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AUG 16 2007
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March 12, 2002

Fred Hills Materials
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Revised Report
Gravel Resource Evaluation
Geotechnical & Hydrogeologic Conditions
Shine Pit -Thorndyke Expansion Area
Jefferson County, Washington
Job No. OlyRes.03R3

INTRODUCTION

This report summarizes our site observations and subsurface explorations and provides our conclusions with regard to geologic and hydrogeologic conditions at the proposed Thorndyke Gravel Mine area. This includes an evaluation of the post mining reclamation slopes. In addition, a summary of our evaluation of the gravel resources at the site is included.

In general, the site is located south of SR 104 and northeast of Thorndyke Creek. The site is situated within a larger block of property owned by Pope Resources, LP and managed by ORM (Olympic Resource Management). Effectively, the adjacent property is also owned by Pope Resources. The location of the site is shown on the Vicinity Map, Figure 1.

The proposed Thorndyke mine site and the Shine mine area have been historically mined for aggregate materials prior to, during and following the construction of the Hood Canal Bridge. Currently, aggregate material is mined at both the Shine Pit (by Fred Hills) and the north Thorndyke site (Olympic Property Management). Material mined at the Shine Pit is for commercial use. Material currently mined at the existing Thorndyke site is for on-site (road maintenance) use and on select fill for Olympic Property Management construction projects. The proposed Thorndyke mine expansion area is located in the south portion of the Thorndyke gravel resource deposit.

We understand that Fred Hills is entering into a lease agreement with Pope Resources to operate the expansion site as a commercial aggregate resource area. The permitted area will be approximately 300 acres in surface area. We further understand that processing of the excavated material from the Thorndyke mine site will be done at the existing Shine mining/processing area located to the northeast. Material from the Thorndyke mine site will be transported to the process area via an overland conveyor system. The processed materials will be exported from the Shine site via the existing site access onto SR 104 at the Shine site. The locations of the existing mine site, proposed expansion area and the conveyor system are illustrated on the Site Plan, Figure 2. A copy a larger scale Site Plan is included as Plate 1.

We understand that conventional mining methods will be utilized to mine the aggregate resources above the water table. The mine floor will remain a minimum of 5 feet above the normal seasonal high groundwater level.

The purpose of our site investigation is to evaluate the geologic and hydrogeologic conditions in the site area for additional aggregate resources for the expansion of the existing operations and long term aggregate supply for the region. In addition, we will evaluate the hydrogeologic conditions in the site area in order to address groundwater issues for the proposed mine expansion.

We understand that you are in the process for revising the DNR (Washington State Department of Natural Resources) and Jefferson County permits to expand the aggregate

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resource or mine area from the current 144 acres by 156 acres to a total 300 acres. This document will be utilized as part of that process.

SITE CONDITIONS

GENERAL

The site is situated within a glacial upland area west of the Hood Canal Bridge. The area of interest relative to aggregate resources is situated within a generally north-south trending valley or topographic trough located northeast of Thorndyke Creek. The ground surface in the general site area is flat to moderately sloping. Slopes in the site area range form 10 to 30 percent. Areas of 30 to 60 percent slope occur near the site where the adjacent ridges meet the valley floor.

Topography in the site area generally ranges from approximately Elevations 300 to 350 MSL (Mean Sea Level) in the valley floor area and from Elevations 350 to 400 MSL in the northwest valley wall area. Localized terraces occur along the valley walls and within the valley floor area.

Vegetation in the site area ranges from dense forest to recently harvested areas with localized areas of meadow and wetland/lake shoreline vegetation. Undergrowth in the forested area ranges from moderate to dense.

Local drainage swales dissect the site, in a general north-south direction. The larger of these is the Thorndyke Creek drainage course, which is located south and west of the proposed mine expansion area. Wahl Lake, a localized wetland area, is situated northeast of the mine area. Buffers of 200 feet or more will be maintained around the wetland and creek areas. Site topography is shown on the Site Plan, Figure 2.

GEOLOGIC CONDITIONS

Interpretation of the geologic conditions at the site are based on our site observations, soil exposures in the area, test pits and borings completed at the site, and our review of the available geologic literature. In general, the soils in the site area consist of, from oldest to youngest, undifferentiated pre-Vashon glacial and interglacial sediments, overlain by Vashon advance outwash, glacial till (hardpan) and recessional outwash sediments. Locally ice marginal or ice contact deposits also occur along the ridge slopes. We also expect that localized areas of lake sediments may occur in the valley floor area. A generalized geologic map of the area is included as Figure 3.

The older glacial sediments are exposed along portions of the Puget Sound shoreline bluff located several miles east of the site. These soils typically consist of bedded sands and gravels and occasional till deposited by pre-Vashon glaciers. The interglacial deposits typically consist of bedded silt, sand and occasional clay. These older sediments are in a very dense or very hard condition where undisturbed.

The Vashon advance sediments generally consist of sand with variable silt, gravel and cobbles. The advance sediments were deposited in front of the advancing glacial ice and subsequently overridden by the glacier. It is likely that portions of the denser sand and gravel deposits in the site area are advance sediments.

Vashon glacial till was encountered in the test pits and borings excavated along the margins of the valley and in the ridge areas. It is likely that the till deposits in this area are underlain by Vashon advance deposits. Till generally consists of silty sand with variable gravel, cobbles and boulders. The Vashon till was deposited at the base of the most recent (12,000 to 15,000 years ago) glacial ice as it advanced across the site area. Because the till was deposited and overridden by the glacial ice, it is over-consolidated and in very dense condition where undisturbed.

Where the glacial ice was adjacent to an upland remnant area or topographic high, ice-marginal or ice-contact soils were deposited. These generally consist of silty sand and gravel with cobbles and boulders, laminated silts, and occasionally blocks of glacial till. The ice contact or marginal deposits are highly variable laterally and vertically.

As the glacial ice receded, melt waters deposited recessional sand and gravel deposits. The recessional soils are generally in a medium dense to dense condition where undisturbed. The recessional soils at the site occur as a thin veneer over the glacial till in the ridge area and as channel fill deposits in the valley or low-lying areas. The channel fill deposits generally occur within ancient outwash channels or river courses that flowed from the melting glacial ice.

Based on our site observations and data review, the area of interest is likely a glacial outwash channel deposit that extends through the Thorndyke area in a general north-south direction. The estimated outwash channel margins are shown on Figure 4.

Within the outwash channel area, it is likely that the glacial till was either not deposited or removed through erosion by the scouring melt water. Where this occurred, the recessional sand and gravel deposits were deposited directly over the advance sand and gravel deposits, resulting in a thicker section of aggregate material.

Based on the results of our subsurface explorations, there appears to be an area of delta-like deposits located just east and north of Thorndyke Creek in Section 1. This area likely reflects an intersection of glacial outwash channels or deposition within an ice-dammed lake. This resulted in a locally thicker accumulation of high quality aggregate material.

SUBSURFACE CONDITIONS

General

Shallow subsurface conditions at the site were evaluated by excavating 85 track-hoe test pits and nine power borings in the site area. Observations wells were installed in the borings to allow for monitoring of groundwater conditions. The test pits extended to depths of several feet to approximately 20 feet. Many of the test pits encountered sand and gravel to the full depth explored. Ground water was observed in several of the test pits excavated in the lower northwest portion of the site, a localized depression. Glacial till was encountered at depth in the test pits excavated in this area. The groundwater appears to be perched on the till. The glacial till has been eroded or removed within the outwash channel proper.

The borings were completed with an air-rotary drilling rig to depths ranging from 20 to 100 feet below the existing ground surface. Grab samples were collected on a 10-foot interval for further evaluation. Six-inch steel observation wells were installed in the borings to allow for long term monitoring of groundwater conditions.

The locations of the test pits and power borings/observations wells are illustrated on the Channel Map, Figure 4. The boring locations are shown on the Site Plan, Figure 2 and Plate 1. The soil and ground water conditions encountered in the test pits were logged and will be maintained in our files. Logs of the conditions encountered in the test pits and borings will also be maintained in our files. A summary of the conditions encountered is provided below.

In general, sand and gravel were encountered from the ground surface to depths of approximately 45 feet. The aggregate resource material appears to occur in a north-south trending valley or trough, and thins towards the east and west valley margins. The aggregate material becomes finer (less 3 inch plus material) with depth and towards the west portion of the site.

Basalt bedrock was encountered in boring B-3 at a depth of approximately 32 feet below the existing ground surface. This is likely a continuation of the surficial bedrock outcrop located north of SR 104 and east of the Beaver Valley Road cutoff.

Several test pits located near the existing Thorndyke Pit and throughout the site area encountered significant groundwater. Groundwater was also encountered in the test borings at depths of 16 to 30 feet. Specific groundwater depths in the borings are indicated on the boring logs in Appendix A.

Ponded surface water was observed in an area generally northwest of the existing Thorndyke mine area. We expect that this water reflects a local ground water table, which may be perched, at least partially, on the glacial till and bedrock, where present. It should be noted that not bedrock or glacial till was encountered in the central portion of the outwash channel. It is likely that the glacial was scoured or removed from this area.

Aggregate Quality

Based on our site observations during excavation of the test pits, sand and gravel deposits located within the outwash channel consist of high quality sand and gravel aggregate with cobbles and occasional boulders that is suitable to produce a variety of aggregate products. The material encountered typically ranged in grain size from fine sand to coarse gravel and cobbles with occasional boulders to 24 inches. Visual estimates of the fines content in the channel areas ranged from 2 percent to 6 percent on average. The coarse fraction of the aggregate material decreases to the west. There is also an increase in the fines content (minus 200 fraction, U.S. No. 200 Sieve) towards the margins of the channel. We understand that reject material that cannot be exported from the site will be utilized as a topsoil amendment for reclamation of the site.

Adequate coarse gravel, cobbles and boulders occur in the material encountered to produce crushed products. Sufficient fine to medium sand occurs as lenses and along the margins of the channels to provide for binder and concrete sand.

HYDROGEOLOGIC CONDITIONS

Surface Water

The sand and gravel deposits that underlie the Thorndyke site area are highly permeable. Surface water that falls on these soils rapidly infiltrates into these materials. No evidence of direct surface water runoff was observed at the site at the time of our site visits. During periods of significant precipitation or in localized areas where a shallow ground water table occurs, temporary ponding may occur. Wahl Lake, a wetland/shallow lake, located northeast of the proposed mine expansion area is an example of this type of shallow groundwater condition. Water in these areas is likely perched on the glacial till that occurs at a shallow depth.

Thorndyke Creek is located south and west of the proposed mine expansion area. Based on our site observations and the results of our subsurface explorations, the water in Thorndyke Creek is perched on a layer of low permeability soils, glacial till.

Ground Water

Based on our review of the 1998 Robinson & Noble hydrogeologic (DRASTIC) report, observation well logs and monitoring data at the site, and our experience in the area, there are several aquifer systems that occur in the site area. These include the intermittent shallow perched groundwater in the Vashon recessional and advance sand and gravels (above the till where present) and a deeper regional aquifer. Based on our groundwater monitoring records, the shallow water levels at the Thorndyke site range from approximately Elevation 282 in the north down to approximately 278 in the southwest. This is between approximately 30 and 109 feet below the existing ground surface. Season fluctuations in the shallow aquifer system are on the order of 3 to 4 feet.

Based on the existing information, it appears that the shallow groundwater system in the site area is recharged by infiltration of direct precipitation and laterally from the contiguous sand and gravel deposits located to the north, as well as overflow from Wahl Lake located to the northeast. Based on the water level data in the observation wells, groundwater in the shallow aquifer flows to the south-southwest. Water elevations in the wells and the direction of groundwater flow of the shallow aquifer are shown on the Site Plan, Figure 2. A schematic cross section of the site area is included as Figure 5.

A deeper regional aquifer occurs in the underlying and older pre-Vashon soils, including the Salmon Springs Formation. Based on our data review for the site area, the deep aquifer is likely on the order of several hundred feet below the existing ground surface at the site. The groundwater flow direction of the deeper aquifer is likely towards Puget Sound, to the east. Recharge of the deeper regional ground water systems is through a combination of downward percolation through the overlying soils and regionally from adjacent up-gradient areas.

No domestic or production water supply wells are located in the site area, other that the existing on-site wells. Water use at the site generally consists of process water and domestic/office use. Process water is made up of collected stormwater and makeup water. The

process water is recycled to reduce makeup water levels.

Previous Water budgets prepared for similar projects indicate that the removal of vegetation and the surficial silty soils will result in a slight increase in ground water recharge at the site. Little or no change is expected in the overall recharge level of the seasonal perched aquifer. In turn, little or no change is expected to the recharge of the regional aquifers.

Based on the previous DRASTIC report for the asphalt plant at the Shine Site, no significant impacts were expected or have been observed at the site or adjacent areas. A DRASTIC index of 149 was calculated for the Shine Site at the time of the report. This was based on the potable water source for the area being in a deeper aquifer, below a zone of low permeability soils. Similar conditions occur at the Thorndyke site. A copy of the DRASTIC report for the Shine Site is attached, Appendix A.

CONCLUSIONS

GENERAL

Based on the results of our subsurface explorations, site reconnaissance and review of the available data, it is our opinion that the area contains economic and minable aggregate resources. These gravel resources generally occur as an outwash channel fill and advance outwash deposit that range from several feet to approximately 100 feet in depth.

The sand and gravel material within the outwash channel thins toward the margins of the channel. Glacial till likely occurs below the outwash sand and gravels in portions of the site area. The till material is likely underlain by advance and gravel outwash material. Where the till is eroded or removed, the recessional material rests directly on the advance sand and gravel resulting in a thicker sequence of sand and gravel. The material is suitable for use in the production of aggregate products.

Based on our site observations and experience, it is our opinion that conventional mining practices and geotechnical guidelines can be utilized at the site. Standard mine reclamation practices and slopes (between 2 to 1 and 3 to 1 - Horizontal to Vertical) will be utilized for reclamation. Steeper temporary slopes may be utilized in active mine areas.

Groundwater was encountered in the north portion of the site. We expect that the groundwater in this area is perched on the glacial till or bedrock where present. A deeper groundwater system (table) occurs in the south portion of the site. Mining at the site will consist of conventional mining methods above the groundwater table, 5 feet above the normal seasonal high water level.

Based on our experience with similar projects, we expect no significant impact to the groundwater system as a result of the proposed mining activity. All regulatory guidelines will be followed at the site. Based on our review of the available data, there are no third-party water supply wells located within ½-mile of the site area. We have extensive experience with both above and below water level gravel mining operations through Western Washington. To date, no significant impacts have been observed at any of the mine site being monitored.

Based on the soils observed at the site and encountered in the subsurface explorations, it is our opinion that the infiltration of stormwater runoff at the site is feasible. Areas with remaining thicker sand and gravel soil will have adequate permeability and storage capacity to infiltrate stormwater from the site, provided adequate design and construction practices are used.

Pertinent conclusions and geotechnical recommendations regarding the design and construction of the proposed development are presented below.

SLOPE STABILITY

Based on our field observations and our experience with the soil types encountered on the property, we conclude that although portions of the slopes exceed 30 percent, they are generally stable relative to deep-seated failure in their present configuration. Mining activity at the site will result in the excavation of the upper portion of the existing ground surface and a decrease in the height of the existing ground surface. No change in slope stability is expected as a result of the proposed mine expansion. Engineered cuts and fills (grading) will not adversely impact slope stability at the site. The controlled infiltration of a portion of the stormwater and release of runoff

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at the site will be balanced to match the soil conditions. The stability of the slopes will, therefore, not be negatively impacted.

No significant groundwater seeps or springs were observed at the site at the time of our site visits. Little or no changes in ground water conditions as a result of the site activity are expected.

EROSION AND SEDIMENTATION CONTROL

It is our opinion that the potential erosion hazards at the site are not a limiting factor for the proposed mine expansion. Removal of natural vegetation at the site should be minimized and limited to the active mine area. Temporary and permanent erosion control measures should be installed and maintained during mining to limit the additional influx of water to exposed areas and protect storm ponds and potential receiving waters. Erosion control measures may include but not be limited to berms and swales with check dams to manage surface water run-off. Graded or reclaimed areas should be shaped to avoid concentrations of runoff water onto cut or fill slopes, natural slopes or other erosion-sensitive areas. In addition, ground cover/protection should be used in exposed or disturbed areas and silt fences where appropriate. Temporary ground cover/protection may include hydro-seeding, various mulches, jute matting, excelsior matting, wood chips or clear plastic sheeting. These temporary measures should be used until the permanent erosion protection is established.

EARTHWORK

Site Preparation

All areas to be graded/mined should be cleared of deleterious matter including existing debris and vegetation. The organic-laden strippings should be stockpiled on-site and later used for reclamation purposes

Prior to placement of any fill material, the exposed subgrade areas should then be compacted to a firm and unyielding surface. In fill areas, we recommend that trees be removed by overturning so that a majority of the roots are removed.

Any soft, loose or otherwise unsuitable areas should be recompacted, if practical, or over excavated and replaced with structural fill.

Structural Fill

All fill material used to achieve design grades within the structural areas should be placed as structural fill. The structural fill should be placed in horizontal lifts of appropriate thickness to allow adequate and uniform compaction of each lift. Structural fill should be compacted to at least 90 percent of MDD (maximum dry density as determined in accordance with ASTM D-1557). Where the fill will be used for structural support of structures or roadways, the upper 2 feet should be compacted to 95 percent MDD.

The appropriate lift thickness will depend on the fill characteristics and compaction equipment used. We recommend that the appropriate lift thickness be evaluated by our field representative during initial placement.

The suitability of material for use as structural fill will depend on the gradation and moisture content of the soil. As the amount of fines (material passing No. 200 sieve) increases, soil becomes increasingly sensitive to small changes in moisture content and adequate compaction becomes more difficult to achieve. During wet weather conditions, it may be necessary to stockpile the imported soils until appropriate moisture conditioning can take place.

Material placed for structural fill should be free of debris, organic matter and trash. Particle sizes larger than 6 inches should be excluded from the top 1-foot of fill. The moisture content of the fill material should be adjusted as necessary for proper compaction.

CUT AND FILL SLOPES

Temporary cut slopes may be necessary during mining/grading operations. As a general guide, temporary slopes of 1.5 to 1 (horizontal to vertical) or flatter may be used for temporary cuts in the upper 3 to 5 feet of the recessional gravels or glacially consolidated soils that are weathered to a loose/medium dense condition. Temporary slopes of 1/2 to 1 or flatter may be

used in the unweathered dense to very dense sands and gravels or till. These guidelines assume that the temporary cut slopes will not exceed 30 feet in height, and that all surface loads are kept at a minimum distance of at least one half the depth of the cut away from the top of the slope. In addition, the slope inclination should be flattened where significant seepage occurs on the slope face.

We recommend a maximum of 2 to 1 for permanent cut and fill slopes. Where 2 to 1 slopes are not feasible, retaining structures should be considered. Our understanding of the project is that reclamation slopes at the site will range between 2 to 1 and 3 to 1 or flatter.

Fill placed on slopes that are steeper than 5 to 1 should be "keyed" into the undisturbed native soils by cutting a series of horizontal benches. The benches should be 1½ times the width of equipment used for grading and a maximum of 3 feet in height. Subsurface drainage may be required in seepage areas. Surface drainage should be directed away from all slope faces. Some minor raveling may occur with time. All slopes should be seeded as soon as practical to facilitate the development of a protective vegetative cover or otherwise protected.

SITE DRAINAGE

All ground surfaces should be sloped away from structures and erosion sensitive areas. Surface water runoff should be controlled by a system of berms, drainage swales, and or catch basins, and conveyed to an appropriate discharge point. Drains for structures adjacent to steep slopes should be tightlined to discharge into the stormwater collection system or to the toe of the slope. Surface water should not be discharged into subdrains in fills and roadways. Drains should be provided behind all retaining walls.

Permanent drainage systems should be installed at the top and/or bottom of cut and fill slopes to intercept surface runoff and prevent it from flowing in an uncontrolled manner across the slopes. Surface water should not be discharged over the undisturbed slopes outside the grading areas.

