ISLAND COUNTY
GROUND WATER QUALITY
ASSESSMENT AND MONITORING PROGRAM

- FINAL REPORT -

JULY 2, 1986

SUBMITTED TO:
ISLAND COUNTY HEALTH DEPARTMENT
P.O. BOX 700
COUPEVILLE, WA 98239

SUBMITTED BY:
SWEET, EDWARDS & ASSOCIATES, INC.
P.O. BOX 328
KELSO, WA 98626

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EXECUTIVE SUMMARY
ISLAND COUNTY GROUND WATER QUALITY ASSESSMENT
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The purpose of this investigation was to characterize the water quality in the vicinity of nine Island County waste disposal sites and design ground water monitoring programs for the Island County Health Department. The sites investigated included:

- Naval Air Station Landfill
- Oak Harbor Landfill
- MELCO Manufacturing Drainfield
- Hastie Lake Landfill
- Coupeville Landfill
- Freeland Landfill
- Langley Landfill
- Camano Island Landfill
- Cultus Bay Landfill

The accompanying report presents a detailed description of the data collected, the approach, conclusions and recommendations of our investigation.

Approach

The general approach in the investigation was to evaluate the waste characteristics, hydrogeology, beneficial use, and leachate generation capacity for each of the sites using existing data. Based on this information, we defined the "relative" pollution potential for each of the sites and designed monitoring programs consistent with existing regulations and our experience in the field.

Considering the relative pollution potential and project funds available, three monitoring wells were constructed at the Freeland Landfill and one monitoring well at the Coupeville Landfill. All four monitoring wells and the dog pound well at Coupeville were sampled and tested for water quality parameters.

Site Characteristics

All nine sites are located in upland areas or on their sloping margins. Seven landfills and MELCO Manufacturing are located on Whidbey Island and one landfill is located on Camano Island. All of the landfills, with the exception of Freeland, Langley, and Cultus Bay, are located within the Olympic Mountains rain shadow, which significantly reduces the amount of landfill leachate generated.

Waste Characterization

Eight of the facilities are disposal sites where land burial is/was the operational method. Subsurface disposal of electroplating industrial effluent via drainfield was used at the MELCO site. Many of the land burial sites began as burning dumps in the 1950s, located for convenience in a gravel/sand pit. This was typical waste disposal practice for rural areas at the time. Only the Naval Air Station and Coupeville disposal sites are currently operating, although the Oak Harbor site still has operating sewage sludge lagoons. The Freeland site is a recycling center and has open top box collection and transfer to the Coupeville Solid Waste site.

All of the sites except MELCO have received domestic/municipal types of solid waste. At least four of the sites have reportedly received sewage sludge and/or septage. Some liquid industrial wastes have been reportedly disposed at the NAS Landfill.

Hydrogeology

All of the sites are located in areas underlain by glacial sand and gravel. Where less permeable Vashon till (hardpan) occurs, it has been stripped to provide access to the underlying Vashon sand and gravel for quarrying.

Two major aquifers were identified beneath most of the sites. A shallow water table aquifer occurs in the Vashon sand and gravel. The shallow aquifer is generally perched on a thick sequence of clay, silt and sand (transition beds) and is the most vulnerable to contamination from site operations.

A deeper confined (artesian) aquifer occurs beneath the transition beds and is referred to as the sea level aquifer. Many of the sites are located near or over ridges in the ground water table, therefore, it is difficult to determine the direction of ground water flow beneath those sites with existing data. At most sites, however, data are sufficient to deduce regional ground water flow directions and downgradient areas which might be impacted by landfill operations.

Water Quality

Ground water quality is relatively good throughout the study area. However, ground water is comparatively hard near the Coupeville and Hastie Lake landfills. Elevated concentrations of iron and manganese are typical of natural ground waters throughout western Washington and occur in the vicinity of several of the sites studied.

Ground waters beneath both the Coupeville and Freeland landfills exhibited manganese concentrations above the state of Washington's maximum contaminant level (MCL). Sulfate and total organic carbon (TOC) concentrations downgradient of the Coupeville landfill are greater than background concentrations.

Ground water quality beneath the Freeland landfill appears to be significantly degraded. Electrical conductivities in the shallow aquifer are greater than 1,100 micromhos/cm. Sulfate and chloride concentrations are elevated.

Beneficial Use

Both the shallow and deep aquifers are used for water supply throughout the county. Except for the Hastie Lake and Camano Island landfills, ground water development is relatively intense in the vicinity of all the sites.

Leachate Generation

Infiltration of precipitation through a landfill generates leachate. If unimpeded, the leachate percolates down to and contaminates the ground water beneath the site. Leachate generated by each of the eight landfills is estimated to range from 220,000 gallons per year (Hastie Lake) to 1.7 million gallons per year (NAS). The quantity of leachate generated can be substantially reduced using properly designed cap and cover techniques. None of the sites investigated were effectively capped and covered.

Pollution Potential

Relative pollution potential was evaluated for the nine sites. The evaluation consisted of rating each site with respect to:

- o Leachate generation
- o Age and type of facility
- o Type of waste
- o Depth to ground water
- o Beneficial use

The higher the rating, the greater the relative pollution potential. Below, we have listed the sites in order of priority for monitoring based on the sites' pollution potential.

