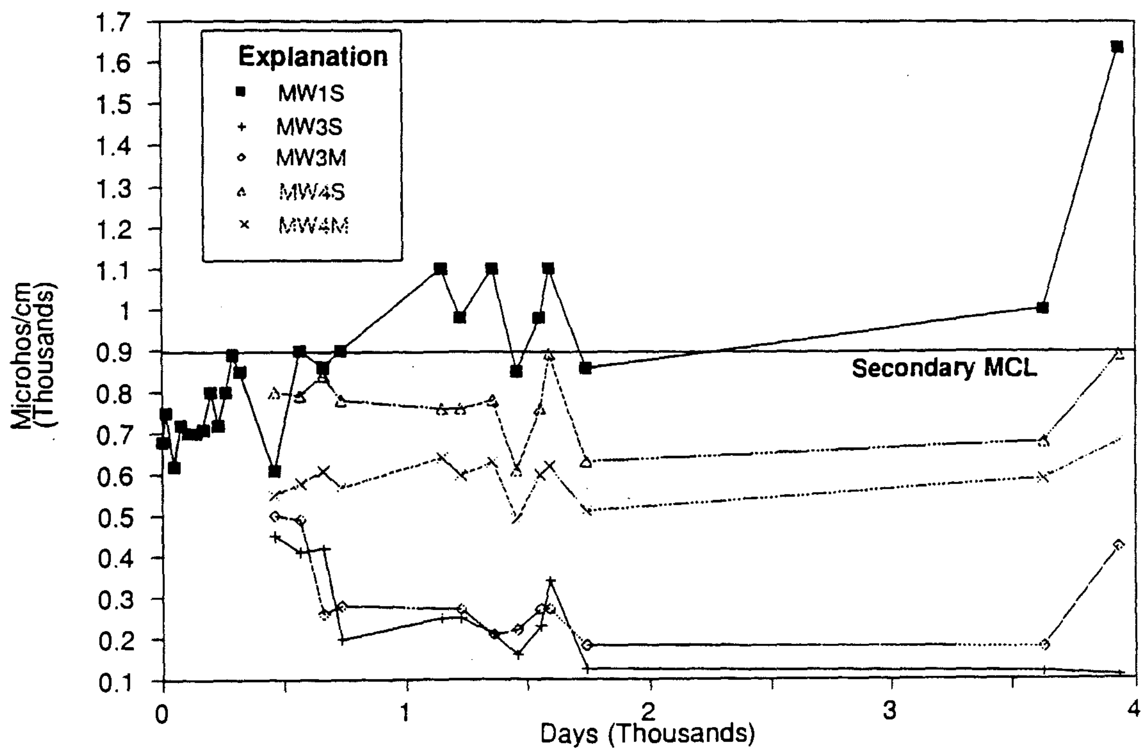

Figure 4. Specific Conductance, "S" and "M" Wells.