STORMWATER CONTROL

Based on our observations, a large portion of the precipitation on the site currently percolates into the surficial sand and gravel soil. Infiltration of the storm runoff at the site will closely match the existing conditions.

Soils in much of the site post-mined area will generally still consist of permeable sand and gravel. It is our opinion that on-site infiltration of storm runoff water is feasible at the site where this condition occurs. Areas of soil with higher silt content may require special design considerations or rerouting to more permeable areas. Specific design criteria for infiltration systems will be provided, as appropriate. No stormwater runoff will be released from the site.

In general, ground surface infiltration (percolation ponds) is preferred over percolation trenches because maintenance is easier and less costly. Where percolation trenches are used, the stormwater should be treated in accordance with current Jefferson County regulations.

GROUND WATER IMPACTS

It is our opinion that there will be no adverse impacts on groundwater as a result of the proposed mine development. The potential groundwater impacts are related to the relationship between precipitation, surface water, shallow subsurface runoff, evapotranspiration, groundwater recharge and the proposed site activities. Mining at the site will not extend into the groundwater system. A minimum 200-foot buffer will be maintained from the surface water bodies in the site area.

As the site is developed, a portion of the natural vegetative cover will be replaced with mine and reclaimed areas. The replacement of the natural cover with mine and reclamation area will result in a slight, but temporary, decrease in evapotranspiration, with a consequent increase in runoff and/or groundwater recharge. The permeable soils at the site will rapidly infiltrate any runoff and/or precipitation. The net result of the proposed mine expansion will essentially be a temporary minor increase in total groundwater recharge at the site. Therefore, relative to up-gradient shallow seasonal perched aquifer system, no significant impact is expected.

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We do not expect any adverse affects on the recharge condition of the deep aquifers. As stated above, recharge to the deeper aquifers occurs by infiltration of rainfall through the overlying aquifers and aquitards. Because the recharge of the perched aquifer will not be significantly affected, the recharge of the deep aquifer will not be adversely affected. It should also be noted that the recharge area for the aquifers, in particular the deeper aquifer, essentially occurs over the entire southeast portion of Jefferson County. This site comprises less than 0.1 percent of that total recharge area.

The shallow perched groundwater that exists at the site is potentially susceptible to contamination from the surface. Mining activity at the site will be conducted in accordance with the BMPs (Best Management Practices), Washington State and Jefferson County regulatory guidelines for mining operations. Processing of the aggregate from the Thorndyke area will occur at the Shine site, not in the proposed Thorndyke mine expansion area. No fuel storage is proposed at the Thorndyke site. Fueling of the on-site equipment will be done in designated areas with appropriate protection in accordance with the BMP's. The layer of sand and gravel soil material that remains above the seasonal high groundwater level will act as a filter or buffer to protect the groundwater in the unlikely event of a release.

The site activities will be closely monitored and spill prevention plans and kits will be kept on-site. Mining personnel will be trained in spill response. The deeper aquifers are protected from possible contamination by the filtering effect of the overlying sand and gravel and fine-grained silt and clay that occur at the site.

The shallow aquifer is not used as a potable water supply source in the site area. Based on our data review, there are also no wells in the site area that withdraw water from the deeper aquifer. A previous DRASTIC report prepared for the Shine Site (Appendix A) determined an index of 149. The proposed activities at the Thorndyke expansion site do not include processing. Material mined at the Thorndyke site will be transported to the Shine site via a conveyor system. Historic processing practices at the Shine site will continue. No adverse impact to the water systems has been observed at the Shine site.

It is likely that the shallow groundwater in the site area flows toward Thorndyke Creek. No significant adverse changes in groundwater quantity or quality related to mining operations will occur at the site. As discussed above, mining will remain a minimum of 200 feet (typically 350 feet) from the creek and its tributaries. No impacts to groundwater quality or quantity have been observed at either Thorndyke or Shine sites or are expected because of mining activity.

No significant adverse impacts to Wahl Lake will occur as a result of mining activity. Wahl Lake is locate up gradient of the proposed mine expansion area and a minimum 200-foot buffer will be maintained. Wahl Lake is perched on the shallow glacial till. Water levels in the lake are controlled by the surface elevations of the till. Water flows through the overlying shallow sand and gravel when the Lake is at Capacity. This perched/overflow condition will not be modified or impacted by mining activity.

Surface water runoff at the site will be retained on-site and infiltrated into the permeable site soils. It is likely that there may be a slight, but temporary, increase in infiltrated water and therefore local recharge at the site. This may also result in a slight, but temporary, increase in groundwater flow towards the Thorndyke Creek drainage system. Based on the soil types observed at the site, peak stormwater infiltration at the mine area will likely reach the Thorndyke Creek area after approximately 2 to 4 months. The slight increases in recharge would be than normal fluctuations in monthly rainfall/infiltration levels.

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LIMITATIONS

We have prepared this report for Fred Hills Materials and Olympic Property Management, and their representatives for use in evaluation the potential aggregate resources of the above-described area. Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time this report was prepared.

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If you have any questions regarding this report or need additional information please call.

Yours Very Truly,
GeoResources

Bradley P. Biggerstaff, RPG
Engineering Geologist

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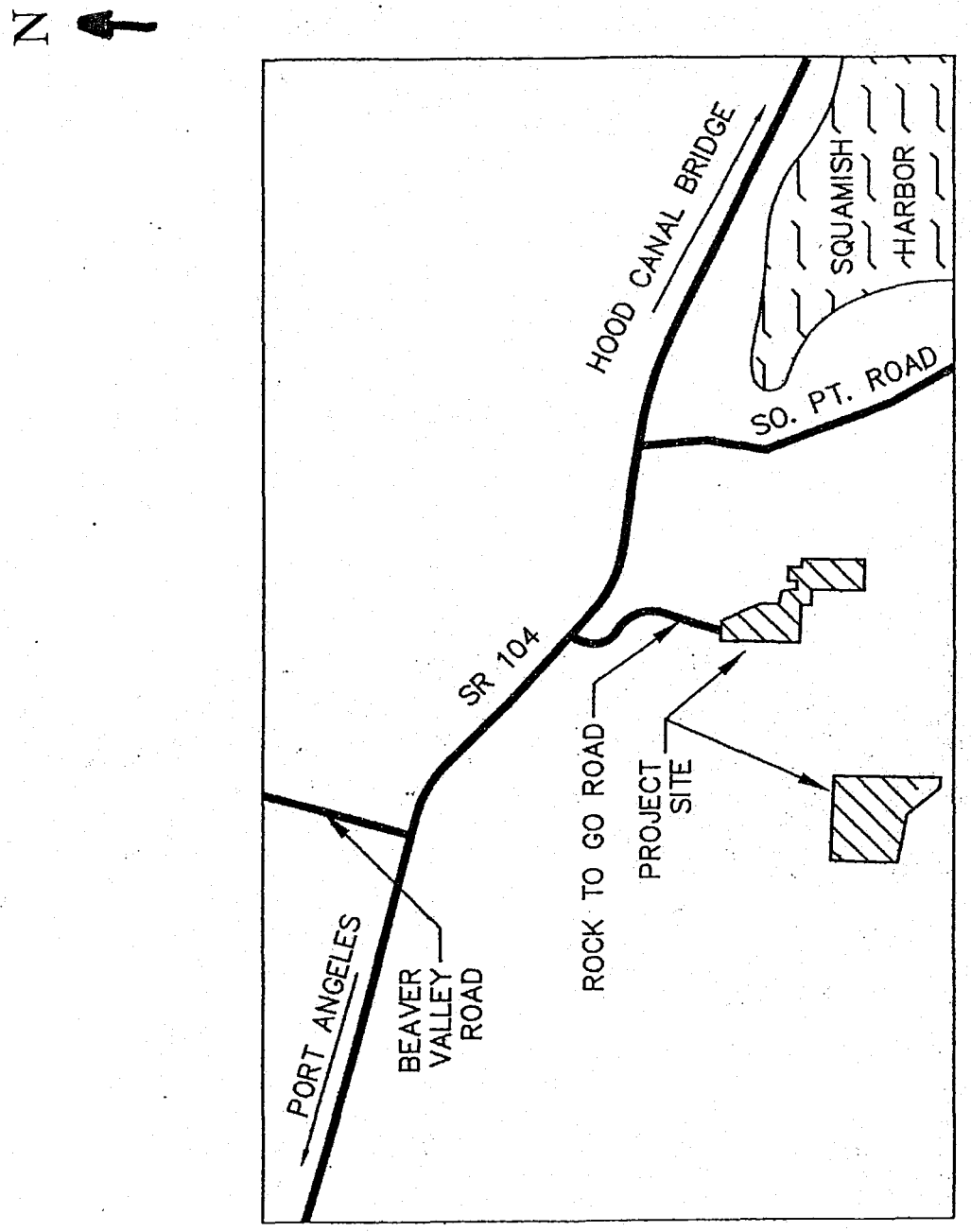

VICINITY MAP

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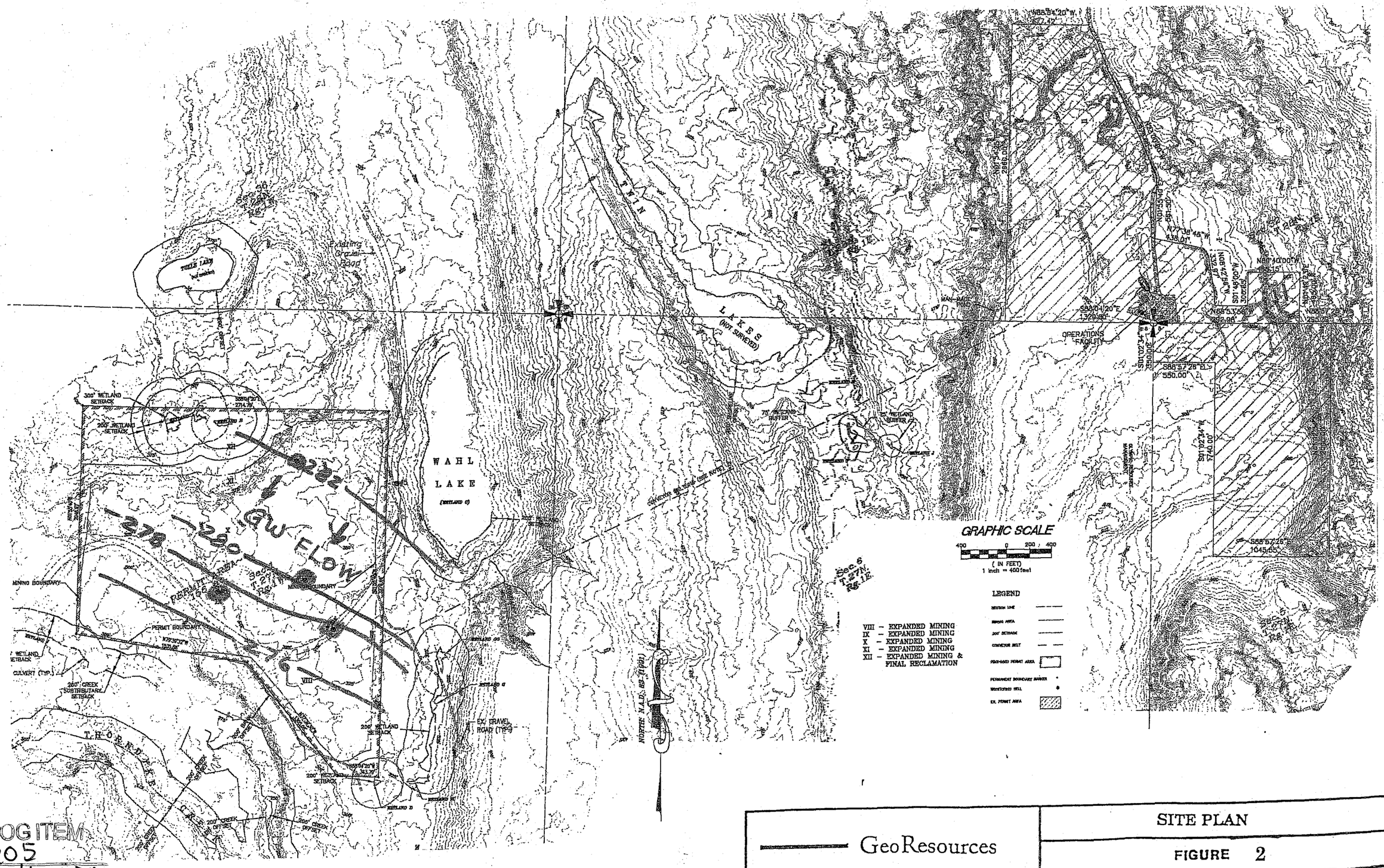
	Figure 1



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SITE PLAN

FIGURE 2

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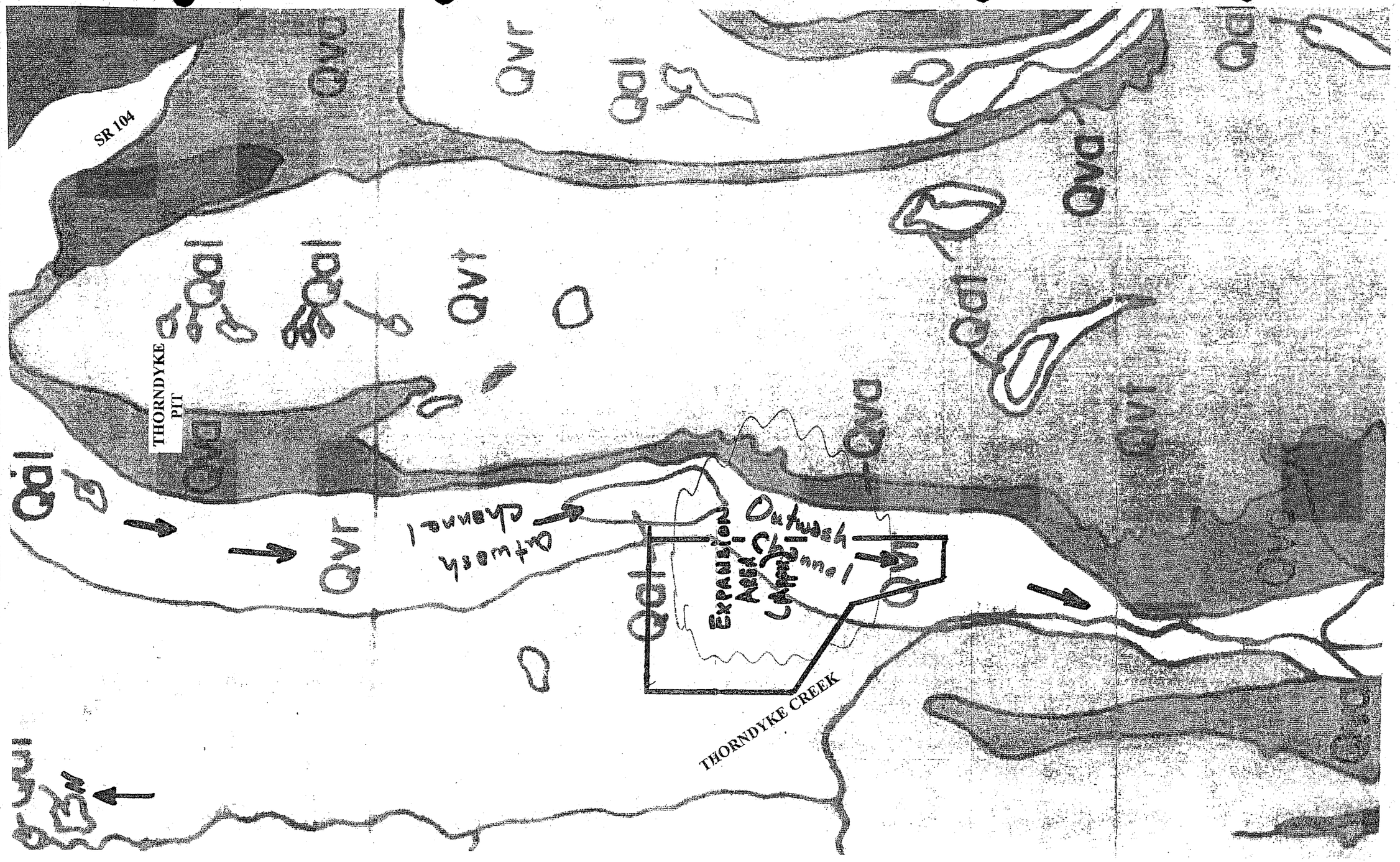

Tv	Tertiary Volcanics		
Qal	Alluvial Soils	Qvt	Vashon Till Soils
Qvr	Vashon Recessional Soils	Qva	Vashon Advance Soils

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GEOLOGIC MAP

FIGURE 3

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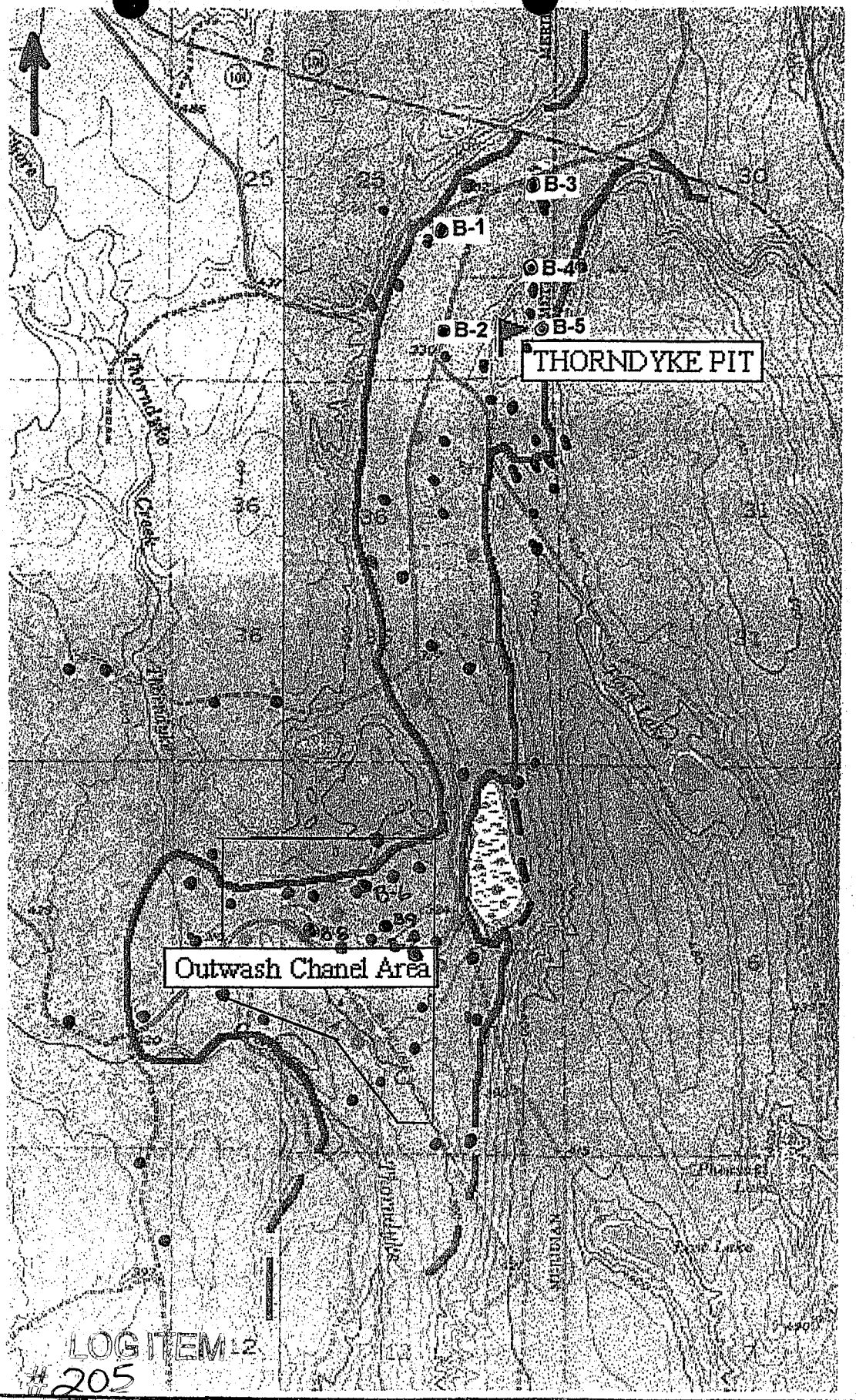