Monitoring priority	Site	Pollution potential rating
1	NAS	43
2	Oak Harbor	40
3	Coupeville	35
4	Freeland	34
5	Langley	33
6	MELCO	32
7	Cultus Bay	27
8	Hastie Lake	25
9	Camano Island	17

Monitoring Strategy

The three main elements considered in developing the monitoring strategy were:

- o Pollution potential
- o Data requirements
- o Cost

Monitoring programs were designed employing newly constructed monitoring wells (Program-A) and existing wells (Program-B). The lack of potentially suitable existing wells precluded developing a Program-B for the Coupeville and MELCO sites. A monitoring program was not developed for the Cultus Bay site due to the lack of information and complex hydrogeology. However, the locations of exploration boreholes with monitoring wells have been proposed.

Program-A costs for the first two years of monitoring range from about $23,000 (MELCO site) to about $88,000 (Coupeville site). Program-B costs for the first two years of monitoring range from $6,900 (Langley site) to $51,000 (NAS site).

Conclusions

The following general conclusions are presented in addition to those detailed within the body of this report.

1. Waste disposal operations at the Freeland and Coupeville Landfills have significantly impacted site ground water.

2. The nature of the wastes disposed in the older sites (i.e., Freeland) is not well known and may represent a greater hazard than indicated by waste characterization based on existing data.

3. Additional hydrogeologic information will be needed to better characterize subsurface conditions beneath many of

the sites, including Hastie Lake, Coupeville, Camano Island, Freeland, Langley, and Cultus Bay.

4. Total estimated monitoring costs for the recommended program (first two years) at all nine sites ranges from $94,700 (Type B program) to $292,700+ (Type A program).

5. The potential for ground water contamination at the eight landfill sites studied is increased by the lack of effective landfill cap and other engineered measures to reduce leachate generation.

Recommendations

The following recommendations are presented sequentially for implementation of the monitoring programs detailed in the body of this report and to address potential hazards to public health. These tasks will be required at active landfill sites to meet newly promulgated Minimum Function Standards for solid waste handling (WAC-173-304).

1. Continue monitoring existing wells at Freeland and Coupeville.

2. Install three additional monitoring wells at the Freeland landfill to further characterize subsurface conditions.

3. Sample and test water quality of domestic wells west and southwest of the Freeland site.

4. Complete engineered measures at the Freeland site to reduce leachate generation and meet WAC Minimum Functional Standards.

5. Complete installation of monitoring system at Coupeville.

6. Implement Program-A monitoring at Oak Harbor landfill.

7. Begin implementation of recommended monitoring programs by installation of single monitoring wells (downgradient where possible) at the Hastie Lake, Cultus Bay, MELCO, Langley and Camano Island sites.

8. Complete implementation of recommended monitoring programs based on initial data collection.

9. Design and implement engineered moisture control measures at all landfills to reduce leachate generation and/or meet WAC Minimum Functional Standards.

FINAL REPORT

ISLAND COUNTY GROUND WATER QUALITY ASSESSMENT
AND MONITORING PROGRAM

This report is divided into the following sections:

- INTRODUCTION
- STUDY AREA CHARACTERISTICS
- HYDROGEOLOGY
- LANDFILL LEACHATE GENERATION
- WASTE CHARACTERIZATION
- POLLUTION POTENTIAL
- MONITORING STRATEGY
- SITE ANALYSIS AND EVALUATION

INTRODUCTION

This report presents our evaluation of nine Island County waste disposal sites and recommended monitoring programs for each site.

Authorization and Scope of Work

The Island County Ground Water Quality Assessment and Monitoring Program was performed during the period September, 1984 through May, 1986. The program consisted of two phases. The following tasks outline the scope of work performed for this investigation and authorized in our September 19, 1984 Phase I contract with the Island County Health Department.

Task 1 - Review Existing Information
Task 2 - Site Reconnaissance
Task 3 - Develop Preliminary Conceptual Ground Water Model
Task 4 - Evaluate Hydrogeology and Prioritize Sites
Task 5 - Develop Monitoring Strategy
Task 6 - Draft Report Preparation

Contract price for the Phase I work was $29,149.00.

The Phase II effort was authorized in our July 16, 1985 contract and amended October 21, 1985 and included the following scope of work.

Task 1 - Field Locate Wells
Task 2 - Install Freeland Monitoring Wells
Task 3 - Install Coupeville Monitoring Wells
Task 4 - Prepare Boring Logs and Drilling Reports

Task 5 - Provide Ground Water sampling
Task 6 - Update Draft and Prepare Final Report

Contract price for the Phase II work was $48,250.

Both phases of the project were funded by the Washington State Department of Ecology 205 J Program.

Previous Investigations

To our knowledge, other than the Initial Assessment Study for the Naval Air Station, there have been no previous hydrogeologic investigations performed at eight of the landfills studied. The U.S. Environmental Protection Agency's Field Investigation Team conducted a preliminary evaluation of the MELCO site in 1984. The County is currently conducting investigations at the Coupeville landfill associated with long-term close out.