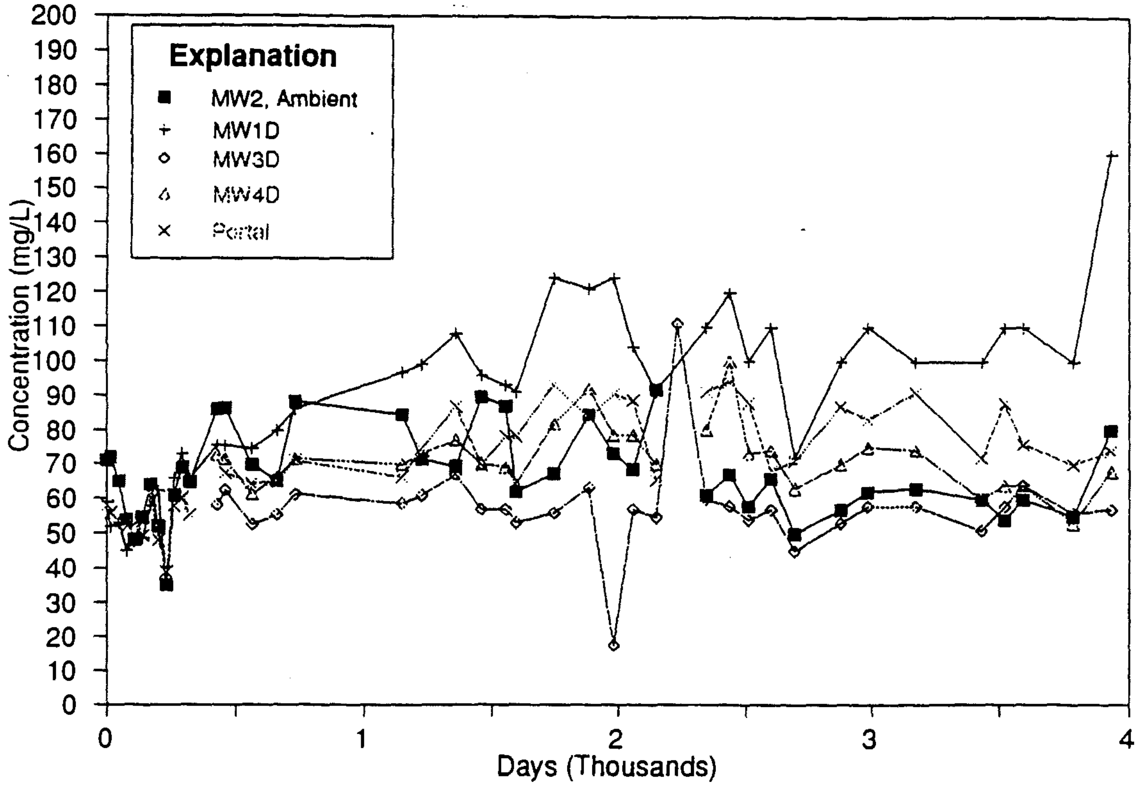

Figure 5. Holnam Pit, Calcium, Deep Wells and Portal.

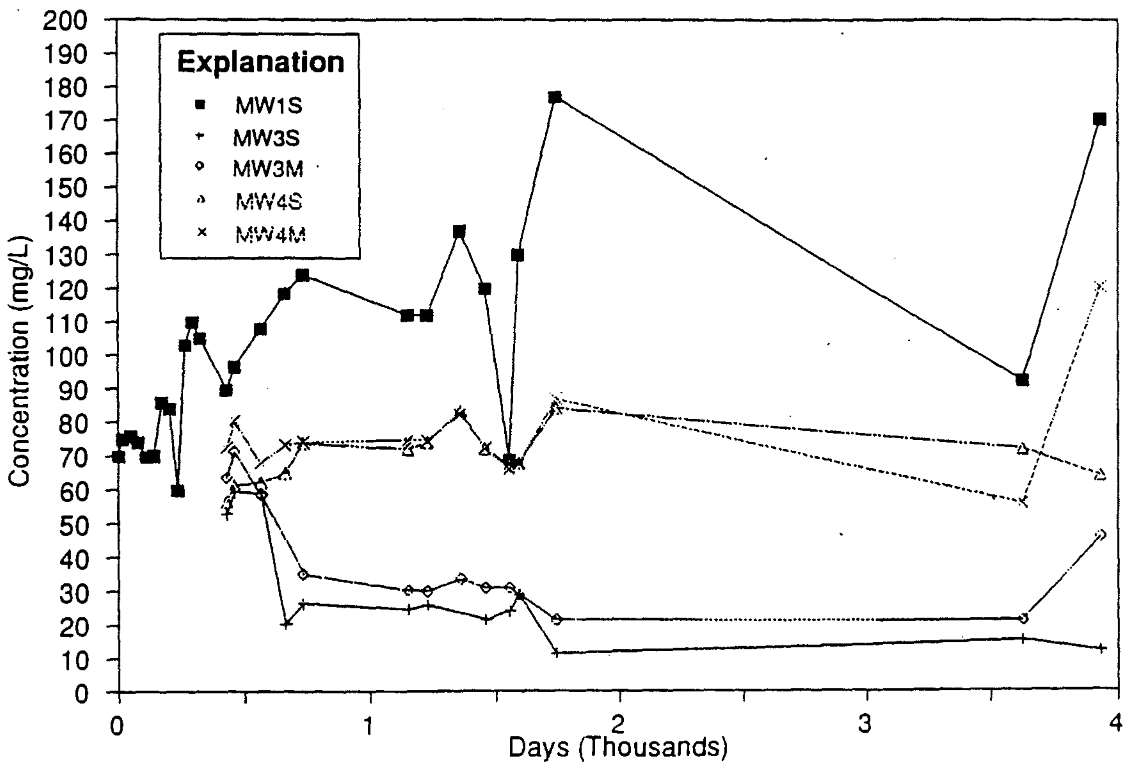

Figure 6. Holnam Pit, Calcium, "S" and "M" Wells.