GRAVEL
SAND W/ GRAVEL
TILL

TEST PITS

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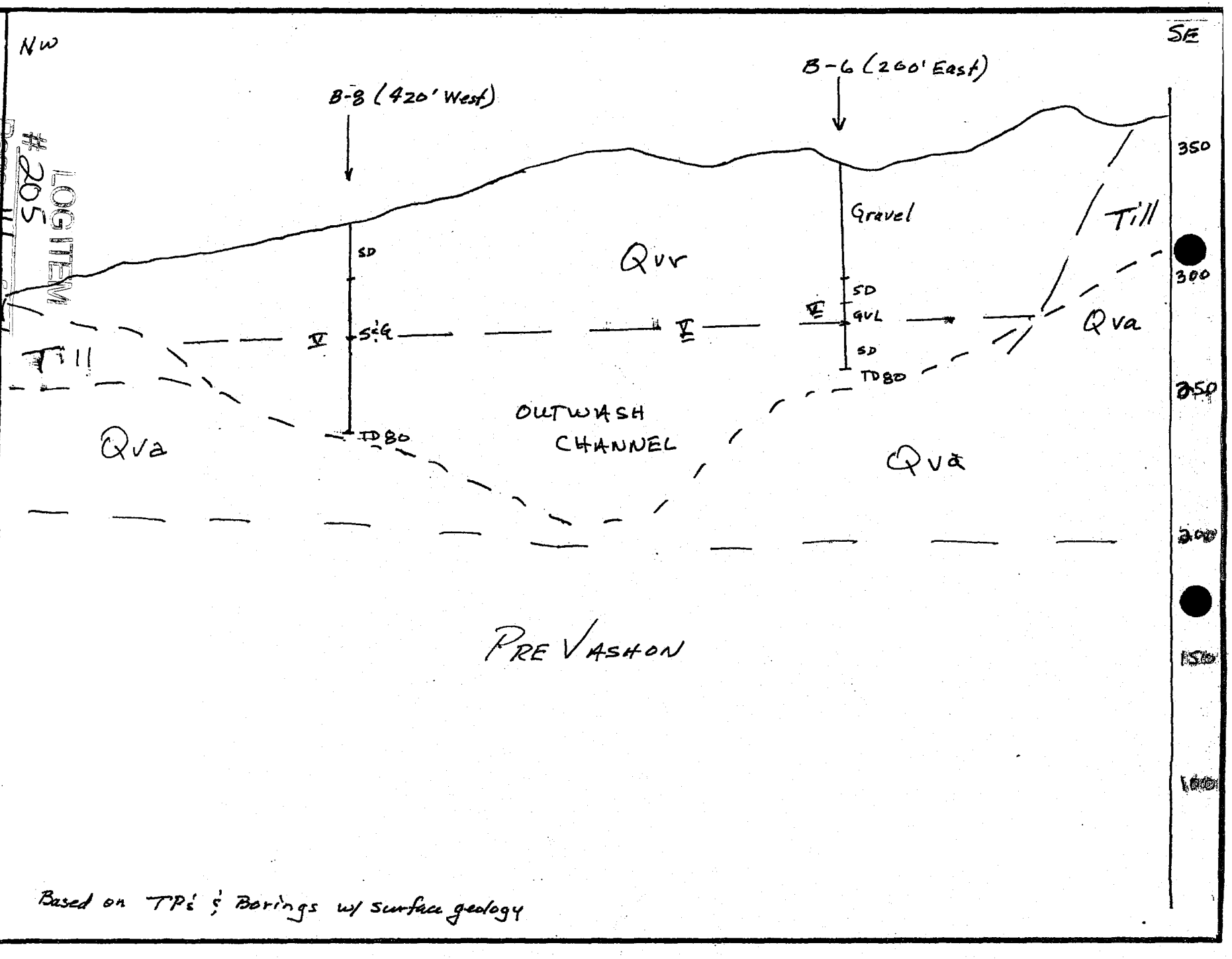
SITE PLAN

Figure 4



Based on TP's & Borings w/ surface geology

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Cross - Section

Figure 5

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 D2488-90.
2. Soil classification using laboratory tests is based on ASTM D2487-90.
3. Descriptions of soil density or consistency are based on interpretation of blow count 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

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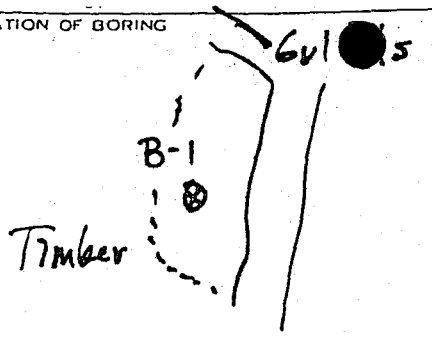
GeoResources

SOIL CLASSIFICATION SYSTEM

FIGURE

BPB | Olympic Res M. | Thorndyke

LOCATION OF BORING



NORTH ARROW

DRILLING METHOD: Rotary

BORING NO. B-1

SHEET 1 OF 2

SAMPLING METHOD: Grab

DRILLING

					START TIME	FINISH TIME
WATER LEVEL	2.16'	BG.				
TIME						
DATE	6/15/98				DATE 6/15	
CASING DEPTH						

DATUM

ELEVATION

SURFACE CONDITIONS: Partically cleared area next to Road Intersection

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0	TS	Top soil w/ gvl	
						1			
						2		BRN SAND w/ gvl & sdy gravel w/ cobbles, occ. boulders.	
						3			
						4		(Med dense- dense, moist)	
						5			
						6	SP/GP		
						7			
						8			
						9			
						10			
						1			
						2			
						3			
						4			
						5			
						6	W	Becomes wet @ ~16.0'	
						7			
						8			
						9			
						20			

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6a

continued B-1

DRILLING METHOD					BORING NO. B-1	
					SHEET 2 OF 2	
SAMPLING METHOD:					DRILLING	
					START TIME	FINISH TIME
WATER LEVEL						
TIME						
DATE					DATE 6/15	
CASING DEPTH						

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						20			
						1		Brn sd (med to coarse) w/ gvl & occ cobbles.	
						2		Dec. in gravel content	
						3		@ ~ 24' to minor (≤ 15%)	
						4	SP		
						5			
						6			
						7			
						8			
						9			
						30		Brn/ Gry fi-med sd w/ occ. coarse sd & fine gvl lenses.	
						1			
						2			
						3	SP		
						4			
						5			
						6			
						7			
						8			
						9			
						40		TD @ 40' Bag Sample @ 10-10' (F.H.)	

LOG ITEM #205

LL

PTD | Org. Res. Mgmt. | Thorndyke

LOCATION OF BORING	NORTH ARROW	DRILLING METHOD: Rotary	BORING NO. B-2
			SHEET 1 OF 4
		SAMPLING METHOD: Bag	DRILLING

					START TIME	FINISH TIME
WATER LEVEL	~22'					
TIME						
DATE					DATE 6/15	
CASING DEPTH						

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0			
						1	SP	Brn / Org gully sand	
						2		& Sdy gvl w/ cobbles	
						3		& occ. Boulders.	
						4			
						5			
						6			
						7			
						8			
						9			
						10	....	Inc in sand / fine gravel	
						1		↓	
						2			
						3	SP/		
						4	GP		
						5			
						6			
						7			
						8			
						9	....	Sdy Gvl w/ cobbles	
						20	GP		

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Le

LOCATION OF BORING

NORTH ARROW

DRILLING METHOD

SAMPLING METHOD:

BORING NO. B-2

SHEET 2 OF 4

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING

START	FINISH
TIME	TIME
DATE	

DATUM

ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						20			
						1		Continues	
						2			
						3		GW @ ~22'	
						4			
						5			
						6			
						7	SP		
						8			
						9		Gritty sand w/ cobbles	
						30			
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9		Continues	
						40			

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Ld

NORTH ARROW

DRILLING METHOD

SAMPLING METHOD:

BORING NO. B-2

SHEET 3 OF 4

					DRILLING	
					START	FINISH
WATER LEVEL					TIME	TIME
TIME						
DATE					DATE	
CASING DEPTH						

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						40			
						1	SP/		
						2	GP		
						3			
						4			
						5		Brn sand coarse	
						6		to fine w/ depth	
						7	SP	occ. gvl	
						8			
						9			
						50			
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						60	SP/SM	Brn/Gry V. fine sand & fi sdy silt.	

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LOCATION OF BORING

NORTH ARROW

DRILLING METHOD

SAMPLING METHOD:

BORING NO. B-2

SHEET 4 OF 4

					DRILLING	
					START	FINISH
WATER LEVEL					TIME	TIME
TIME						
DATE					DATE	
CASING DEPTH						

DATUM

ELEVATION

SURFACE CONDITIONS:

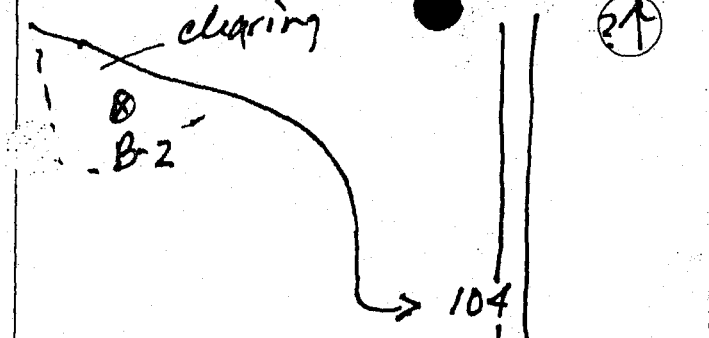
SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						60			
						1		A.A.	
						2			
						3		Fi sand w/ silt	
						4			
						5	SP / SM		
						6			
						7			
						8			
						9			
						70			
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						80		TD. 80' Samples @ 30-40 & 70-80	

LOG ITEM #205

66

PED 100 Rec. Hwy. Normdale

LOCATION OF BORING



NORTH ARROW

DATUM

ELEVATION

DRILLING METHOD:

SAMPLING METHOD:

BORING NO. B-3

SHEET 1 OF 2

DRILLING

					START TIME	FINISH TIME
WATER LEVEL						
TIME						
DATE					DATE 6/15	
CASING DEPTH						

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0		Brn Sd & Gvl w/ occ cobbles.	
						1			
						2			
						3			
						4			
						5	SP/GP		
						6			
						7			
						8			
						9			
						10			
						1			
						2		Decrease in cobbles, fi gvl	
						3			
						4			
						5			
						6	SP		
						7			
						8			
						9			
						20			

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LOCATION OF BORING	NORTH ARROW	DRILLING METHOD	BORING NO. B-3
			SHEET 2 OF 2
		SAMPLING METHOD:	DRILLING
			START / FINISH
		WATER LEVEL	TIME / TIME
		TIME	
		DATE	DATE
DATUM	ELEVATION	CASING DEPTH	

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						20		Sd & Gvl a.a.	
						1			
						2			
						3			
						4	SP/		
						5	GP		
						6			
						7			
						8		Trace GW	
						9			
						30		Gry / Bl si clay w/ gvl (weathered bedrock)	
						1	CL		
						2		Dk Brn Basalt Bedrock (Fractured)	
						3	Bslt		
						4		TD 34 FT.	
						5			
						6		Minor GW @ 30'	
						7			
						8			
						9			
						40			

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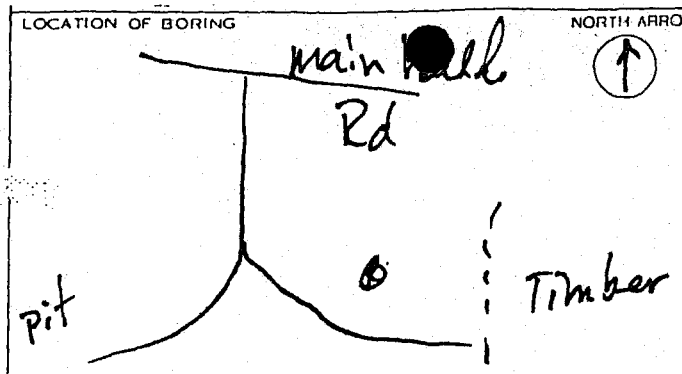
LL

LOCATION OF BORING	NORTH ARROW	DRILLING METHOD	BORING NO.
		Air Rotary	B-4
		SAMPLING METHOD: Grab	SHEET 1 OF 2
			DRILLING START TIME / FINISH TIME
		WATER LEVEL 24-26'	
		TIME	
		DATE	DATE 6/16
		CASING DEPTH	

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0		BRN sd w/ GVL / gully	
						1		sd w/ occ cobbles	
						2	SP/		
						3	GP		
						4			
						5			
						6			
						7			
						8			
						9			
						10		increase in sand	
						1			
						2	SP		
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						20			

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NORTH ARROW

DRILLING METHOD	BORING NO. B-4
	SHEET 2 OF 2
SAMPLING METHOD:	DRILLING
	START TIME / FINISH TIME
WATER LEVEL	
TIME	
DATE	DATE
CASING DEPTH	

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						20	SP/GP		
						1			
						2		Brn Sand w/ min gvl	
						3			
						4			
						5	V		
						6	SP		
						7		decrease in gvl	
						8			
						9			
						30			
						1		Brn/Gry Sand w/ tr si	
						2			
						3			
						4	SP		
						5		occ. gvl	
						6			
						7			
						8			
						9			
						40		TD @ 40'	
								Minor GW @ 24-26'	

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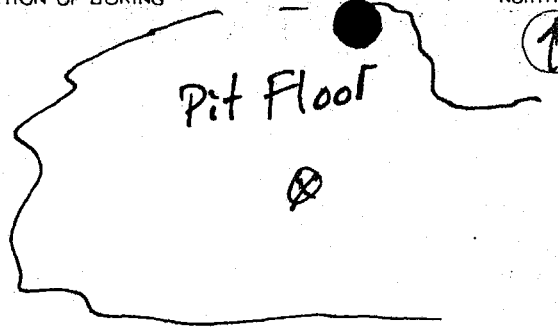
LOCATION OF BORING



NORTH ARROW

DRILLING METHOD: Air Rotary

SAMPLING METHOD: Grab

BORING NO. B-S4a

SHEET 1 OF 1

					DRILLING START TIME	DRILLING FINISH TIME
WATER LEVEL	~20'					
TIME						
DATE					DATE 6/16	
CASING DEPTH						

DATUM

ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0			
						1		Brn gravel w/ sand, cobbles & boulders	
						2			
						3	GP		
						4			
						5			
						6			
						7			
						8			
						9			
						10			
						1			
						2			
						3			
						4			
						5			
						6	SP/GP	Gry sand w/ gravel/sdy gravel.	
						7			
						8		Gry sand	
						9	SP		
						20		TD @ 20'	

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6K

GEORESOURCES | Olympic Res | Hornadyke

LOCATION OF BORING	NORTH ARROW	DRILLING METHOD: Air Rotary	BORING NO. B-65
		SAMPLING METHOD: Grab	SHEET 1 OF 1

						DRILLING START TIME	DRILLING FINISH TIME
WATER LEVEL	62'						
TIME							
DATE						DATE	
CASING DEPTH							

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0	SP/GP	Brn Sdy Gravel / gvlly SAND w/ Cobbles (Md/dense, moist)	
						10			
						20			
						30			
						40			
						5	SP	Brn fi-md SAND (dense, moist)	
							GP	Brn sdy gvl w/ cob, occ boulders (d, m to wet)	
						6			
						7	SP	Brn f-md SAND w/ occ gvl (d, wet)	
						8			
						9		TD 80'	
						0		GW @ ≈ 62'	
						1			
						2			
						3		325	
						4		-39	
						5		285	
						6			
						7			
						8			
						9			
						0			

LOG ITEM # 205

GEORESOURCES

OCM | Horrady Re

LOCATION OF BORING	NORTH ARROW
DRILLING METHOD: Air Rot.	BORING NO. B/X6
	SHEET 1 OF 1
SAMPLING METHOD: Grab	DRILLING START / FINISH
WATER LEVEL: 51'	TIME
TIME	
DATE	DATE
CASING DEPTH	
DATUM	ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0			
						10		ORG → Brn Sdy gvl w/ occ. COB (loose → dense, m)	
						20	GP		
						30			
						40		Brn fi SAND w/ occ gvl (d, wet)	
						50	SP		
						60			
						70			
						80		TD 80	
						9		GW @ 51'	
						0			
						1			
						2			
						3		355 -70	
						4		285	
						5			
						6			
						7			
						8			
						9			
						0			

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LOCATION OF BORING	NORTH ARROW	DRILLING METHOD: Air Rotary	BORING NO. B-87
			SHEET 1 OF 1
		SAMPLING METHOD: Grab	DRILLING
			START / FINISH
		WATER LEVEL: 42	TIME / TIME
		TIME	
		DATE	DATE
		CASING DEPTH	

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0			
						10	GP	Brn Sdy GVL w/ cob (f-md, m)	
						20	SP	SAND w/ min fine GVL	
						3	GP	Brn sdy gvl w/ min cob occ boulders (d, m)	
						4	SP	Bn fi sd (dense, wet)	
						5	GP	Bn fine gravel w/ SAND occ cob. (d, wet)	
						6			
						7	SP	SAND w/ gvl (d, wet)	
						8	GP	Brn sdy gvl (d, wet)	
						9			
						0			
						1			
						2		TD 80' wet @ ~40 GW @ 42'	
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						0			

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GeoResources | Overn | Riverdale

LOCATION OF BORING	NORTH ARROW	DRILLING METHOD: Rotary	BORING NO. B9
			SHEET 1 OF 1
		SAMPLING METHOD: Grab	DRILLING START / FINISH

WATER LEVEL	64'				TIME	TIME
TIME						
DATE					DATE	
CASING DEPTH						

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	DEPTH OF CASING	SAMPLE NO. / SAMPLE DEPTH	BLOWS/FT. SAMPLER	NUMBER OF RINGS	DEPTH IN FEET	SOIL GRAPH	SOIL DESCRIPTION	COMMENTS
						0		Org Brn gvlly sand / sdy	
						10	SP/GP	gravel w/ occ cob (l-md, m)	
						20			
						30			
						40			
						50	SP	Brn SAND, w/ minor gvl (md-d, m)	
						60			
						70	GP	Brn GVL w/ sand (d-wet)	
						80			
						90	SP/GP	Brn sdy gravel w/ occ cob (d, wet)	
						100			
						1		TD 100'	
						2		GW @ 64'	
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						0			

LOG ITEM # 205

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

STATE OF WASHINGTON

Permit No. 28·1E·31K

(1) OWNER: Name Fred Hill Materials - Shine Address State Rt. 104 - mile Post 10 Port

(2) LOCATION OF WELL: County Jefferson SE ¼ SE ¼ Sec 31 T 28 N. R 1E W.

(2-A) 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 feet. Depth of completed well ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6" Diam. from 0 ft. to 160 ft.

Welded ☒ Liner installed ☐ Threaded ☐

" Diam. from ft. to ft.

" 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

Type Stainless Steel Model No.

Diam 6" Slot size #80 from 155 ft. to 160 ft.

Diam 6" Slot size #12 from 150 ft. to 155 ft.

Gravel packed: Yes ☐ No ☒ Size of gravel

Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 22 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 Flint & Walling

Type: Submersible H.P. 3

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

Static level 71' 3" ft. below top of well Date 2-92

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? Driller

Yield. 60 gal./min. with 11 ft. drawdown after 1 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.