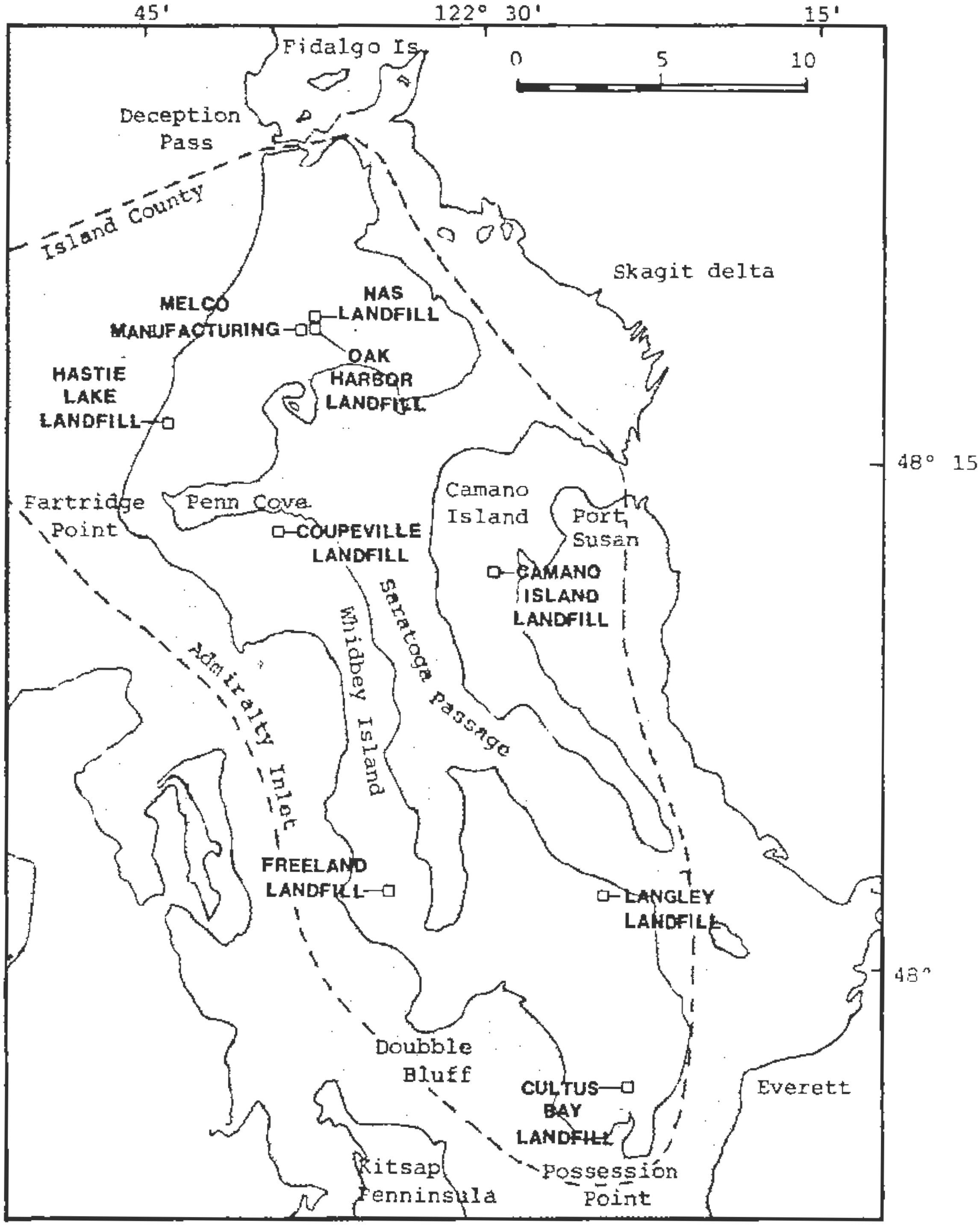
Acknowledgements

We would like to extend our appreciation to the Island County Health Department staff who provided valuable input to the development of this project. Particular thanks go to Joye Bonvouloir whose thorough collection and organization of well information, water levels, and waste characterization data significantly reduced the cost of this investigation and facilitated our evaluation. We would also like to extend our appreciation to NAS staff: Commander J.H. Lehman, Lt. Spangler, and James Johnson for their ready cooperation in this investigation.

STUDY AREA CHARACTERISTICS

Geographic Setting

Island County is located in the Puget Lowland at the eastern end of the Strait of Juan de Fuca. It includes Whidbey and Camano Islands, a total area of approximately 210 square miles. Both islands are long and narrow, refer to Figure 1, Site Location Map. Whidbey Island is 40 miles long and Camano 15 miles long. No point on either island is more than 2-1/2 miles from marine waters due to the irregular shape of the shorelines. Rolling uplands characterize the land surface and typically range from 100 to 300 feet above sea level, although some areas reach elevations from 400 to 600 feet. The shorelines are generally backed by steep slopes or cliffs. The sites under investigation are all located in upland areas or on their sloping margins. Seven landfills and MELCO Manufacturing are located on Whidbey Island while one landfill is on Camano Island. Most of the sites are surrounded by woodland in various stages of growth, but open grasslands are usually nearby.