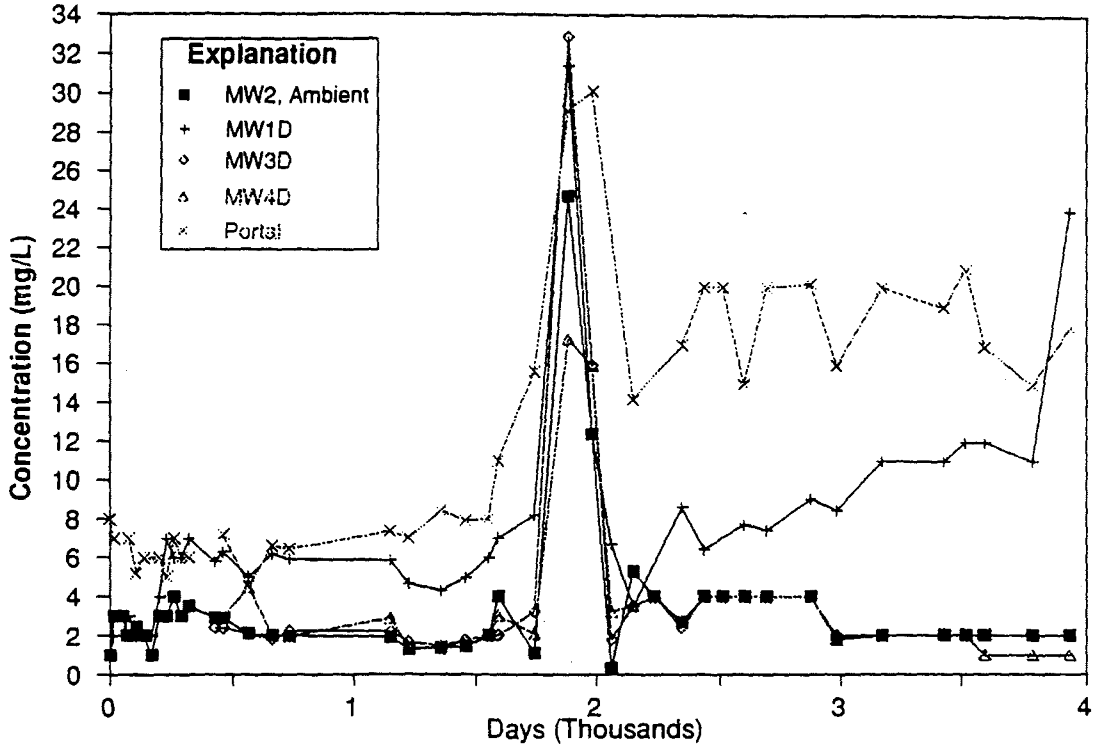

Figure 7. Chloride, Deep Wells and Portal.

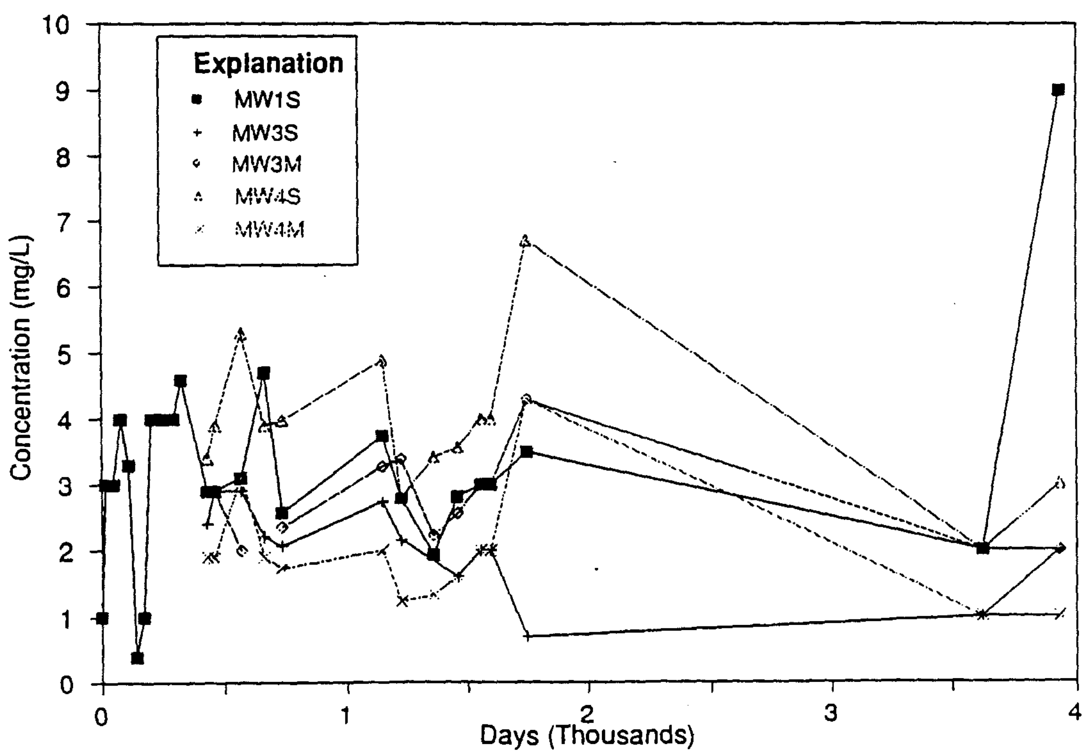

Figure 8. Chloride, "S" and "M" Wells.