Artesian gal./min. with stem set at ft. for 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
Sand & Gravel	0	20
Sand	20	35
Hardpan	35	40
Sand	40	85
Fine Sand, little water	85	96
Brown Sandy clay	96	105
Sand, some water	105	161

RECEIVED
MAR 09 1992
DEPT. OF ECOLOGY

Work started Feb. 19 Completed Feb. 19

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 Burt Well Drilling, Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address 19782 N.E. Lincoln Rd. Poulsbo

(Signed) George Burt (WELL DRILLER) License No. 0048

Contractor's Registration No. BURTWI * 227BU Date 3-4 19

(USE ADDITIONAL SHEETS IF NECESSARY)

LOCATION
#205
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APPENDIX "A"

LOG ITEM
#205a
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RECEIVED
FEB 26 1999
JEFFERSON COUNTY
PERMIT CENTER

ROBINSON & NOBLE, INC.
GROUND WATER & ENVIRONMENTAL GEOLOGISTS
ESTABLISHED 1947

5320 ORCHARD STREET WEST
TACOMA, WASHINGTON 98467
(253) 475-7711 • FAX 472-5846

LOG ITEM
#205a
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LOG ITEM

ROBINSON & NOBLE, INC.
GROUND WATER & ENVIRONMENTAL GEOLOGISTS
ESTABLISHED 1947

RECEIVED
FEB 26 1999

February 25, 1999

Mr. Jerry Smith
Jefferson County
621 Sheridan Avenue
Port Townsend, WA 98368

Subject: Ace Paving Conditional Use Application, Critical Aquifer Recharge Area Report

Dear Mr. Smith:

Enclosed you will find a copy of our Critical Aquifer Recharge Area report for the proposed Ace Paving asphalt batch plant to be located at the Shine Pit operated by Fred Hill Materials. The report was written to be consistent with Section 11.502 of the County's Critical Areas Ordinance.

If you have any questions concerning the report, please call Jim Hay or myself at your convenience.

Sincerely,
ROBINSON & NOBLE, INC.

Joseph E. Becker
Principal Hydrogeologist

enclosure

cc: Ande Grahn, Madrona Planning

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#205a
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5320 Orchard Street West ▪ Tacoma, Washington 98467 ▪ (253) 475-7711 ▪ Fax: (253) 472-5846
rninc@wolfenet.com ▪ http://www.wolfenet.com/~rninc

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operation will be located upon concrete or asphalt pads, engineered to provide for the controlled routing and detention of accidental spills and stormwater runoff. As most of the required gravel will be obtained onsite from Fred Hill Materials, truck traffic will be limited to bringing in hot asphalt and removing hot mix. Therefore, the location of the asphalt batch plant is expected to increase truck traffic by 40 to 60 trips per day into the Shine Pit.

The production of hot-mix is a relatively straightforward process. Aggregate, stored in "cold" bins, is delivered to a dryer (via a conveyor belt) to remove any moisture. Dust and exhaust fumes (from the combustion of LP gas) are collected and sent to the "baghouse" where the air is filtered. The dry gravel is lifted, via another conveyor belt in the tower ("hot elevator"), to a screening unit that separates the aggregate by size. The aggregate is then temporarily stored in "hot" bins. Next, appropriate proportions of each aggregate size are weighed out and combined in a mixing unit or pugmill. The final step involves mixing hot, liquid asphalt with the aggregate. The resulting hot-mix is then delivered directly into waiting haul vehicles or sent via a conveyor system to a temporary storage silo for subsequent loading. When a batch plant is operational, a batch of hot-mix can often be produced in less than a minute, and is, therefore, generally produced on demand.

No water is used, or required, in the production of hot-mix. As proposed, stormwater generated from the impervious cement/asphalt pad will be collected and detained on-site, treated using an oil-water separator, and then routed to the existing gravel washing pit operated by Fred Hill Materials. This water will mix with existing water in the wash pit and eventually either evaporate after being used to wash gravel, or run into an overflow pit and infiltrate to the groundwater system. Water routed to this overflow pit is monitored by Fred Hill Materials employees for compliance with groundwater discharge requirements. The oil-water separator will be maintained by Ace Paving employees.

The potential for the proposed activities to contaminate ground water in the area is low. Not only are the physical location and the hydrogeologic setting (discussed below) of the Site favorable, the proposed activities and associated materials themselves generally present a low potential for contamination. The most abundant material on-site, aside from the native sand and gravel, will be asphalt. At ambient temperatures, asphalt is a solid substance. In order to facilitate its mixing with gravel at the batch plant, the asphalt is heated to the point at which it becomes a slow-moving liquid. Should an accidental release of liquid asphalt or hot-mix occur, whether within or beyond the concrete/asphalt pad, the material will quickly congeal allowing for the complete recovery of all released material.

The asphalt batch plant itself will operate using compressed liquid propane (LP) fuel. This fuel is a gas at atmospheric pressures. If any of this fuel were accidentally released, it will rapidly vaporize, presenting little opportunity for infiltration to occur and eliminating any risk to the local groundwater system. A 500-gallon, above-ground diesel tank will also be located on Site to provide a fuel reserve for plant generators. Additionally, a small quantity of detergents, solvents, oils, and greases will be kept on-site for general equipment maintenance and cleaning. As with all materials storage on Site, the diesel tank and other chemical storage will be integrated into the plant's spill prevention plan. The storage

facilities will be located on a concrete/asphalt pad with controlled routing and detention of any spilled material and stormwater runoff. All appropriate Best Management Practices (BMPs) regarding the filling, dispensing, and storage of diesel and other chemicals will be implemented. Therefore, the potential of groundwater contamination from these materials is slight.

Element 2: Hydrologic Evaluation

Element 2 of Section 11.502 requires a hydrogeologic evaluation of the property be performed. This evaluation needs to cover seven specific points providing descriptions of setting, topography, drainage, groundwater characteristics, locations of wells and springs, and evaluations of recharge.

As indicated in the initial DRASTIC evaluation (Appendix A), few groundwater related studies covering, or in the vicinity of, the Site have been performed. Two regional studies (Grimstad and Carson, 1981, and Economic & Engineering Services, Inc., and Pacific Groundwater Group, 1994) both mapped the predominant surface geology of the Site and adjacent areas as a sequence of glacial sediments (Quaternary in age) from the Vashon Stade of the Fraser Glaciation. The Site itself is mapped as recessional outwash, comprised of sand and gravel, which was deposited by meltwater streams as the glaciers receded. As mapped by both the 1981 and 1994 studies, the glacial till typically deposited between the advance and recessional deposits is locally absent or discontinuous. Glacial till is a poorly sorted mix of clay, silt, sand, and gravel deposited at the base of a glacier and subsequently compacted by the glacier's weight. Both studies indicate the presence of advance outwash, beneath the recessional outwash and till, if present. This advance outwash is predominantly sand with some gravel, deposited as the glaciers advanced into the area. Both regional studies grouped sediments below the advance deposits and overlying Tertiary bedrock as undifferentiated Quaternary deposits.

A more localized groundwater study (Robinson & Noble, 1992), centered on the Shine area two miles east of the Site, indicates a similar sequence of glacial sediments, but further subdivides the materials beneath the advance deposits. This study also indicates a thin and discontinuous till layer. According to this local study, which has better well control than the regional studies, the advance materials are underlain by Vashon lacustrine deposits (Qvl--glacial), Quaternary Whidbey Formation (Qw--non-glacial), Quaternary Double Bluff Drift (Qdb--glacial), and Tertiary volcanics (Tv--bedrock). Of these lower units, only the Double Bluff Drift, known to the north of Shine as the Port Ludlow South Aquifer (Robinson & Noble, 1992), is used for water production.

On February 12 and 13, field visits were performed to gather site specific information regarding the surface geology, aquifer characteristics, groundwater flow gradient and direction, and current drainage characteristics. As previously mentioned, the Site is located within an active sand and gravel mining operation and Site topography has been extensively

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modified from its pre-mining state shown on U.S. Geological Survey topographic maps (Port Ludlow and Lofall 1:24,000 quadrangles) and soil survey photographs. During these visits, a pumping test was made on the Fred Hill Materials Shine Pit well. Additionally traverses of the area were made to map locations of springs and other water features.

Element 2a: Regional Hydrogeologic Setting

In order to import the results of the 1992 Shine study into the current project area, all well logs cataloged with the Department of Ecology for the 16 sections surrounding the Site were collected and analyzed. These well logs were used to extend a cross-section from the 1992 study into the Site area. This cross-section is presented as Figure 2.

The previous studies, as well as the present work, found that there are generally two units in the region used for groundwater production: the Vashon advance outwash and the Double Bluff Drift. The two units are separated by a very thick confining layer formed by the Vashon lacustrine deposits and the Whidbey Formation. The extension of the lacustrine deposits, the Whidbey Formation, and the Double Bluff Drift into the Site area has not been proven due to a lack of deep well drilling in the area, but their existence beneath the advance outwash in the area is very probable.

Recharge to the aquifers of the region is the result of local precipitation infiltrating through surficial materials. Discharge from the Vashon outwash aquifer is via wells, spring discharge along hillsides, or through evapotranspiration. Discharge form the deep aquifer (Double Bluff) is through wells or springs and leakage to Hood Canal. In the Shine area, the majority of both domestic and purveyor wells produce water from the deep aquifer. A few domestic wells also produce from the advance outwash aquifer. There are no known wells in the Vashon recessional outwash. For additional discussion on the "local" regional hydrogeology, the reader is referred to the 1992 Shine area study.

Element 2b: Site Location, Topography, Drainage, Geology, and Surface Water

The pit area containing the Site is located on a portion of a ridge that runs roughly north south along the margin of a bluff that overlooks Squamish Harbor to the east. The thin veneer of recessional gravel, which originally was the surficial geologic unit in the area, has been removed from the portion of the pit where the site is located. The overall current topography of the pit area can best be described as relatively level to rolling, sloping slightly to the west and into the hill. The general Site area has occasional "steps" separating mining activities at different elevations. Drainage in the area is internal such that areas still covered with gravel and exposed portions of the advance outwash serve to infiltrate precipitation, and areas where clay/till is at surface generally route water towards the gravel washing pit in the northwest portion of the pit. Precipitation falling on the eastern side of the north-south ridge, upon which the Site is located, likely drains to the east down the bluff. Where till is present at the surface, water will collect into various small ephemeral stream channels. Where advance outwash is present at surface, the water may infiltrate until it reaches the

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water table which discharges along a spring line. At the spring line, water discharges to surface again, ultimately running into Shine Creek before reaching Squamish Harbor.

The only surface water body in the immediate area is the settling pond in the gravel-washing pit. This small pond is not a natural feature. Its presence is due to its location on glacial till and the constant influx of water used to wash gravel. In addition, pit employees add a flocculent to the water leaving the gravel washing apparatus causing fine-grained material to settle out of the water onto the ponds base, further reducing infiltration losses.

Element 2c: Soils and Geologic Units

Everett gravelly, sandy loam and Hoypus gravelly, loamy sand are mapped for the Site area in the Soil Survey of Jefferson County Area, Washington (U.S. Soil Conservation Service, 1975). However, these soils have been removed or disturbed as part of the mining process. In fact, no outcrops of undisturbed surficial material are available in the immediate proximity of the Site and the area has likely undergone significant compaction as a result of mining activities. In the vicinity of the Site, it appears that the material currently at land surface is a relatively thin layer of glacial till, underlain by compact advance outwash deposits composed predominantly of medium to coarse sand. However, according to the Shine Pit manager John Van Hulle, when gravel was removed from the area immediately to the west of the Site, no clay (glacial till) was encountered. Rather, the material changed abruptly from gravel to a compact coarse sand with only minor quantities of gravel. Indeed, surficial material in this area, though also highly compacted as a result of mining activities, is much less clay-rich than further east and appears to be composed of advance outwash deposits.

The presence or absence of a glacial till, if present, can be significant to the overall hydrogeology of a site. By impeding the downward movement of water, glacial till can support a perched aquifer system, particularly during the wet, winter season. However, there is no evidence of a perched aquifer system in the area. Also, the till can act as a confining layer and provide additional contamination protection for deeper aquifers. The only well located within this section (the Fred Hill Shine Pit well—attached as part of Appendix A) does indicate a thin zone of "hardpan" at a depth of 30 to 35 feet, which may possibly be glacial till or alternatively may be a clay and gravel zone within the advance outwash. However, the materials overlying this unit are not indicated as water bearing, despite the fact that the well was drilled during February, a typically wet month throughout Puget Sound. This suggests that the glacial till in this area is thin, discontinuous, and unlikely to support a significant perched aquifer system. This conclusion is supported by other observations. Mining, both near the Site (as described above) and north of the Site reportedly found recessional outwash directly overlying advance outwash. Regional geologic mapping (also described earlier) also found a lack of till.

The soils and geologic units underlying the Site can be summarized as follows. No natural soils remain on the Site or the surrounding pit area. Surficial materials are compacted

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recessional outwash (highly gravelly), advance outwash (less gravel more sand), or in a few places glacial till (clay-rich gravel). In the Site area itself, part of the surface material is clay-rich and part not. Three geologic units are confirmed to be in the area: recessional and advance outwash, and a discontinuous, thin till. Beneath the advance outwash, a clay-rich lacustrine unit probably exists.

Elements 2d and e: Ground Water, Well, and Spring Characteristics

During the site visit on February 13, a 2-hour constant rate test was performed on the Fred Hill Shine Pit well in order to determine aquifer characteristics. This well is located approximately 400 feet west of the Site. No other wells were found, or are known to exist, nearby in which observations could be made. Drawdown and recovery graphs for the pumping well are presented as Figures 3 and 4, respectively. Prior to test, the well had been dormant for approximately 16 hours and the static water level in the well was 61.54 feet BTC (below the top of casing). Pumping was initiated at a rate of 36 gallons per minute, as measured at a water meter installed on the well's discharge line. After the start of pumping, the water level declined rapidly to approximately 70 feet below top of casing (a drawdown of six-and-a-half feet) where it stabilized for the remainder of the test (Figure 3). The pump was turned off after two hours of production. The water level in the well recovered slowly for the first two minutes after pump shutdown due to a siphoning effect in the discharge line (Figure 4). After approximately two-and-a-half minutes, when suction in the discharge line was broken, water was able to freely enter the well and the water level quickly rose to approximately 62.5 feet BTC. Recovery during the remainder of monitoring was steady and predictable. The transmissivity of the aquifer, as determined from the recovery plot, is 27,000 gpd/ft^2 (gallons per day per foot squared).

During the field visits, the area within several thousand feet of the Site was canvassed to locate wells and springs. No wells were found, and no springs were located within 1,000 feet of the Site. However, three springs were located east and below the Site at approximate distances of 1,500 to 2,000 feet. These spring locations are shown on Figure 1. These springs exist as numerous small seeps which collectively discharge at flow rates estimated to be 50 to 100 gpm. These springs are believed to represent discharge point for the advance outwash aquifer, occurring at or near the base of the aquifer.

Altimeter surveys were performed to determine the elevation of the well relative to the springs (and to surveyed road intersections indicated on the USGS topographic maps). The survey found the water level in the well to be 259.5 feet above MSL (mean sea level), and the elevation of the springs range from 155 to 171 feet above MSL. This implies that the depth to the water table beneath the Site is currently about 100 feet. The elevations of these springs and of the static water level in the well allowed an approximate flow direction and gradient to be calculated. This data indicates that flow direction is almost due east towards Squamish Harbor (as was initially suggested by a cursory potentiometric map constructed for the area as part of this investigation). Because the water surface from the position of the well to the spring line is convex-up in nature and not straight, the straight-

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line gradient (0.05) calculated from this elevation data represents an upper-bound estimate of gradient. However, due to the lack of other wells in this area, this straight-line gradient was used in the analytical flow model discussed below.

On February 12, water samples were collected from the well and submitted to Water Management Labs for inorganic, bacterial, and volatile organic compound (VOC) analyses (Appendix B). All aspects of the water quality meet the Department of Health's water quality standards. An additional sample, analyzed in our in-house lab, confirms these findings. The water appears to be free from current contamination.

Element 2f and g: Groundwater Recharge

Recharge to the groundwater system can be determined by taking the amount of water imported to the system (i.e., precipitation) and subtracting that amount of water that is exported from the system (i.e., evapotranspiration and runoff). The 1994 Economic & Engineering Services and Pacific Groundwater Group (EES/PPG) study estimates annual recharge for the Site area to be 15 to 20 inches per year based upon assumptions of typical evapotranspiration and runoff for the region. Given the lack of soil and vegetation across the majority of the pit area and the predominantly internal drainage of the pit area, this recharge estimate likely represents a lower-bound estimate for the Site. An upper-bound estimate of recharge to this area can be obtained directly from the long-term average precipitation. Recharge occurs from precipitation after the demands of evaporation, transpiration and runoff are satisfied. In this case, there will be little to no transpiration because the pit area is largely devoid of vegetation. Evaporation will be minimal because most precipitation occurs during the winter months. Runoff is minimal because of the permeable nature of much of the area. The runoff that does occur is internal, with pond overflow infiltrating (as recharge).

A U.S. Weather Bureau map (U.S. Weather Bureau, 1965--presented in the 1994 EES/PPG study) presents an isohyetal map of the long-term (1930-1957) mean annual precipitation for eastern Jefferson County. This map indicates that the Site receives approximately 33 inches of precipitation per year. More recent (incorporating data through 1998) long-term mean annual precipitation calculations (Robinson & Noble, Inc., 1999) indicate that the long-term mean annual precipitation for the Site is more appropriately 38 inches per year. Assuming small evapotranspiration losses, the recharge is possibly greater than 30 inches per year on average.

The proposed facility uses no water in the production of hot-mix. As proposed, the asphalt batch plant will collect and route stormwater to the existing settling pond in the gravel washing pit. Water entering this pond is either evaporated or, in times of peak flow, infiltrated into the subsurface via the overflow pits. Because of the small size of the impermeable area within the project (one-half acre) and the fact that some of the runoff from this area will still ultimately be recharged through infiltration, the project will have essentially no impact on the amount of recharge to the aquifer.

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Element 3: Contaminant Transport Model

The proposed project will not involve the importation of significant quantities of materials with the potential to contaminate local groundwater resources. As indicated above, the primary materials associated with the proposed activities are sand and gravel (native to the area), liquid asphalt, and compressed LP fuel. None of these pose a threat to the groundwater resource either because the material is not a contaminant or because the materials, at atmospheric temperatures and pressures, will not have an opportunity to infiltrate into the subsurface. The only hazardous material that will be brought on site in any quantity which constitutes a potential contaminant is diesel fuel. Although diesel fuel does adsorb to particles in the vadose zone (which is calculated to be approximately 100 feet thick at the Site; see element 2d) and partition in a specific fashion into the saturated zone, the assumption made here is that, if contaminants are introduced via a surface spill, some will eventually move with the water through the groundwater system. In order to evaluate flow through this system, an analytical flow model (WinFlow Version 1.02) was utilized. The inputs for the model (gradient, transmissivity, and aquifer thickness) were based on the hydrogeologic evaluation conducted for Element 2.

The project is located downgradient of the only well on site. Based upon the analytical model results, a contaminant infiltrating into the subsurface in proximity to the Site would flow to the east-southeast and discharge to surface along the bluff within a matter of six months after reaching the water table. The steep gradient, high aquifer transmissivity, and short travel time within the aquifer function to minimize the dispersal of contaminants within the aquifer. A spill confined to the Site itself would likely result in a contaminant plume that is no more than several hundred feet wide at the spring line. In this scenario, not all the contaminated water from such a spill would end up in the surface water system because a significant portion of this discharged water would be expected to feed the evapotranspiration demand of trees and underbrush that covers the bluff. It is unlikely that any contaminated water would discharge from the three springs located during the field survey as they are not directly downgradient from the Site.

Elements 5 and 6: Spill Response, Training, and Best Management Practices

The applicant will prepare spill response and prevention procedures consistent with those presented in National Asphalt Pavement Association guidance manuals (Rugg, 1994; Rugg, 1996). The primary on-site spill containment equipment will consist of the above-grade cement/asphalt slab engineered to capture and detain both stormwater and potential spills. This system will route and detain stormwater (and spills) for treatment prior to delivery to the gravel-washing pit maintained by Fred Hill Materials. All employees will receive spill response training and be trained in the proper use of all spill response equipment. Ace Paving will contact the local Fire District and prepare a pre-fire plan to address the fire department's response to foreseeable plant emergencies. Should a waste material spill

occur, plant employees will contact either Jefferson County Planning or Environmental Health Department staff and submit a spill response report documenting the quantity and type of materials spilled, and response procedures implemented. Land surface in the immediate proximity of the Site is relatively impermeable due to the presence of glacial till, however the plant and its employees will exercise spill prevention methodologies consistent with the Puget Sound Stormwater Manual Best Management Practices (BMPs).