Base Map after Water Supply Bulletin 25

ISLAND COUNTY
Study Area Location Map
Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	2-5-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 1

Climate

The climate of Island County is characterized by dry summers and wet winters. The temperature varies from a January average of 38° F to a July and August average of 61° F. The annual mean temperature is 50° F. The central and northern parts of Whidbey Island and part of Camano Island are within the rain shadow of the Olympic Mountains. This results in an average annual rainfall of 18 to 20 inches (refer to Figure 2, Rainfall Map). The rain shadow begins to lift at Greenbank so rainfall on the southern part of Whidbey Island is well over 30 inches per year and increases with land surface elevation.[1,2] The three southernmost sites are on the boundary of or outside of the rain shadow. The prevailing winds in the county are from the northwest in the summer and the southwest in the winter. Strong winds are not common. The Strait of Juan de Fuca modifies this general pattern over northern Whidbey Island increasing the strength and shifting the direction to the west and northwest.

HYDROGEOLOGY

Island County is underlain by a complex sequence of glacial and interglacial materials deposited during the Quaternary period (approximately 11,000 - 2.5 million years ago). Older (pre-Tertiary) metamorphic bedrock is present on the north end of Whidbey Island, but has not been identified near or underlying any of the sites under investigation. Most of the county is located in a downdropped regional structural block (Marysville Low) filled with as much as 2,000 feet of sediment.[3] In order to understand the complex geology and its influence on the occurrence and movement of ground water and contaminant flow, a knowledge of the area's geologic history and depositional environment is necessary.

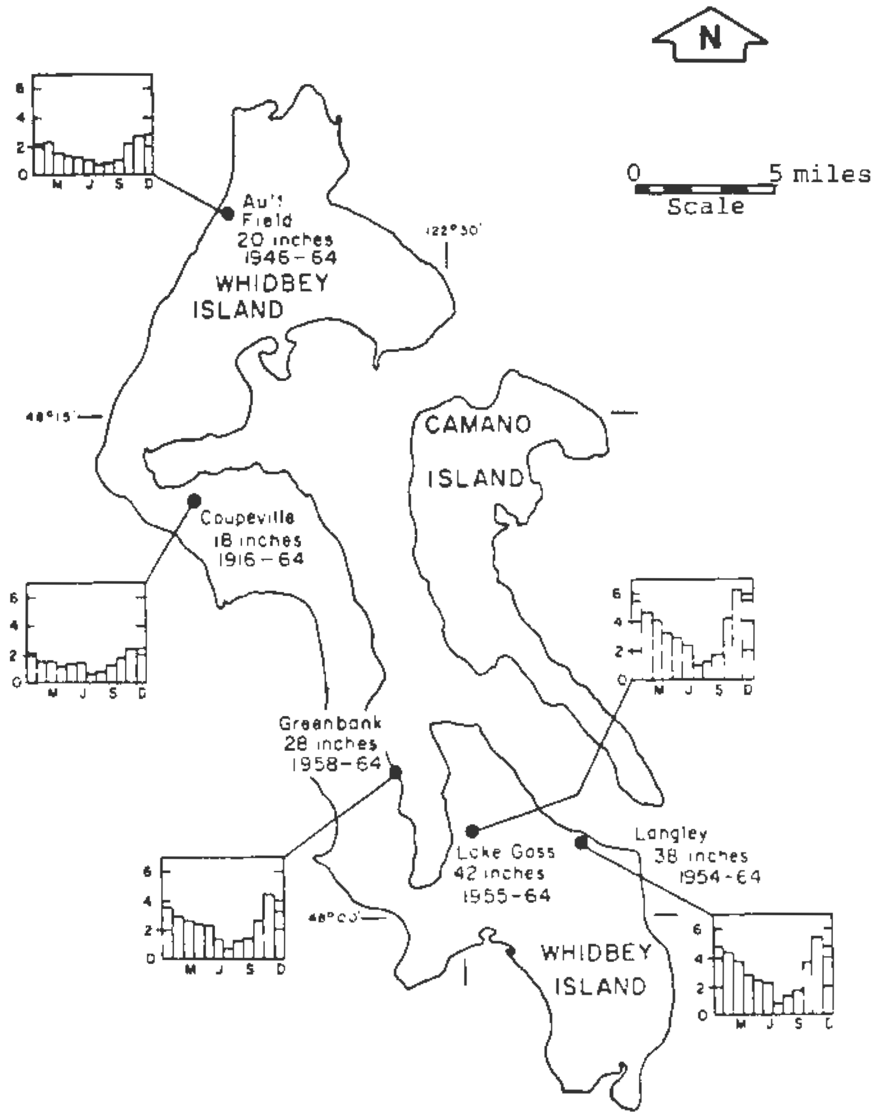
Geologic History

The geology and physiography of the Puget Sound Lowland is the product of a number of complex geologic processes over a long period of time. Sylwester, 1971, has succinctly summarized these events in their order of occurrence.[4]

1. Submergence of the region under shallow seas from the Cambrian Period--600 million years ago (mya) to the early Mesozoic Era--200 mya.