Table 1. Holnam Pit Trace Metal (Dissolved) Results, December 1995 (Units= mg/L).

Site ID	Arsenic	Barium	Cadmium	Lead	Zinc
MW1D	0.15 U	0.083	0.02 U	0.05 U	0.02 U
MW1D (Duplicate)	0.15 U	0.09	0.02 U	0.05 U	0.02 U
MW1S	0.15 U	0.074	0.02 U	0.05 U	0.02 U
MW2	0.15 U	0.17	0.02 U	0.05 U	0.02 U
MW3D	0.15 U	0.17	0.02 U	0.05 U	0.02 U
MW3M	0.15 U	0.063	0.02 U	0.05 U	0.02 U
MW3S	0.15 U	0.032	0.02 U	0.05 U	0.02 U
MW4D	0.15 U	0.091	0.02 U	0.05 U	0.02 U
MW4M	0.15 U	0.17	0.02 U	0.05 U	0.02 U
MW4S	0.15 U	0.11	0.02 U	0.05 U	0.02 B
Portal	0.15 U	0.085	0.02 U	0.05 U	0.02 U

U= Analyte not detected above the listed value.

B= Analyte detected in laboratory blank.

Appendix 9:
Use of Onsite Materials as Capping Material

USE OF ON-SITE MATERIALS AS CAPPING MATERIAL

On-site soils may be available for use as capping materials. Testing and analysis of these soils is necessary to ascertain their suitability for this purpose. Soil suitability testing should be initiated to determine the types of soils present and their quantities. Based on our conversations with John Melfi of Reserve Silica and visual examination of surface soils in one area, the soils are expected to be weathered and unweathered glacial till above bedrock in the proposed source area.

Sufficient test pits should be excavated to determine the lateral extent and quality of the soils above bedrock in the proposed new mine area that Reserve Silica wishes to open up beginning this year. Glacial soils can vary considerably over short distances and the soils may be suitable in some areas, but not in others. The ultimate test of these soils regarding their suitability will be if they are near optimum moisture content for compaction and if they contain sufficient fines to meet the hydraulic conductivity specifications required by State regulations. The test pits should be excavated with a trackhoe to ensure the machine can move onto the proposed test pit locations, due to uneven ground and vegetation in the area. Soil samples should be collected from each test pit and from each soil type encountered for laboratory testing. Sieve analyses and hydrometer tests should be run on all samples to determine the grain size distribution of the soils, their fines content and the lateral variability of the soils across the site. Moisture content of the soil should also be run on the samples to find the range of natural water content. Quantities of available fill material could also be roughly estimated by multiplying the average thickness of each soil type times the approximate square footage of the areas in which they are found. Reserve Silica may have exploratory information that also could be used to estimate quantities and probably have a rough estimate of the total amount of overburden they will have to remove.

If the soils appear useable, laboratory testing to determine the hydraulic conductivity or permeability of the compacted soils will be necessary. Modified Density (Proctor) Tests (ASTM-D1557) will be run on selected soil samples to determine the degree of compaction necessary for remolding the soils for permeability testing and the criteria for structural fill placement.

Permeability tests will also be required. Falling or constant head tests could be run to make an initial determination of the permeability of the soils after compaction. However, falling head test should not be used for final analyses of the potential permeability of the compacted soils. For final design, triaxial permeability tests should be run on selected samples. The advantage of screening the samples initially with falling head tests is that this test costs roughly 1/3 of the cost of a triaxial permeability test. If samples appear to be suitable and not marginal for the required permeability of the cap, the falling head test would not be run and only the triaxial permeability tests would be run.

Permeability tests in these types of soils may take several days for each test. These tests will prolong the amount of time necessary for testing and may result in a delay through the dry summer months. Civil and geotechnical engineering of the cap could begin while a source is being located or evaluated to allow for determination of quantities necessary for the cap and to have the cap design completed prior to the drier months of the year.

If these soils are used as fill and cap material, they must meet standards for cap design and permeability. Soils used in construction of the cap will need to be tested prior to installation, the placement of the fill will need to be observed and density tests must be taken on each compacted lift. An on-site soils technician should document if the fill soils remain consistent or if they vary

CONFIDENTIAL • ATTORNEY - CLIENT PRIVILEGED and require additional testing to maintain the required permeability. The soil technician will perform compaction testing under the direction of a licensed geotechnical engineer. Inspection must be full time during filling operations for documentation purposes.

We would expect that following source test pit explorations, laboratory testing would take approximately 6 to 8 weeks. A report on cap design would follow the testing and meeting. Drainage design may lengthen the amount of time necessary for report preparation depending on the complexity of the final discharge arrangement.