Elements 4 and 7: Cumulative Impacts and Monitoring Program

Element 4 deals with cumulative impacts to groundwater quality. This proposed land use should have no impact to water quality, cumulative or otherwise. Element 7 deals with a water quality monitoring program. Stormwater runoff from the Site will be directed to the present gravel-wash pit. Fred Hill Materials currently operates a monitoring program for this wash pit, and runoff from the Site will be handled under this current program.

Conclusions

The proposed Ace Paving asphalt batch plant to be located within the Shine Pit operated by Fred Hill Materials should have no impact to local ground water. The proposed location does overlie a water table aquifer, which exists within Vashon advance outwash sediments. However, there is only one known user of this aquifer, that is Fred Hill Materials which maintains a well for wash water in the aquifer. No domestic residences were found in the area.

The batch plant should have a negligible effect on groundwater quantity. Though the plant is to have an impermeable footprint, stormwater runoff from the plant will be routed to the gravel wash pond where some of it will infiltrate anyway. Additionally, the small size of the plant itself precludes any significant impact, particularly in a regional sense since the plant is to be located in an area of enhanced (above natural levels) recharge due to the stripping of vegetation and soils by the gravel mining.

The batch plant should have no impact to groundwater quality. The main materials to be used by and produced from the plant do not present a contamination hazard. Small amounts of diesel fuel and solvents will be stored on the site; however, if accidentally spilled, they should be detained by the stormwater capture system where they can be cleaned up. The use of BMPs will further prevent contamination events. In the unlikely event contamination does reach the aquifer, modeling indicates it will discharge to the surface several thousand feet east of the site where most the contaminated water should be consumptively used by natural vegetation.

The statements, conclusions, and recommendations provided in this report are to be exclusively used within the context of this document. They are based upon generally accepted hydrogeologic practices and are the result of analysis by Robinson & Noble, Inc. staff. This report, and any attachments to it, are for the exclusive use of Ace Paving. Unless specifically stated in the document, no warranty, expressed or implied, is made.

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APPENDIX A

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ROBINSON & NOBLE, INC.
GROUND WATER & ENVIRONMENTAL GEOLOGISTS
ESTABLISHED 1947

August 19, 1998

Scalf

Mr. Al Scals, Planning Director
Jefferson County
621 Sheridan Avenue
Port Townsend, WA 98368

Subject: Application of DRASTIC to the proposed asphalt batch plant, near Port Ludlow, Jefferson County, Washington.

Dear Mr. Scals:

We were asked by Madrona Planning to provide a DRASTIC evaluation for an asphalt batch plant proposed by Ace Paving. The proposed asphalt batch plant is located near Port Ludlow, Washington, in Jefferson County, T. 28 N., R. 1 E., Section 32. The site is approximately 60 acres in size, although for this evaluation, the 100 acres surrounding the site was evaluated (Figure 1).

The site is mapped as Quaternary Vashon recessional outwash, which consists primarily of gravel with some sand, silt and clay (Carson and Grimstad, 1981). The site is currently located within a gravel quarry on a piece of land that is no longer being quarried. The Vashon recessional outwash is assumed to be the unit that has been quarried in this area. Field inspection of the site has shown that underlying the Vashon recessional outwash is the Quaternary Vashon lodgement till, which has a high clay content with some gravel and sand and has been described as hardpan. The lodgement till is the exposed unit on which the plant will stand on. This unit has low permeability. Other studies suggest the till is thin and underlain by Vashon advance outwash at a shallow depth (Economic and Engineering Services, Inc., and Pacific Groundwater Group, 1994).

The DRASTIC evaluation procedure (Aller and others, 1987) provides slightly different evaluations for confined and unconfined aquifers. Based on available data, it is not totally clear whether the aquifer beneath the proposed batch plant site is unconfined. Well logs for a one-mile radius surrounding the plant were collected from the Department of Ecology. Only one well within the hundred-acre study area was found, the Fred Hill Shine Pit Well (well log attached). This log shows water-bearing sand from 85-96 feet and 105-160 feet in depth. Immediately above these units is also sand which was not noted as water-bearing. The reported static water level is 71.25 feet; however, this water level is for the lower of the two water-bearing zones, and a water level is not reported for the upper zone. The nine feet of material separating the two zones is described as sandy clay. Two possibilities exist for

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the described situation. First, that the two zones are actually part of the same aquifer, which is unconfined (and the materials between 71 and 86 feet are actually water-bearing, though not noted as such). Or second, that the zones represent two separate aquifers, the upper one being unconfined with a water level around 85 feet and the lower one confined with a water level at 71 feet. Since the site is situated in a hydrogeologic setting in which deeper aquifers typically have lower water levels than upper aquifers, the second possibility is less likely than the first. Additionally, Aller et. al. (1987) state that if an aquifer cannot be determined to be confined or unconfined, it should be treated as unconfined. Therefore, for this DRASTIC evaluation, the aquifer will be considered as unconfined.

Creating a DRASTIC index for a site allows for the evaluation of its relative vulnerability to groundwater contamination. DRASTIC incorporates the following seven factors to characterize possible danger of contamination: depth to water, net recharge, aquifer media, topography, impact of the vadose zone, and hydraulic conductivity.

Depth to Water

The depth to water reported on the attached well log was 71.25 feet below land surface, as measured in February 1992. Reportedly, this well was drilled after the area was quarried and, therefore, the water level depth is appropriate for today's conditions. This depth fits in the DRASTIC water level range of 50 to 75 feet, which has a rating of 3.

Net Recharge

Recharge is often difficult to quantify. In this case, however, an aquifer study was completed for the Shine area several miles northeast of the site. According to the report entitled *South Aquifer Study, Port Ludlow/Shine Area* (Robinson & Noble, 1992), the Shine area has a net recharge of 11 inches per year. The net recharge for the Ace Paving site can conservatively be estimated at more than 11 inches per year due to it being located to the southwest of the Shine area (and less in the rainshadow of the Olympics), and to the site having less evapotranspiration than the Shine area (since the site is largely devegetated). In a separate study of eastern Jefferson County, the general area of the site was thought to have a recharge rate of 15 to 20 inches (Economic and Engineering Services, Inc., and Pacific Groundwater Group, 1994). All recharge values above 10 inches yield a DRASTIC rating of 9.

Aquifer Media

The aquifer tapped by the Fred Hill Materials - Shine Pit well was described by the driller as sand. According to DRASTIC, sand and gravel have ratings of 4 to 9. Due to the lack of gravel within this aquifer, a conservative rating of 7 was chosen.

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Soil Media

The site being evaluated is currently a gravel pit from which the soil has been removed during quarrying. However, portions of the 100-acre study area extend outside the quarry area and do have soils. Because these soils are very gravelly (due to the surface geology being recessional outwash gravel) and the majority of the study area is without soil, a DRASTIC rating of 10 was given for this factor.

Topography

Most of the site being evaluated has a gentle slope. However, the northeast portion of the study area dips downward to an elevation of approximately 200 feet, while the southwest corner has an elevation of 320 feet. This results in a maximum slope of 4 percent across the study area, although the average slope is certainly at 2 percent or less. A DRASTIC slope rating of 10, which is assigned to slopes of 0-2 percent, was used here.

Impact of Vadose Zone

According to the Fred Hill Shine Pit well log, the vadose zone materials are "hardpan" and sand. The hardpan is likely till and can be considered the same as the DRASTIC vadose zone material range called "sand and gravel with significant silt and clay", which is rated from 4 to 8. Sand is given a rating of 6 to 9. With the combination of the two units, a conservative rating of 7 was assigned.

Hydraulic Conductivity

The aquifer material is described as sand and fine sand. The specific capacity of the Fred Hill Materials Well at the time of construction was about 5.45 gpm/ft (gallons per minute per foot of drawdown) after pumping for one hour. According to a chart for estimating hydraulic conductivity from Heath (1983), the hydraulic conductivity for fine to medium sand materials is in the range of 10 to 700 gpd/ft^2. Using an equation for estimating transmissivity from Driscoll (1986) based on specific capacity, the aquifer has a transmissivity of 8175 gpd/ft, which computes to a hydraulic conductivity of 92 gpd/ft^2. Using the Theis equation and estimating a storage coefficient of 0.1, the estimated hydraulic conductivity based on test data form the well log is 586 gpd/ft^2. It can be concluded from these analyses that the conductivity is likely in the 300 to 700 gpd/ft^2 range, which has a rating of 4.

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Drastic Index

The DRASTIC index for this unconfined aquifer is given below. The weighting for each DRASTIC factor is multiplied by the rating as determined above and the sum of the products forms the DRASTIC index.

Factor	Weight	Rating	Total
Depth to water	5	3	15
Net Recharge	4	9	36
Aquifer Media	3	7	21
Soil Media	2	10	20
Topography	1	10	10
Impact of Vadose Zone	5	7	35
Hydraulic Conductivity	3	4	12
	DRASTIC Index =		149

Summary

The DRASTIC index for this aquifer is 149. This rating reflects the low permeability of the exposed surface and vadose zone, the low slope, the moderate depth to water for the aquifer, and the relatively low to moderate hydraulic conductivity of the aquifer. This aquifer is apparently tapped by only one well in the near vicinity of the site. Other nearby wells, based on Department of Ecology logs, are approximately 4000 feet from the site and at a considerably lower elevation (located east of the site, near the Squamish Harbor). Based on the relatively low DRASTIC index and the lack of nearby wells, the drinking water supply for the area does not appear to be vulnerable to potential contamination by the proposed plant.

Respectfully Submitted,
Robinson & Noble, Inc.

Krista Sovie
Hydrogeologist

enclosures

cc: Ande Grahn, Madrona Planning
Richard Christopherson, Ace Paving

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APPENDIX B

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USE HEAVY PEN
DO NOT WRITE IN SHADED AREAS

MANAGEMENT LABORATORIES INC.
Tacoma, WA 98401
(253) 531-3121

INORGANIC CHEMICALS (IOCS) REPORT

System ID No: NA | System Name: Shine Pit

Lab Sample No: 08936828 | Date Collected: 2-12-99 | DOH Source No: NA

Multiple Source Nos: NA | Sample Type: B | Sample Purpose: I

Date Received: 2-12-99 | Date Reported: 2-18-99 | Supervisor: [illegible]

County: Jefferson | Date Digested: NA | Group: A B (Other)

Sample Location: Well spigot

Send Report To: Robinson & Noble
5320 Orchard St W
Tacoma WA 98467

Bill To:

DOH#	ANALYTES	RESULTS	UNITS	SRL	TRIGGER	MCL	EXCEEDS Trigger?	EXCEEDS MCL?	Method / Analyst	
	EPA REGULATED									
4	Arsenic	<0.01	mg/l	0.01	0.05	0.05	NO	NO	3113B	[illegible]
5	Barium	<0.1	mg/l	0.1	2	2			3113B	[illegible]
6	Cadmium	<0.002	mg/l	0.002	0.005	0.005			3113B	[illegible]
7	Chromium	0.01	mg/l	0.01	0.1	0.1			3113B	[illegible]
11	Mercury	<0.0005	mg/l	0.0005	0.002	0.002			3112B	[illegible]
12	Selenium	<0.005	mg/l	0.005	0.05	0.05			3113B	[illegible]
110	Beryllium	<0.002	mg/l	0.003	0.004	0.004			3113B	[illegible]
111	Nickel	<0.04	mg/l	0.04	0.1	0.1			3111B	[illegible]
112	Antimony	<0.002	mg/l	0.005	0.006	0.006			3113B	[illegible]
113	Thallium	<0.001	mg/l	0.002	0.002	0.002			3113B	[illegible]
11	Cyanide	<0.05	mg/l	0.05	0.2	0.2			4500-CNF	[illegible]
19	Flouride	<0.2	mg/l	0.2	2	4			4110B	[illegible]
114	Nitrite - N	<0.2	mg/l	0.5	0.5	1			4110B	[illegible]
20	Nitrate - N	<0.2	mg/l	0.5	5	10			4110B	[illegible]
161	Total Nitrate/Nitrite	<0.4	mg/l	0.5	5	10			4110B	[illegible]
	EPA REGULATED (Secondary)									
8	Iron	<0.03	mg/l	0.1	0.3	0.3	NO	NO	3111B	[illegible]
10	Manganese	<0.01	mg/l	0.01	0.05	0.05			3111B	[illegible]
13	Silver	<0.01	mg/l	0.01	0.1	0.1			3111B	[illegible]
21	Chloride	2	mg/l	20	250	250			4110B	[illegible]
22	Sulfate	4	mg/l	10	250	250			4110B	[illegible]
24	Zinc	<0.05	mg/l	0.2	5	5			3111B	[illegible]
	STATE REGULATED									
14	Sodium	7	mg/l	5					3111B	[illegible]
15	Hardness	51	mg/l	10					2340C	[illegible]
16	Conductivity	122	umhos/cm	10	700	700	NO	NO	2510B	[illegible]
17	Turbidity	0.3	NTU	0.1	1		NO		2130B	[illegible]
18	Color	<5	color units	5	15	15	NO	NO	2120B	[illegible]
26	Total Dissolved Solids	82	mg/l	150	500	500	NO	NO	2540C	MSL
	STATE UNREGULATED									
9	Lead	<0.002	mg/l	0.002					3113B	[illegible]
23	Copper	<0.02	mg/l	0.2					3111B	[illegible]

COMMENTS: R+N Special

A 1,2,3

ML 2-18-9

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OH#	ANALYTES	RESULTS	UNITS	SRL	TRIGGER	MCL	EXCEEDS		Method / Analyst	
	OTHER *(Optional)*						Trigger?	MCL?		
171	Orthophosphate	NA	mg/l	0.1						
172	Silica	30	mg/l	1.0					4500-Si D	WMA
402	Aluminum	NA	mg/l	0.05						
403	Alkalinity	NA	mg/l	10						
404	Magnesium	4	mg/l	0.1					3500-Mg E	GPS
405	Calcium	13	mg/l	0.5					3500-Ca D	GPS
406	Ammonia	NA	mg/l	1						
	CARBONATE AS $CaCO_3$	Ø	mg/L						2320	GPS
	BICARBONATE AS $CaCO_3$	59	mg/L						2320	GPS
	POTASSIUM	0.5	mg/L						3111 B	GPS
	pH	7.2	UNITS						4500-H^+	WMA

NOTES:

SRL (State Reporting Level): indicates the minimum reporting level required by the Washington Department of Health (DOH).

gger Level: DOH Drinking Water response level. Systems with compounds detected at concentrations in excess of this level are required to take additional samples. Contact your regional DOH office for further information.

MCL (maximum contaminent level): If the contaminent amount exceeds the MCL, immediately contact your regional DOH office.

A (Not Analyzed): in the results column indicates this compound was not included in the current analysis.

ND (Not Detected): in the results column indicates this compound was analyzed and not detected at a level greater than or equal to the SRL.

(0.001): indicates the compound was not detected in the sample at or above the concentration indicated.

COMMENTS:

ML
2-18-99

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WATER MANAGEMENT LABORATORIES INC.

1515 80th St. E.
Tacoma, WA 98404
(253) 531-3121

VOLATILE ORGANIC CHEMICALS (VOC's) ANALYSIS REPORT
EPA TEST METHOD - 524.2

System ID No. : NA	System Name: Shine Pit Well	
Lab/Sample No. : 08975014	Date Collected : 02/12/99	DOH Source No. : NA
Multiple Source Nos. : NA	Sample Type: B	Sample Purpose : I
Date Received : 02/12/99	Date Reported : 02/18/99	Supervisor :
	Date Analyzed : 02/16/99	Analyst : WMA
County : Jefferson	Group : Private	
Sample Location : Well Spigot		
Send To: Robinson & Noble, Inc. 5320 Orchard St. W; Tacoma, WA 98467	Bill To : SAME	

DOH #	ANALYTES	RESULTS	UNITS	SRL	TRIGGER	MCL	EXCEEDS	
	EPA REGULATED						Trigger?	MCL?
45	Vinyl Chloride	ND	ug/L	0.5	0.5	2	NO	NO
46	1,1 - Dichloroethylene	ND	ug/L	0.5	0.5	7	NO	NO
47	1,1,1 - Trichloroethane	ND	ug/L	0.5	0.5	200	NO	NO
[illegible]	Carbon Tetrachloride	ND	ug/L	0.5	0.5	5	NO	NO
[illegible]	Benzene	ND	ug/L	0.5	0.5	5	NO	NO
50	1,2 - Dichloroethane	ND	ug/L	0.5	0.5	5	NO	NO
51	Trichloroethylene	ND	ug/L	0.5	0.5	5	NO	NO
52	1,4 - Dichlorobenzene	ND	ug/L	0.5	0.5	75	NO	NO
56	Dichloromethane	ND	ug/L	0.5	0.5	5	NO	NO
57	trans-1,2 - Dichloroethylene	ND	ug/L	0.5	0.5	100	NO	NO
60	cis-1,2 - Dichloroethylene	ND	ug/L	0.5	0.5	70	NO	NO
63	1,2 - Dichloropropane	ND	ug/L	0.5	0.5	5	NO	NO
66	Toluene	ND	ug/L	0.5	0.5	1000	NO	NO
67	1,1,2 - Trichloroethane	ND	ug/L	0.5	0.5	5	NO	NO
68	Tetrachloroethylene	ND	ug/L	0.5	0.5	5	NO	NO
71	Chlorobenzene	ND	ug/L	0.5	0.5	100	NO	NO
73	Ethylbenzene	ND	ug/L	0.5	0.5	700	NO	NO
76	Styrene	ND	ug/L	0.5	0.5	100	NO	NO
84	1,2 - Dichlorobenzene	ND	ug/L	0.5	0.5	600	NO	NO
95	1,2,4 - Trichlorobenzene	ND	ug/L	0.5	0.5	70	NO	NO
160	Total Xylenes	ND	ug/L	0.5	0.5	10000	NO	NO
74	m/p Xylenes (MCL for Total)	ND	ug/L	0.5	0.5		NO	
75	o - Xylene (MCL for Total)	ND	ug/L	0.5	0.5		NO	
	EPA UNREGULATED							
27	Chloroform	ND	ug/L	0.5	0.5		NO	
28	Bromodichloromethane	ND	ug/L	0.5	0.5		NO	
29	Chlorodibromomethane	ND	ug/L	0.5	0.5		NO	
[illegible]	Bromoform	ND	ug/L	0.5	0.5		NO	
53	Chloromethane	ND	ug/L	0.5	0.5		NO	
54	Bromomethane	ND	ug/L	0.5	0.5		NO	
55	Chloroethane	ND	ug/L	0.5	0.5		NO	

LOG ITEM

Water Management Laboratories, Inc.
1515 80th St. E.
Tacoma, WA 98404
(253) 531-3121

DOH #	ANALYTES	RESULTS	UNITS	SRL	TRIGGER	MCL	EXCEEDS	
		EPA UNREGULATED (Continued)					Trigger?	MCL?
58	1,1 - Dichloroethane	ND	ug/L	0.5	0.5		NO	
59	2,2 - Dichloropropane	ND	ug/L	0.5	0.5		NO	
62	1,1 - Dichlroropropene	ND	ug/L	0.5	0.5		NO	
64	Dibromomethane	ND	ug/L	0.5	0.5		NO	
70	1,3 - Dichloropropane	ND	ug/L	0.5	0.5		NO	
72	1,1,1,2 - Tetrachlroroethane	ND	ug/L	0.5	0.5		NO	
78	Bromobenzene	ND	ug/L	0.5	0.5		NO	
79	1,2,3 - Trichloropropane	ND	ug/L	0.5	0.5		NO	
80	1,1,2,2 - Tetrachloroethane	ND	ug/L	0.5	0.5		NO	
81	o - Chlorortoluene	ND	ug/L	0.5	0.5		NO	
82	p - Chlorotoluene	ND	ug/L	0.5	0.5		NO	
83	m - Dichlorobenzene	ND	ug/L	0.5	0.5		NO	
154	1,3 - Dichlororopene	ND	ug/L	0.5	0.5		NO	
		STATE UNREGULATED						
65	cis-1,3 - Dichloropropene	ND	ug/L	0.5	0.5		NO	
69	trans-1,3 - Dichloropropene	ND	ug/L	0.5	0.5		NO	
85	Fluorotrichloromethane	ND	ug/L	0.5	0.5		NO	
86	Bromochloromethane	ND	ug/L	0.5	0.5		NO	
87	Isopropylbenzene	ND	ug/L	0.5	0.5		NO	
[illegible]	n - Propylbenzene	ND	ug/L	0.5	0.5		NO	
89	1,3,5 - Trimethylbenzene	ND	ug/L	0.5	0.5		NO	
90	t - Butylbenzene	ND	ug/L	0.5	0.5		NO	
91	1,2,4 - Trimethylbenzene	ND	ug/L	0.5	0.5		NO	
92	s - Butylbenzene	ND	ug/L	0.5	0.5		NO	
93	p - Isopropylbenzene	ND	ug/L	0.5	0.5		NO	
94	n - Butylbenzene	ND	ug/L	0.5	0.5		NO	
96	Napthalene	ND	ug/L	0.5	0.5		NO	
97	Hexachlorobutadiene	ND	ug/L	0.5	0.5		NO	
98	1,2,3 - Trichlorobenzene	ND	ug/L	0.5	0.5		NO	
102	EDB (Confirm by 504.1)	ND	ug/L	0.5	0.5		NO	
103	DBCP (Confirm by 504.1)	ND	ug/L	0.5	0.5		NO	
162	Dichlorodifluoromethane	ND	ug/L	0.5	0.5		NO	

NOTES:

SRL (State Reporting Level): Indicates the minimum reporting level required by the Washington Department of Health (DOH).