2. Marine and continental vulcanism during the Mesozoic--225 to 65 mya.

3. Retreat of the seas as the continental land mass slowly rose during the late Mesozoic--150 to 65 mya.



(Taken after Water Supply Bulletin 25)

ISLAND COUNTY		
RAINFALL MAP		
Sweet, Edwards & Associates		
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CHECKED BY	JEE	3/14/85
REVISED		

Figure 2

4. Mountain building resulting from folding and faulting of the crust contemporaneous with vulcanism and lava flows in the early Tertiary Period--65 to 40 mya.

5. Uplift of the present Cascade and Olympic Mountains beginning in the Pliocene Period (7 mya) and continuing through the present.

6. Advances and retreats of the continental ice sheets during the Pleistocene Epoch--2.5 mya to 11,000 years ago.

7. Incision of valleys and the subsequent deposition of alluvial deposits in recent times--11,000 years ago to present.

8. Local excavation and filling to modify surficial units.

Pleistocene Stratigraphy

During the Pleistocene Epoch, several Cordilleran glaciers advanced into the Puget Sound Lowland. The most recent of these (Vashon) was about 5,000 feet thick at the latitude of Island County and had a terminus about 12 miles south of Olympia. Each glacier was responsible for depositing varying assortments of till, outwash sand and gravel, and glacial lake sediments.

Crandall and others (1958) were first to describe and name a multiple sequence of glaciations and nonglacial episodes in the Puget Lowland.[5] Their sequence from youngest to oldest included:

- Vashon Till
- Unnamed Nonglacial Interval
- Salmon Springs Glaciation (a nonglacial interval suspected within)
- Puyallup Interglaciation
- Stuck Glaciation
- Alderton Interglaciation
- Orting Glaciation

Later, Armstrong and others, described the Vashon as an earlier stade (brief advance and retreat) within a broader glaciation designated Fraser.[6] The Sumas stade was defined as the most recent glacial advance and separated from the Vashon by the Everson interstade. The glacier of the Sumas stade did not extend as far south as Island County. Easterbrook (1965) modified the pre-Vashon glacial nomenclature to include the Whidbey interglaciation and the Double Bluff glaciation.[7] He also suggested that deposits of the Possession glaciation might be equivalent to Crandall and others Salmon Springs. The Olympia interglacial period is the last major nonglacial period in the northwest (excluding the present). "Rock units" or geologic formations are assigned to each time period where possible.

Therefore, Vashon Drift is assigned to the Vashon Glaciation and the Whidbey Formation is assigned to the Whidbey Interglaciation. Figure 3--Stratigraphic Sequence, illustrates how the rock units are related to depositional environments.

Depositional Environments

The origin and types of sediments occurring in Island County are a direct reflection of the glacial activity which occurred during the Pleistocene Period over the last 2.5 million years. Only unconsolidated sediments (clay, silt, sand and gravel) deposited by the glaciers or streams and rivers during the interglacial periods are exposed at the surface near the sites under investigation.

A knowledge of glacial and nonglacial deposition is important to understanding the type of earth materials in the vicinity of the sites and their significance with respect to the movement of ground water and contaminants.

Glacial Deposits. As illustrated on Figure 4, outwash sand and gravel was deposited by meltwater streams in front of the glacier during its advance. Advance outwash deposits consist of medium to coarse-grained sand and gravel with numerous cobbles and boulders. Near the glacier front, poorly sorted sand and gravel is deposited by high energy streams. At greater distance these materials may become more stratified and better sorted. These outwash gravels are generally the most permeable of glacial deposits. Even farther from the glacier, the gravel content is less and sand content more. At the greatest distance, the deposits may be silt and clay which filled glacial lakes. The lake deposits are typically of low permeability.

Glacial till is an unsorted to poorly sorted mixture of clay-size particles through boulders. It is dense and has the general appearance of concrete. As Figure 4 illustrates, till resulted from the grinding and compaction of granular material worked by the advancing and overriding glacier. Consequently, the till materials tend to consist of a reworking of the material at the face of the ice. Till often exhibits low permeabilities.

As the glacier receded, meltwater streams again deposited stratified sediments at the margin of the retreating glacier. Ablation left other sediment irregularly mantling the ground surface. Large meltwater channels flowed over and eroded through the till, often depositing thick sections of sand and gravel in their beds. Lakes formed in depressions and kettle holes formed when ice blocks incorporated in the outwash melted.

Figure 3

STRATIGRAPHIC SEQUENCE

ISLAND COUNTY

DEPOSITIONAL ENVIRONMENT		ROCK UNITS	MAP SYMBOLS
PRESENT		RECENT DEPOSITS	Qb, Qls, Qm, Qml
FRASER GLACIATION	EVERSON INTERSTADE	EVERSON FORMATION	Qe
	VASHON STADE	VASHON RECESSIONAL OUTWASH	Qvr
		VASHON TILL	Qvt
		VASHON ADVANCE OUTWASH	Qva
OLYMPIA INTERGALCIATION		TRANSITION BEDS	Qtb
		OLYMPIA GRAVELS	Qog
POSSESSION GLACIATION		POSSESSION DRIFT	not mapped
WHIDBEY INTERGLACIATION		WHIDBEY FORMATION	Qw
DOUBLE BLUFF GLACIATION		DOUBLE BLUFF DRIFT	Qdb

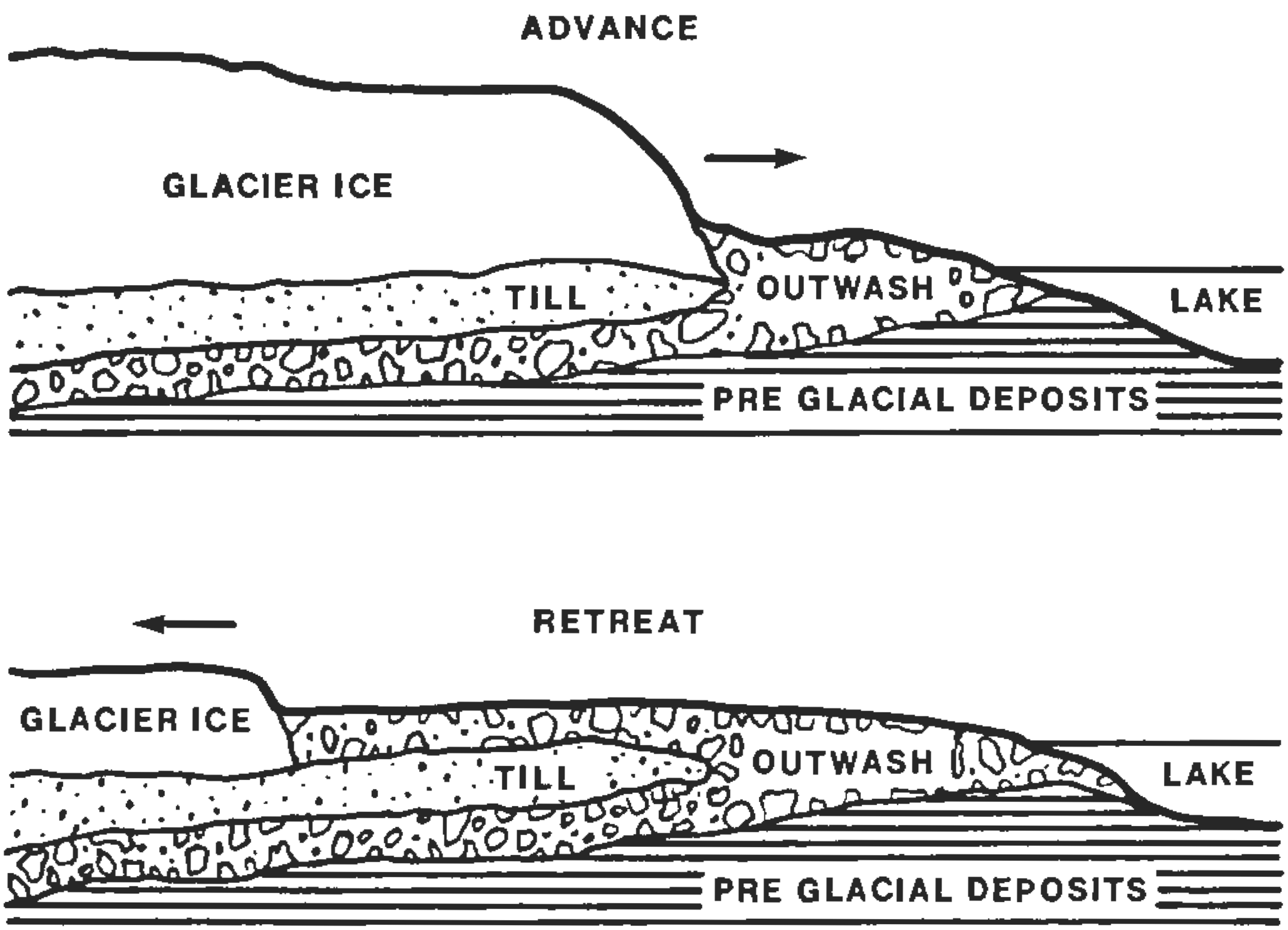


Figure 4

ILLUSTRATION OF GLACIATION

This recessional outwash is similar in character to advance outwash in that it becomes finer grained and less permeable with increasing distance from the glacier.

The typical glacial sequence from top to bottom consists of:

- Recessional outwash (loose sand and gravel, grading finer upward)

- Till (compacted silty gravel)

- Advance outwash (loose sand and gravel, grading coarse upward)

A particularly unique glacial deposit typical of northwestern Washington is glacio-marine drift. These materials generally consist of dark, gravelly silt and sandy gravel, very compact and similar to till. Glacio-marine drift was deposited in a salt water environment beneath floating or rafted ice.