Trigger Level: DOH Drinking Water response level. Systems with compounds detected at concentrations in excess of this level are required to take additional samples. Contact your regional DOH office for further information.

MCL (Maximum Contaminant Level): If the contaminant amount exceeds the MCL, immediately contact your regional DOH office.

NA (Not Analyzed): In the RESULTS column indicates this compound was not included in the current analysis.

ND (Not Detected): In the RESULTS column indicates this compound was analyzed and not detected at a level greater than or equal to the SRL.

< : Indicates less than.

Comments : A level of 100 ug/L total Trihalomethanes (Compounds 27-30) is allowed.

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(253) 561-3121

WATER BACTERIOLOGICAL ANALYSIS

SAMPLE COLLECTION: READ INSTRUCTIONS ON BACK OF GOLDENROD COPY
If instructions are not followed, sample will be rejected.

DATE COLLECTED MONTH / DAY / YEAR	TIME COLLECTED	COUNTY NAME
2 / 12 / 99	9 : 48 ☒ AM ☐ PM	JEFFERSON Co.

TYPE OF SYSTEM	IF PUBLIC SYSTEM, COMPLETE	
☒ PUBLIC ☐ INDIVIDUAL (serves only 1 residence)	I.D. No.	CIRCLE GROUP A B

NAME OF SYSTEM
SHINE PIT

SPECIFIC LOCATION WHERE SAMPLE COLLECTED (ie, kitchen tap @ school, fire station, fountain)	TELEPHONE NO.
WELL SPIGOT	DAY (253) 475-7711 EVENING ( )
SAMPLE COLLECTED BY: (Name)	SYSTEM OWNER / MGR.: (Name) JOHN VAN HULLE

SOURCE TYPE ☐ GROUND WATER UNDER SURFACE INFLUENCE
☐ SURFACE ☒ WELL or WELL FIELD ☐ SPRING ☐ PURCHASED or INTERTIE ☐ COMBINATION or OTHER

SEND REPORT TO: (Print Full Name, Address and Zip Code)
ROBINSON & NOBLE, INC.
5320 ORCHARD ST. WEST
TACOMA WASHINGTON 98467

TYPE OF SAMPLE (check only one in this column)

☒ ROUTINE DRINKING WATER check treatment
- ☐ Chlorinated (Residual:___Total ___Free)
- ☐ Filtered
- ☒ Untreated or Other_____

☐ REPEAT SAMPLE
Previous coliform presence Lab #_____
Previous coliform presence Date_____/_____/_____

☐ RAW SOURCE WATER Source # S
☐ NEW CONSTRUCTION or REPAIRS
☐ Total Coliform
☐ Fecal Coliform

☐ Other (Specify) _____

REMARKS

LABORATORY RESULTS (FOR LAB USE ONLY)

METHOD USED

MF	MPN	PA	MMO	CPRG

TOTAL COLIFORM_____/100 ml
FECAL COLIFORM_____/100 ml
E. COLI_____/100 ml
HETEROTROPHIC_____/per ml

ANOTHER SAMPLE REQUIRED

SAMPLE NOT TESTED BECAUSE:
- ☐ Sample too old
- ☐ Wrong container
- ☐ Incomplete form
- ☐ _____

TEST UNSUITABLE BECAUSE:
- ☐ Confluent growth
- ☐ TNTC
- ☐ Turbid culture
- ☐ Excess debris

DRINKING WATER SAMPLE RESULTS

☐ UNSATISFACTORY, Coliforms present
REPEAT SAMPLES REQUIRED: ☐ E. Coli present ☐ E. Coli absent ☐ Fecal present ☐ Fecal absent

☒ SATISFACTORY Coliforms absent

SEE REVERSE SIDE OF GREEN COPY FOR EXPLANATION OF RESULTS

LAB NO.	DATE, TIME RECEIVED	RECEIVED BY
0897 8009	2-12-99 3:35 pm	TW

DATE REPORTED		ROUTE	ACCT. #
2-16-99			

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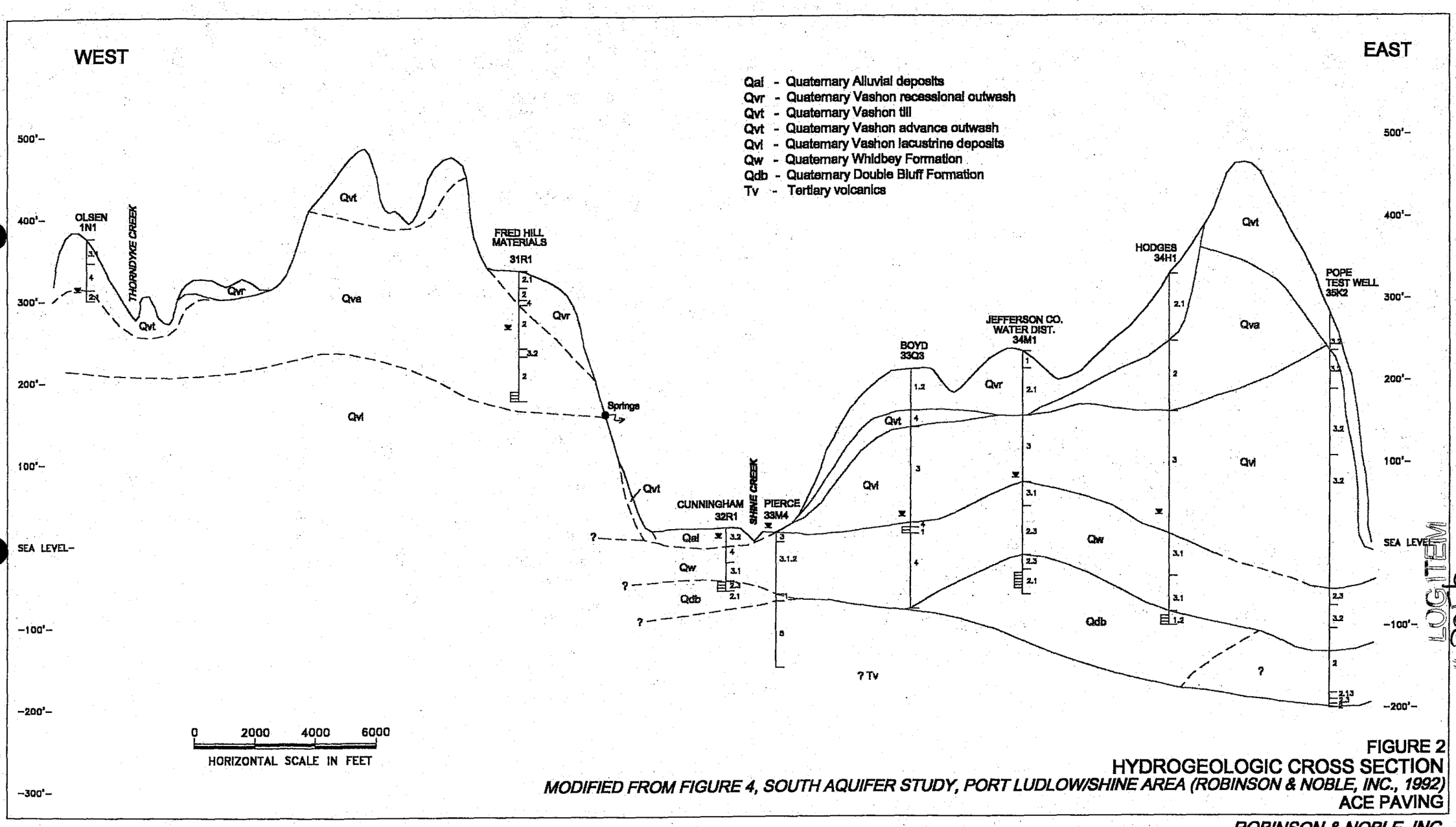

FIGURE 2
HYDROGEOLOGIC CROSS SECTION
MODIFIED FROM FIGURE 4, SOUTH AQUIFER STUDY, PORT LUDLOW/SHINE AREA (ROBINSON & NOBLE, INC., 1992)
ACE PAVING

ROBINSON & NOBLE, INC.

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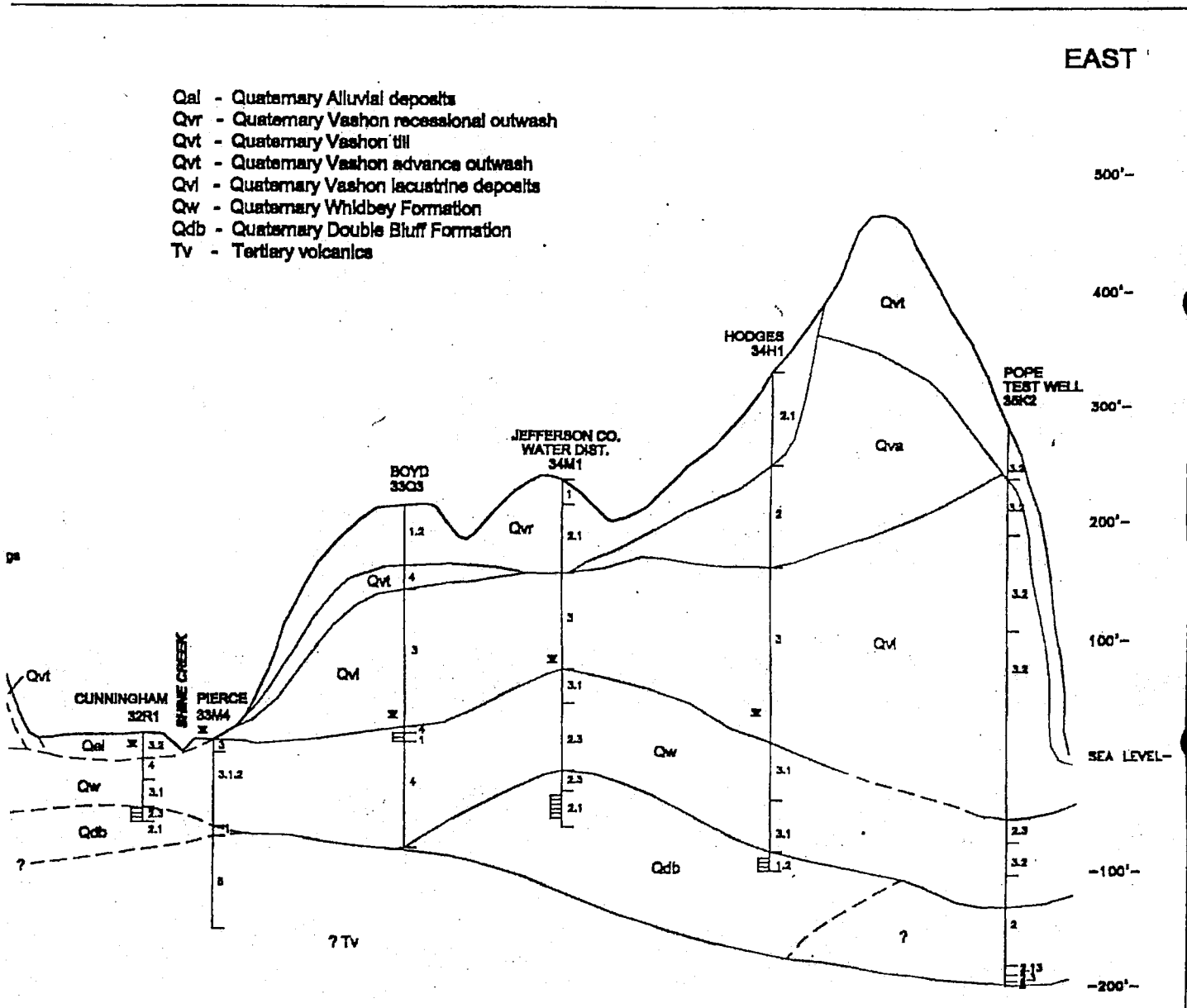

FIGURE 2
HYDROGEOLOGIC CROSS SECTION
FROM FIGURE 4, SOUTH AQUIFER STUDY, PORT LUDLOW/SHINE AREA (ROBINSON & NOBLE, INC., 1992)
ACE PAVING

ROBINSON & NOBLE, INC.

FIGURES

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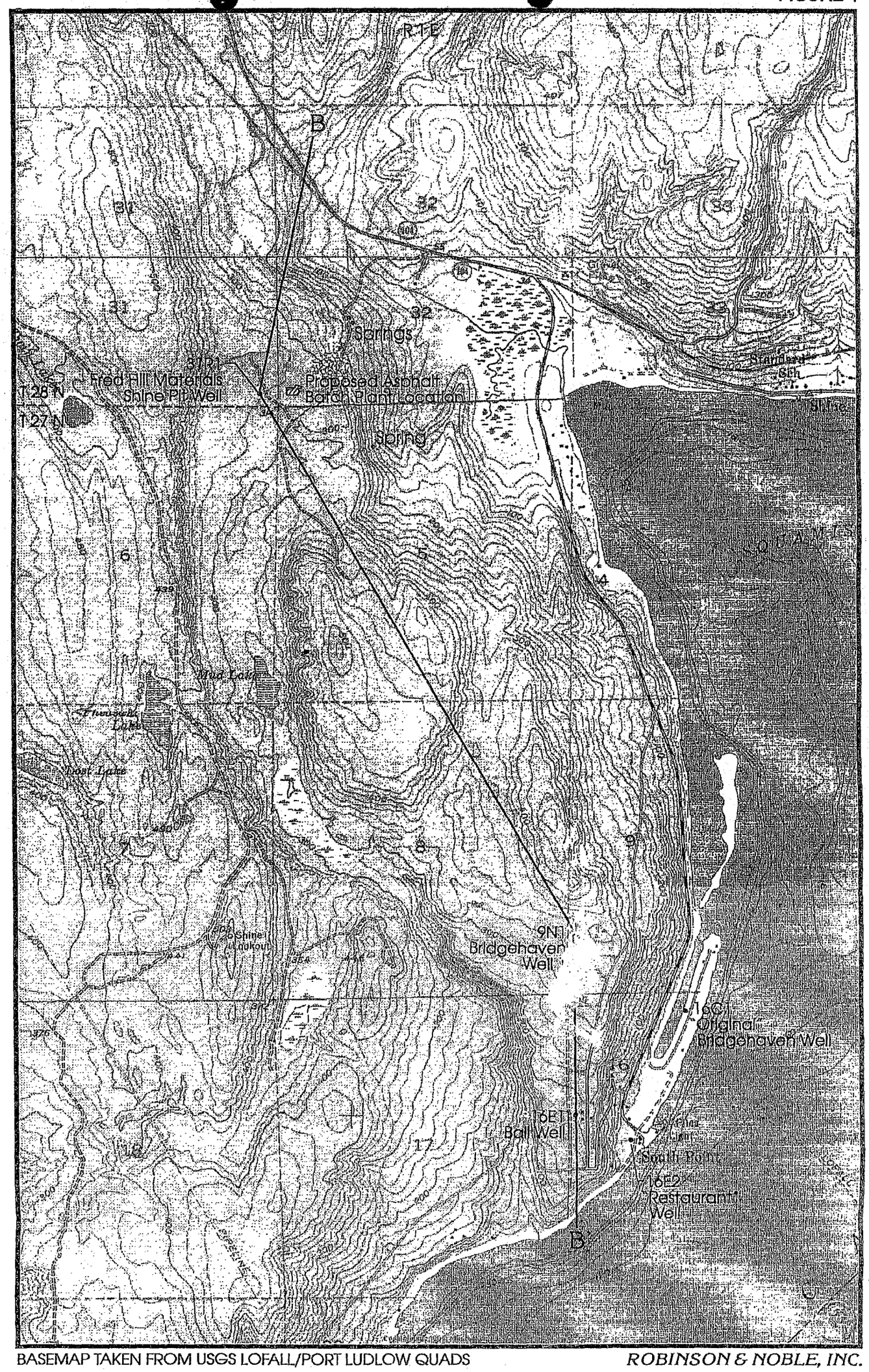
FIGURE 1



BASEMAP TAKEN FROM USGS LOFALL/PORT LUDLOW QUADS

ROBINSON & NOBLE, INC.