Interglacial Deposits. Interglacial materials were deposited during time intervals between glaciations. They are also accumulating today as bottom sediments in Puget Sound, floodplain sediment in the valleys, and both mineral and organic filling of lakes and bogs. In general, interglacial sediments are finer grained than glacial and they commonly contain vegetal material. Sand, silt, and gravel of the interglacial deposits tend to be darker colored than glacial deposits due to the presence of Cascade volcanic fragments.

Hydrologic Character. The glacial deposits, tending to be coarse-grained and more permeable, serve as the major aquifers of the area. However, because of the high energy of deposition and rapidly changing conditions, the glacial deposits tend to be heterogeneous and noncontinuous.

The interglacial deposits, tending to be finer grained and less permeable, are also much more uniform in areal extent than the glacial layers. They do not commonly contain materials suitable for water yield to wells. They are typically regional aquitards, which means they act as confining layers and impede the movement of ground water.

Description of Geologic Units

The units described here are those included on the surficial geology maps and geologic cross sections prepared for this project. The distribution of geologic units is discontinuous throughout the county and thicknesses are variable. The topographic position of a unit does not necessarily conform to stratigraphic position, because much of the sediment was deposited on an eroded land surface of considerable relief. The youngest unit is described first followed by the older ones in chronological order, refer to Figure 5, Stratigraphic Column.

Beach Deposits (Qb). Moderately to well-sorted sand and gravel accumulations along shorelines; mapped only where present above high tide. Individual particles are typically well-rounded. Beach deposits form spits along protected shorelines and are widespread throughout the coastal portions of the study area, especially on western Whidbey Island.

Landslide Deposits (Qls). Clay, silt, sand and gravel. They range from relatively coherent blocks of material to intermixed debris from adjacent units transported downslope as landslide, slumps, and earthflows. The landslides most often involve the units cropping out in steep slopes or bluffs, and are most likely to be active during and after periods of above-average rainfall.

Marsh, Bog or Swamp Deposit (Qm). Sand, silt, and clay mixed with partly decomposed organic matter; deposited in fresh or salt-water. Includes peat deposits and locally contains interlayers of airborne volcanic ash. Deposits are widespread throughout the map area and especially extensive inland from tidal-flat deposits.

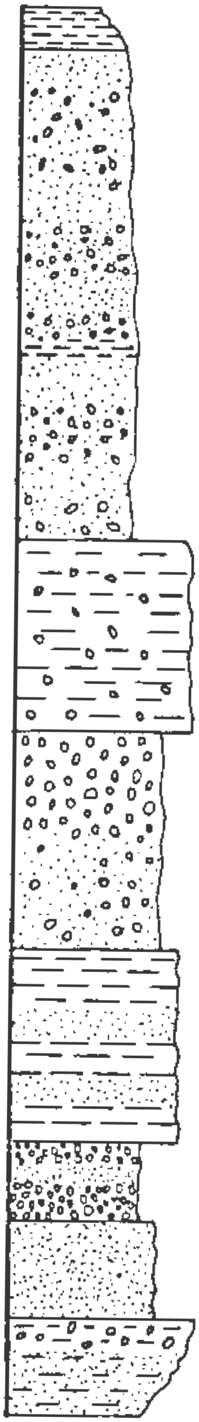
Everson Deposits (Qe). Coarse and fine deposits including medium to well-sorted, massive to laminated marine, lacustrine, and paludal sand, silt, and clay, and thin, poorly stratified partly fluvial sand and gravel. Everson deposits discontinuously overlie till, advance outwash, and older deposits.

Coarse Deposits--Present as a discontinuous cover up to elevations of possibly 140 feet but most are not shown because they are less than 5 feet thick. In a few places uplifted beach deposits form distinct strandlines.

Fine-grained Deposits--Accumulated mostly in marine waters following retreat of the Vashon ice, but the sediment source was probably nearby cliff material eroded by wave and stream activity, rather than ice. Everson age deposits are generally poorly drained.

Vashon Recessional Deposits (Qvr). This unit was deposited while the Vashon ice sheet was receding and includes two types of material, one deposited in a marine environment and the other on land.

Marine Deposits--A complex fossil-bearing stony marine silt, sand and clay. The unit includes lenses and pods of other diamictons, and a medium to well sorted massive to laminated sequence of marine sand, silt and clay. The upper portion is commonly oxidized to pale yellow-brown and dark gray-brown, but becomes gray and less distinctly layered with depth. It is



THICKNESS	UNIT	DESCRIPTION
0'-15'	Qe	EVERSON DRIFT Silt, clay and thin sand and gravel layers.
20'-150'	Qvr	VASHON RECESSIONAL OUTWASH Poorly to well sorted sand and gravel with silt layers. Includes outwash and ice contact deposits. Thickest section is a filled channel which may be over 200' deep.
0'-100'	Qvt	VASHON TILL Poorly sorted, unstratified, compact mixture of clay, silt and sand with variable amount of pebbles, cobbles and boulders embedded throughout.
20'-200'	Qva	VASHON ADVANCE OUTWASH Usually clean, pebbly sand which coarsens upward.
15'-140'	Qtb	TRANSITIONAL BEDS Thick beds of glacial and non-glacial gray clay, silt and fine to very fine sand.
0'-40'	Qog	OLYMPIA GRAVELS Stratified fluvial sand and gravel which is generally oxidized.
0'-50'	Qw	WHIDBEY FORMATION Compact cross-bedded medium to coarse sand.
	Qdb	DOUBLE BLUFF DRIFT Compact gravelly-sandy silt and clay (till).