SCALE 1: 24,000

KITSAP COUNTY

NOTE:
CROSS SECTION A-A' CAN BE FOUND IN THE FEBRUARY 1999 CARA REPORT FOR ACE PAVING

WELL AND CROSS SECTION LOCATION MAP

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Ace Paving

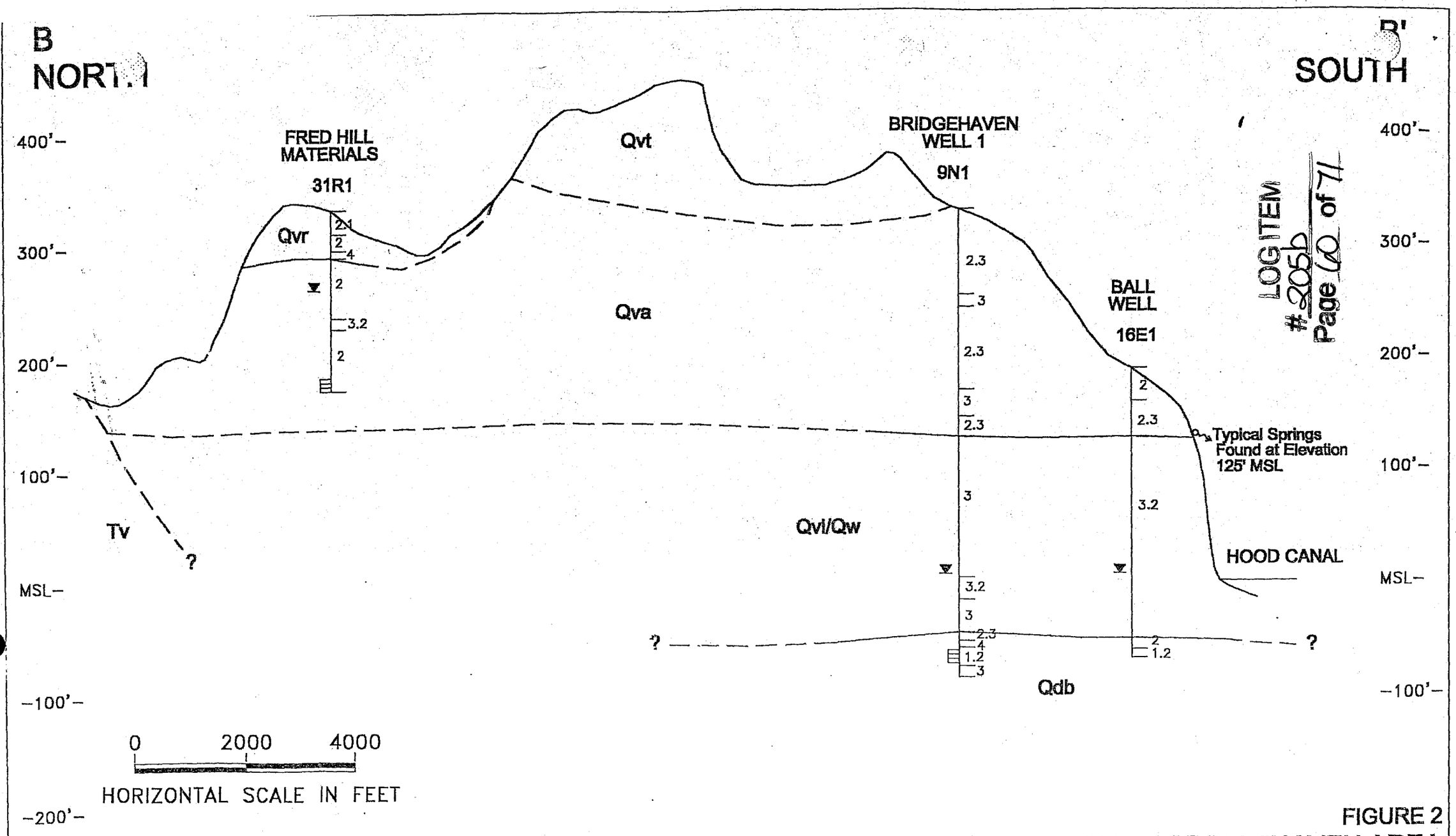

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FIGURE 2

NORTH-SOUTH HYDROGEOLOGIC CROSS SECTION THROUGH BRIDGEHAVEN AREA

ACE PAVING

ROBINSON & NOBLE, INC.

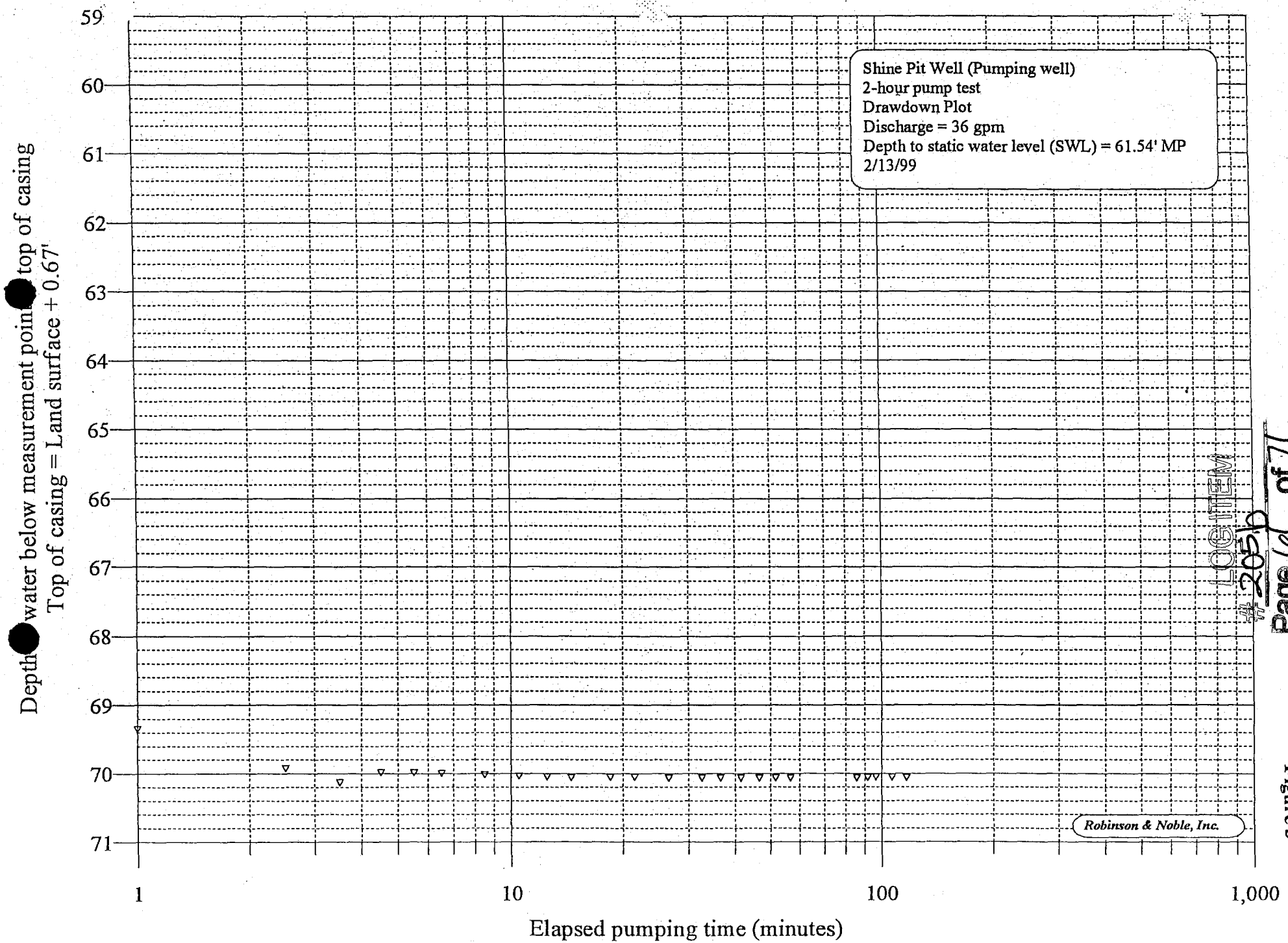

Figure 3

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#2051

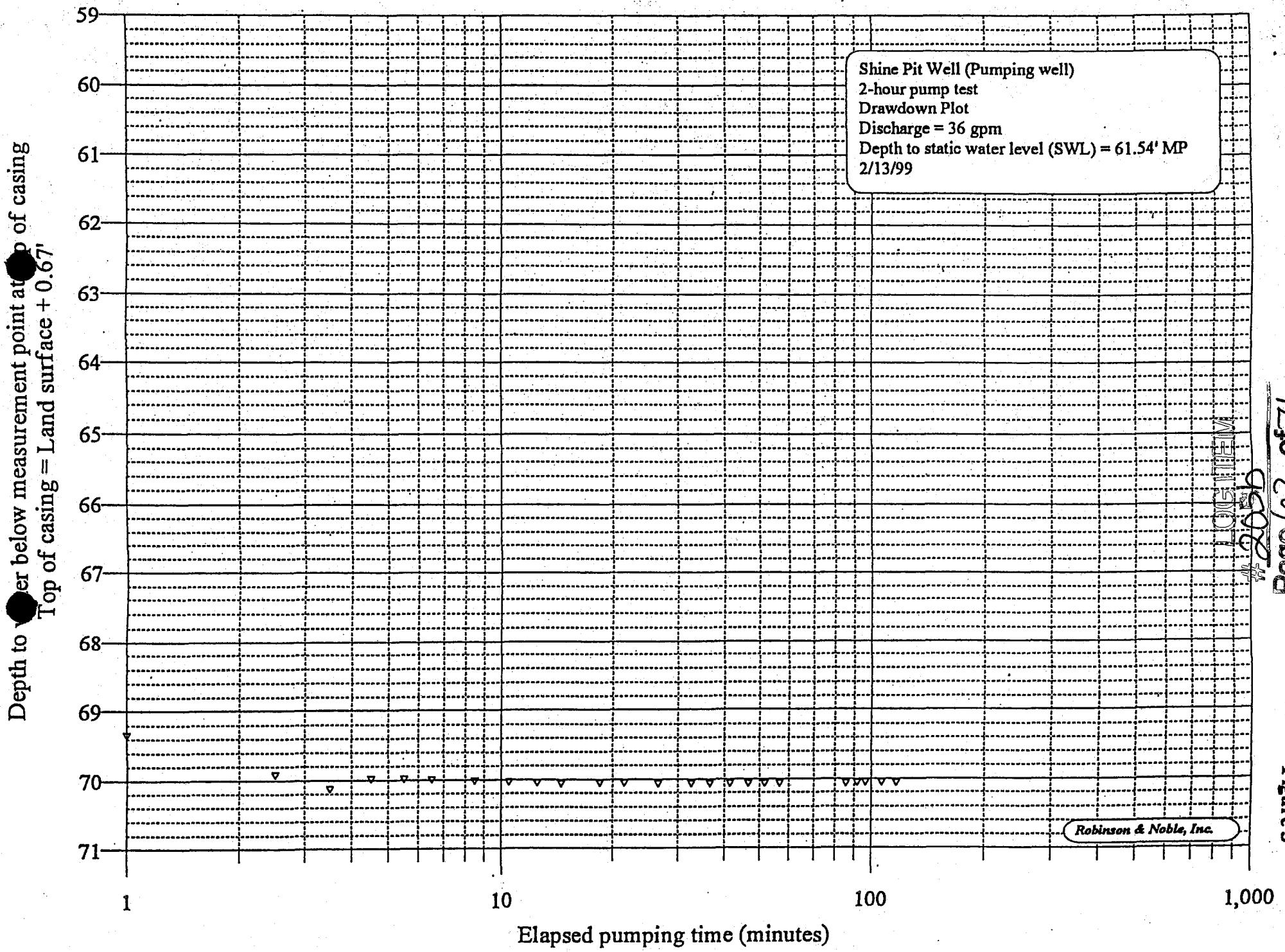
Shine Pit Well (Pumping well)
2-hour pump test
Drawdown Plot
Discharge = 36 gpm
Depth to static water level (SWL) = 61.54' MP
2/13/99
Depth to water below measurement point at top of casing
Top of casing = Land surface + 0.67'
59
60
61
62
63
64
65
66
67
68
69
70
71
1
10
100
1,000
Elapsed pumping time (minutes)
Robinson & Noble, Inc.

Figure 3

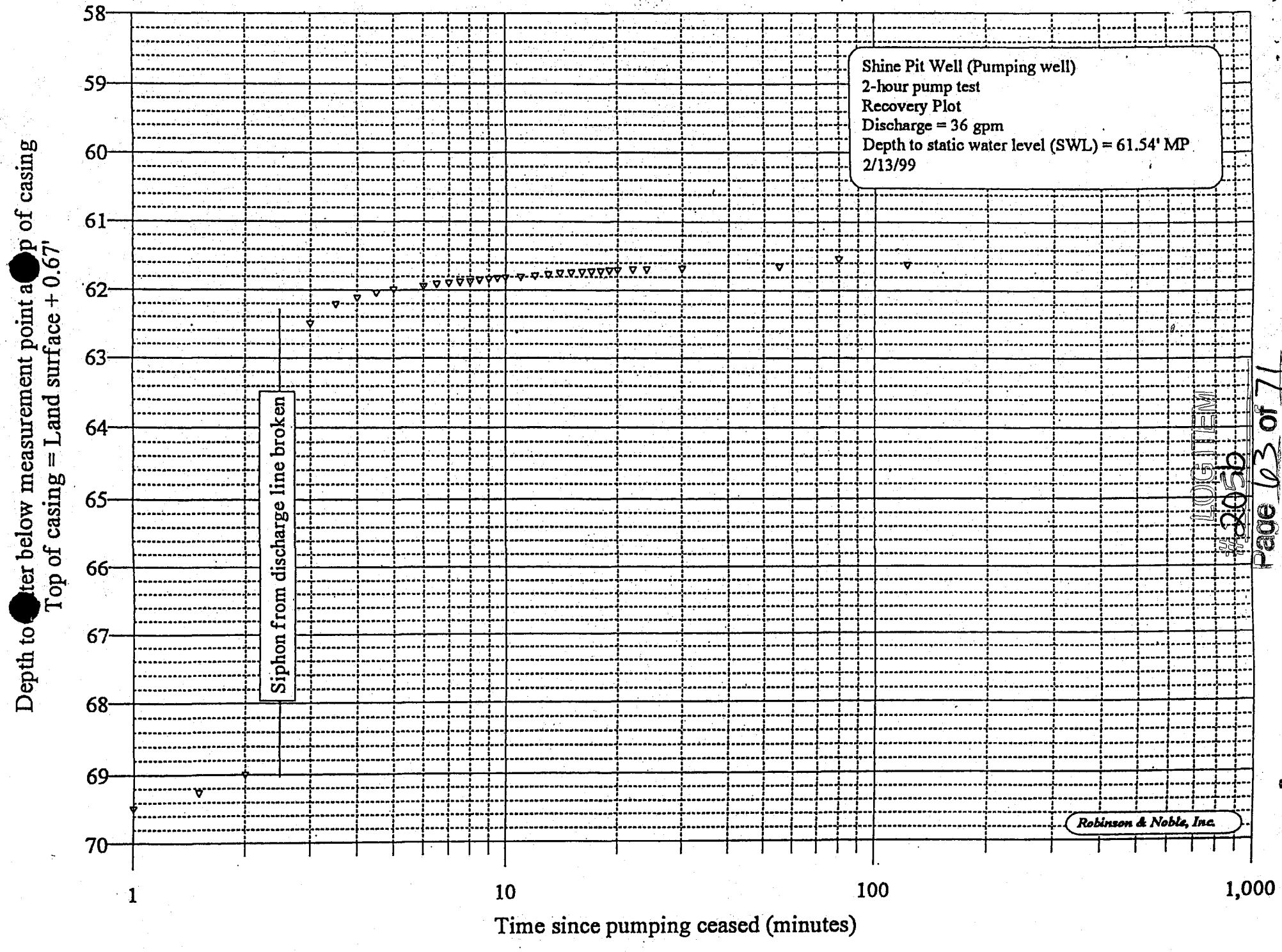

Figure 4

LOG ITEM #2059

ROBINSON & NOBLE, INC.
GROUND WATER & ENVIRONMENTAL GEOLOGISTS
ESTABLISHED 1947

June 3, 1999

Mr. Al Scalf, SEPA Responsible Official
Mr. Jerry Smith, Planner
Jefferson County Department of Development Review
621 Sheridan Avenue
Port Townsend, WA 98368

Subject: Response to Bridgehaven Community concerns to the proposed Ace Paving Asphalt Batch Plant

Dear Messrs. Scalf and Smith:

Recently, Mr. Duane Wells, Chairman of the Bridgehaven Community Club Association Water Utility Commission, expressed concerns regarding the proposed Ace Paving asphalt batch plant for which we wrote a Critical Aquifer Recharge Area (CARA) report in February. His comments are expressed in a letter to the Jefferson County Permit Center dated May 25, 1999.

The Bridgehaven Community is served by two wells located 45 feet apart at 115 Robin Lane, according to Mr. David Mathis, who works for Bridgehaven. Well 1, which serves as their main supply well, was drilled by L.R. Gaudio Well Drilling in 1969 to a total depth of 414 feet. Our company (at the time called Robinson, Roberts and Associates) served as the hydrogeologist on the Well 1 project. It has a 40 horsepower pump capable of producing 230 gpm. I currently have very little information on Well 2, but apparently it is completed in the same aquifer as Well 1 at a depth of 399 feet. Mr. Mathis indicates it contains a 10 horsepower pump capable of producing 50 gpm. The Bridgehaven Well site is located approximately 11,000 feet southeast of the proposed asphalt batch plant site as shown on the attached location map, Figure 1.

In his letter, Mr. Wells states that the mere changing of the critical area description on a map does not change the fact that the proposed batch plant site is located in a recharge area. This is certainly true. The area does provide recharge to underlying aquifers. In relative terms, especially in relation to nearby areas with glacial till or bedrock at the surface, precipitation will fairly easily infiltrate into the ground around the site. In fact, to my understanding, the mapped geology of the area (Vashon recessional outwash) is the reason it was designated initially as a Susceptible Aquifer Recharge Area under Section 7.301. However, the ordinance also acknowledges that site-specific studies are more accurate at determined critical aquifer recharge areas than are generalizations based on large-scale

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5320 Orchard Street West ▪ Tacoma, Washington 98467 ▪ (253) 475-7711 ▪ Fax: (253) 472-5846
rninc@wolfenet.com ▪ http://www.wolfenet.com/~rninc

proposed batch plant area, and causes the springs found east of the batch plant site by forming a bottom confining layer to the water table aquifer in the Vashon advance outwash. The thickness of the clay unit in the batch plant area cannot be directly determined because of lack of well data, though based on well data from the Squamish Harbor shoreline, it is likely several hundred feet thick at this location also.

The Vashon advance outwash, which is expressed as a thick sand unit throughout the area, forms a water table aquifer as discussed in the CARA report. This aquifer also is present in the Bridgehaven area, although no known wells use it. Similar to the proposed plant area, this aquifer discharges in the Bridgehaven area by a series of springs found at an elevation of 100 to 125 feet above sea level (Robinson, Roberts and Associates field notes, October 24, 1967). These springs appear because of the confining properties of the thick clay unit (described above) which retards downward groundwater movement.

Just because both the shallow and deeper aquifer units exist beneath both the proposed batch plant area and the Bridgehaven area does not mean that water from one area travels to the other. As discussed in our CARA report, the gradient of the water table aquifer in the proposed plant area is eastward (approximately 95°) at a slope of approximately 0.05 ft/ft. This gradient indicates that any water (or potential contaminants that travel with water) that enters the ground at the proposed site will move eastwards and likely discharge from the ground at the springs. It will not move towards Bridgehaven.

The gradient of the deeper aquifer in the Bridgehaven area can also be determined. Based on recorded water levels in Bridgehaven Well 1, the Ball domestic well, and the "restaurant" well at South Point (locations on Figure 1),* the gradient of the Bridgehaven aquifer slopes approximately 0.003 ft/ft in an east-southeast direction (at 108°). The water recharging this aquifer in the vicinity of Bridgehaven is derived from the upgradient direction, or west-northwest at 288°. This indicates the recharge area is essentially the center of Toandos Peninsula west of Bridgehaven. The proposed batch plant site is at the northernmost end of the peninsula, at a direction of 330° from the Bridgehaven wells. This area does not provide recharge to the aquifers in Bridgehaven.

The deep aquifer at Bridgehaven Well 1 is 16 feet thick and has an aquifer transmissivity of 12,000 to 15,000 gpd/ft (Robinson, Roberts and Associates, 1969). Using this information, along with the calculated gradient, an analytical model of the Bridgehaven aquifer was created using the modeling program WinFlow. This model was used to simulate Bridgehaven Well 1 pumping at its maximum allowed water right, 200 acre-feet per year, for

* The water level in Bridgehaven Well 1 was 321 feet below ground at construction (Robinson, Roberts and Associates, 1969) and currently 322 feet below ground (D. Mathis, personal communication). The water level in the Ball Well is reported at 185 feet below ground (Robinson, Roberts and Associates, 1967), and the restaurant well has a reported water level elevation of one foot above sea level (Grimstad and Carson, 1981).

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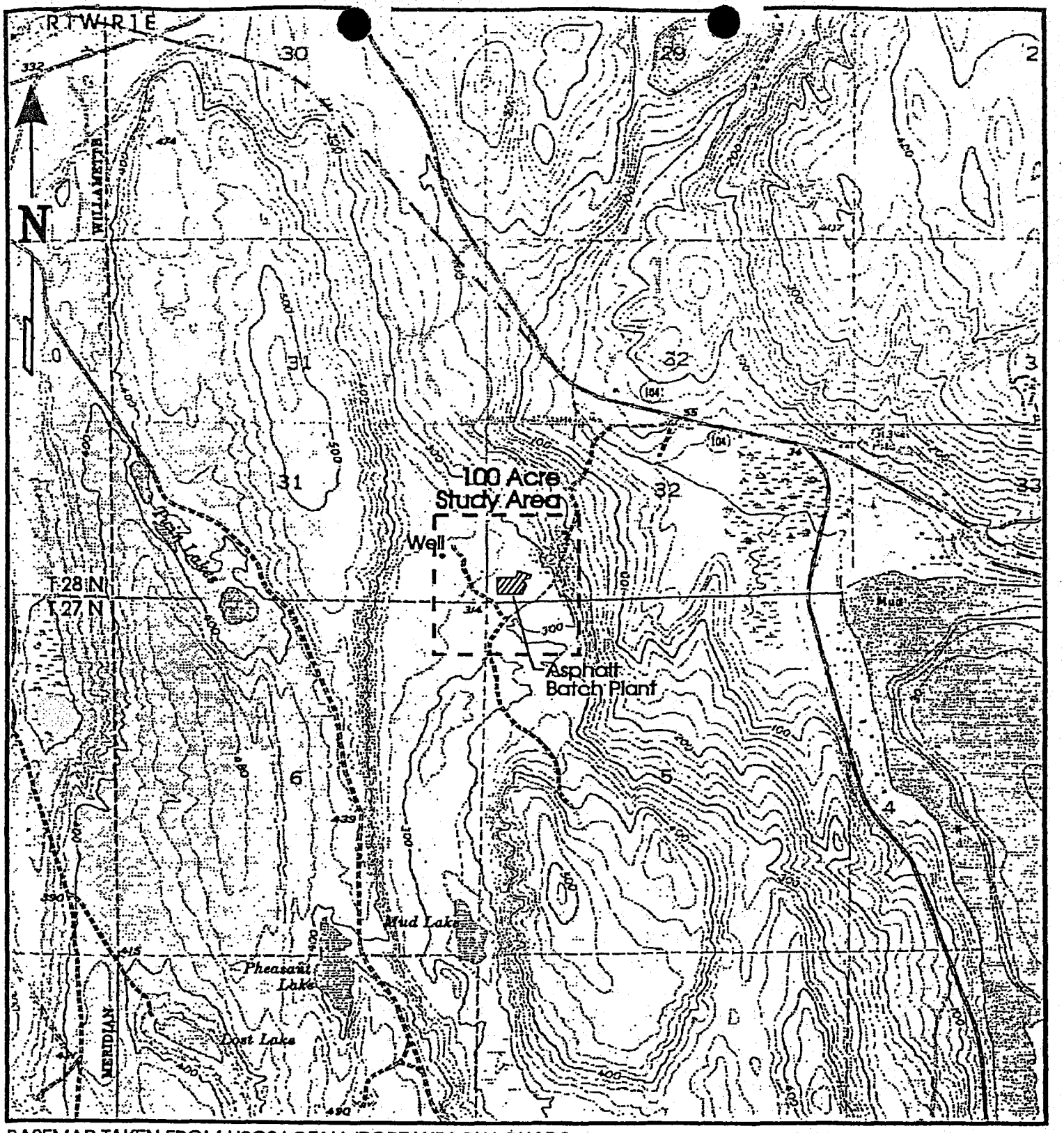
References

Grimstad, Peder, and Carson, Robert J., 1981, *Geology and Ground-Water Resources of Eastern Jefferson County Groundwater Characterization Study*, prepared for Jefferson County Public Utility District No. 1, 13 sections.

Robinson, Roberts and Associates, 1967, letter to Joseph J. Millegan and Associates from John Robinson concerning a potential water supply for Bridgehaven, 3 p., 1 figure.

Robinson, Roberts and Associates, 1969, *Report to Bridgehaven Development*, prepared for Bridgehaven, 6 p., 3 figures.

Robinson & Noble, 1999, *Critical Aquifer Recharge Area Report for Ace Paving*, prepared for Ace Paving, 10 p., 2 figures, 2 appendices.



BASEMAP TAKEN FROM USGS LOFALL/PORT LUDLOW QUADS

ROBINSON & NOBLE, INC.

SCALE 1: 24,000

KITSAP COUNTY

SITE LOCATION MAP

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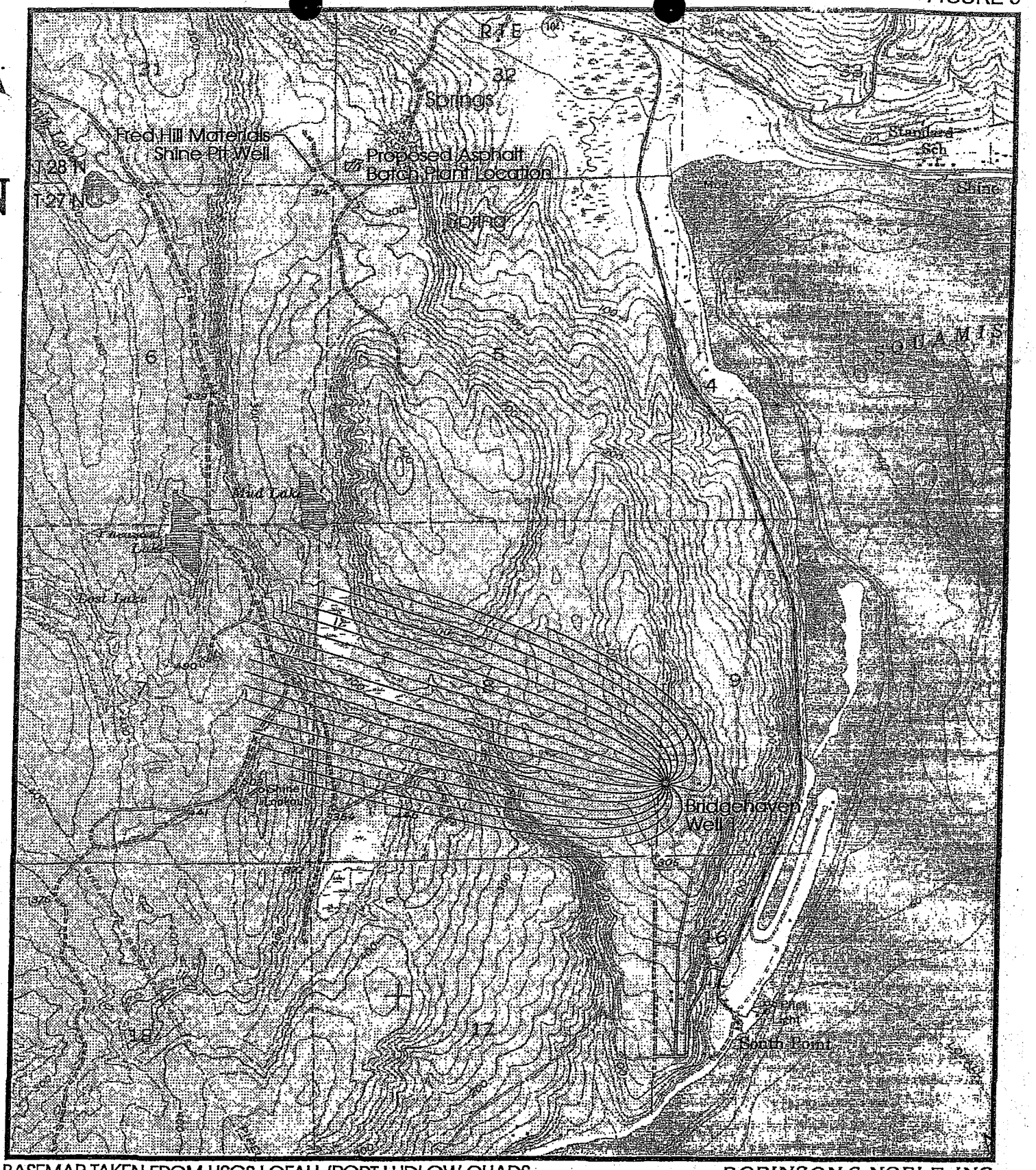
FIGURE 3



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ESTIMATED 10-YEAR CAPTURE ZONE FOR BRIDGEHAVEN WELL 1

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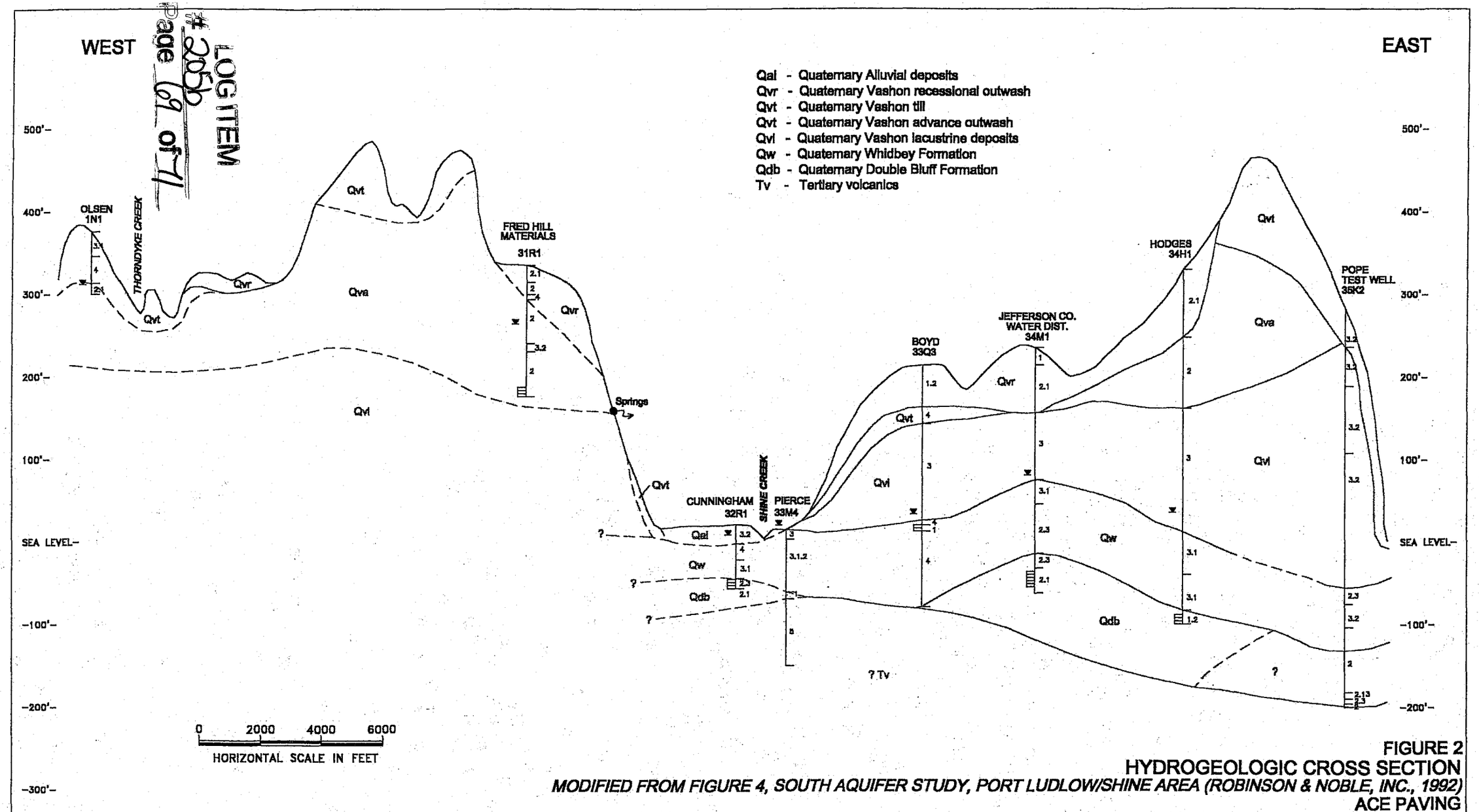

FIGURE 2
HYDROGEOLOGIC CROSS SECTION
MODIFIED FROM FIGURE 4, SOUTH AQUIFER STUDY, PORT LUDLOW/SHINE AREA (ROBINSON & NOBLE, INC., 1992)
ACE PAVING

ROBINSON & NOBLE, INC.

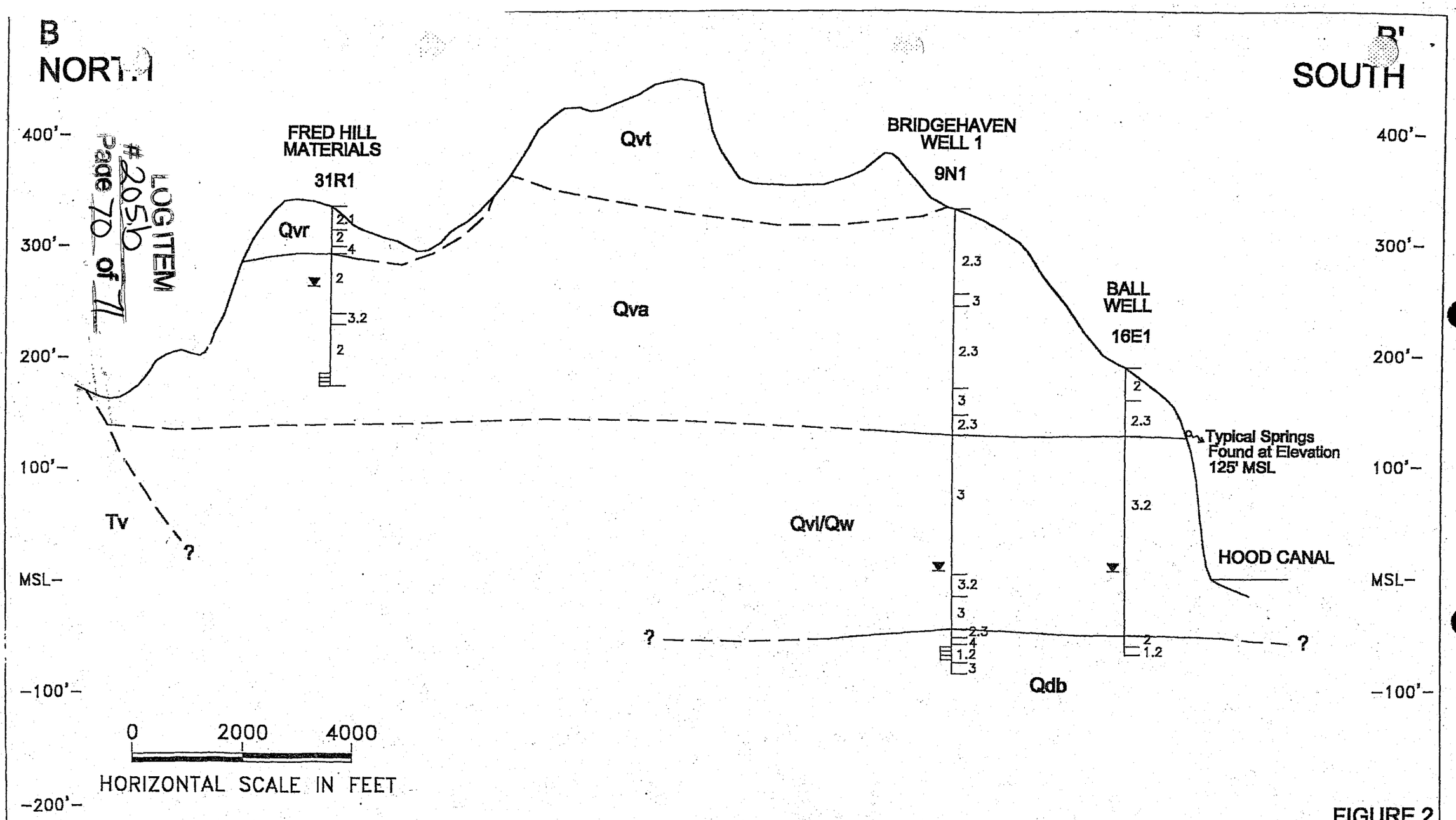

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FIGURE 2

NORTH-SOUTH HYDROGEOLOGIC CROSS SECTION THROUGH BRIDGEHAVEN AREA

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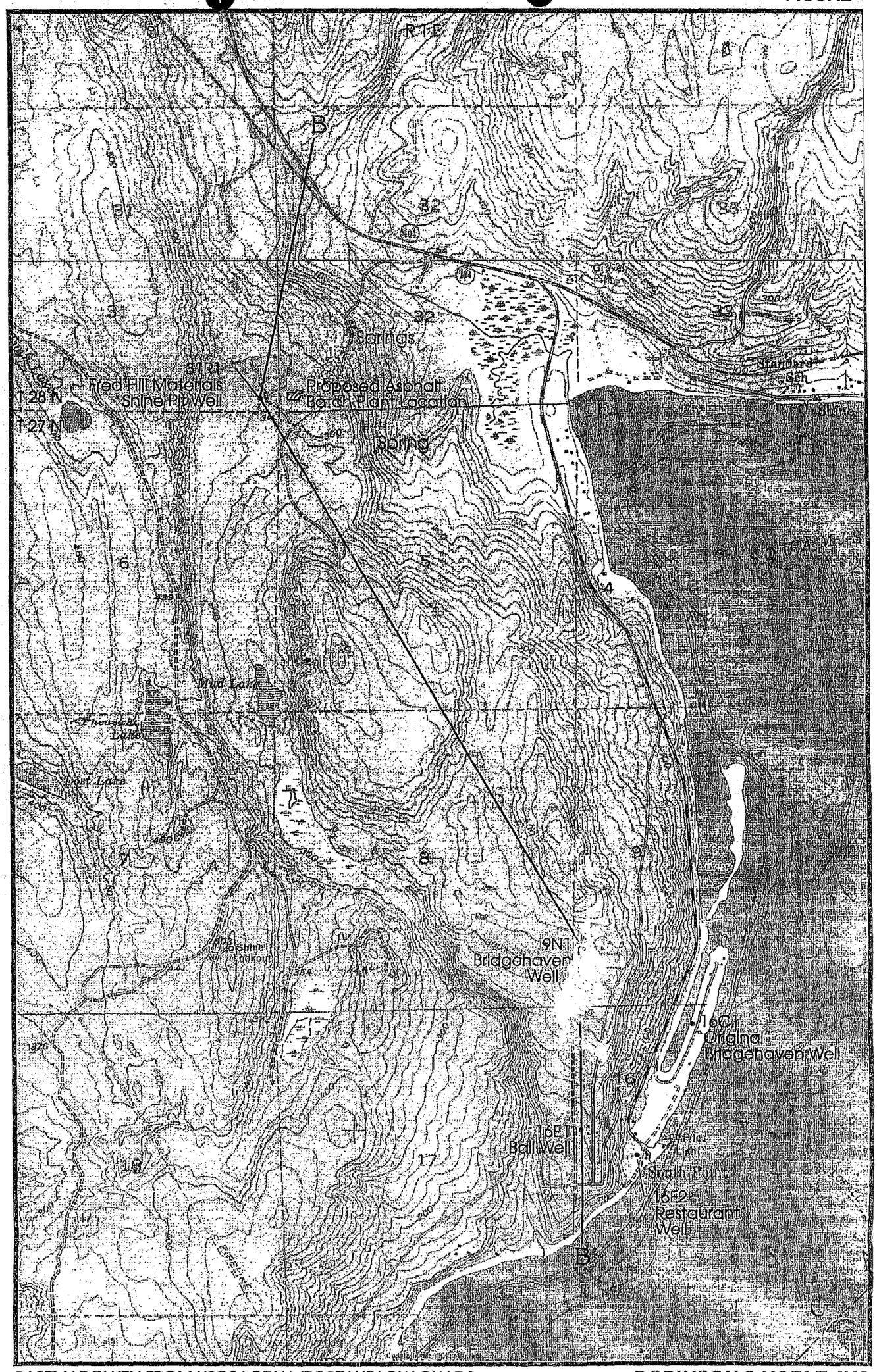
FIGURE 1



BASEMAP TAKEN FROM USGS LOFALL/PORT LUDLOW QUADS

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SCALE 1: 24,000

KITSAP COUNTY

NOTE:
CROSS SECTION A-A' CAN BE FOUND IN THE FEBRUARY 1999 CARA REPORT FOR ACE PAVING

WELL AND CROSS SECTION LOCATION MAP

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