ISLAND COUNTY

Stratigraphic Column

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	2-19-85
CHECKED BY	JEE	3/19/85
REVISED	mmm	12/3/85

Figure 5

typically 3 to 30 feet thick and moderate to very permeable. In some areas this material overlies or is interlayered with poorly sorted deformed ice contact deposits.

Continental Deposits--A poorly to well sorted, locally iron-stained sand, gravel and silt. Thicknesses commonly range from 6 to 30 feet, but a channel fill deposit at the Coupeville site may be as much as 300 feet thick. This unit includes material deposited in contact with the stagnant ice margin and outwash material transported by meltwater. Particle size and degree of sorting vary widely in ice contact deposits and bedding is generally disturbed. The outwash is horizontally stratified, level to gently dipping, with channel crossbeds and cut-and-fill structures. Outwash deposits are generally very permeable, medium to well sorted gravel and coarse to medium grained sand with local lenses of fine grained sand and silt. These deposits typically form a relatively smooth land surface except where kettles formed.

Vashon Till (Qvt). Poorly sorted mixture of rock fragments deposited directly by the Vashon ice sheet. Finer-grained components include silt, sand, and clay in variable proportions, constituting a coherent to friable, moderately to highly compact matrix in which the coarser components (pebbles, cobbles, and boulders) are firmly embedded. The deposit is typically nonstratified, but may contain lenses and pods of stratified sand and gravel. Thickness ranges from a few feet to as much as 100 feet, but is typically between 10 and 50 feet. In fresh exposures the till is light olive-gray to gray in color. Clay-rich till tends to have a bluish-gray aspect, while weathering typically produces an olive to buff coloration. Till stones are commonly subangular to subround and composed of rock types found both locally and in southern British Columbia.

Distinctive features of the till are its low permeability, compactness, the vertical slopes it maintains, a fissility or sheeting develops near and parallel to the ground surface. Its heterogeneous internal structure resembles a concrete mix. When excavated and exposed, the "hardpan" tends to spall and crumble.

Vashon Advance Outwash (Qva). The advance outwash typically is a thick section of mostly clean, gray, pebbly sand with increasing amounts of gravel higher in the section. This unit is very permeable. Distinctive features of the outwash are its well developed horizontal and cross stratification, and cut and fill structures. Locally some of these sediments are stained by iron oxide precipitated from the ground water. Fine grained sand and some silt are common in the lower part of the unit and also locally occur sparingly in the upper part. The advance outwash is mined for gravel throughout the county.

Vashon Meltwater Deposits, Undifferentiated (Qvo). Shown where field criteria for differentiating between Vashon advance and Vashon recessional deposits are unclear; may include one or both Vashon meltwater deposits.

Transitional Beds (Qtb). These glacial and non-glacial deposits occur beneath sand of the Vashon advance outwash and consist mostly of thick beds of gray clay, silt, and fine-to-very-fine sand. Permeabilities for these materials are usually low to moderate. Some layers of peaty sand and gravel may be present in the lower part. These sediments were generally deposited in lakes some distance from the ice front, and in fluvial systems prior to the advance of the ice. The transitional beds seem to grade up into the base of the overlying advance outwash at some localities, but contact is typically sharp and distinct. The transitional beds are as much as 250 to 275 feet thick and may include some upper beds of the Whidbey Formation. The transitional beds are firm-appearing in outcrop, but because of a high water content and jointing, they can become unstable in steep slopes and are included in numerous landslides.

Olympia Gravel (Qog). The informally named Olympia gravel consists of stratified, fluvial sand and gravel. Gravel is mostly pebble size and is locally oxidized and weakly cemented so that it stands vertically in fresh exposure. The unit is reported to be as much as 75 feet thick. The Olympia gravel lies beneath the transitional beds and overlies the Whidbey Formation, or Possession Drift. Although an interglacial unit, the Olympia gravel is highly permeable.

Whidbey Formation (Qw). The sediments mapped as Whidbey are mostly very compact cross-bedded sand, medium- to coarse-grained, and commonly oxidized. Contorted bedding is a common structural feature. Peat beds or organic-rich sand layers are locally present in the upper part of the formation.

The Whidbey Formation has been identified for this study only in the southern part of Whidbey Island where it is as much as 200 feet thick. It is probable that the Whidbey Formation underlies other sites below the deepest well data available. Generally the top of this formation was eroded prior to deposition of the overlying unit. This allows for any of the younger formations including the Vashon to unconformably overlie it.

The Whidbey itself was deposited in a floodplain environment composed of meandering streams which were flanked by shallow lakes and swamps.

Double Bluff Drift (Qdb). The Double Bluff Drift consists of deposits of sand, gravel, lodgement till, and some silt and clay. The unit underlies the Whidbey Formation and is the oldest group of sediments of interest to the project. An exposed section may consist of basal thin bedded clays and silts containing wood (mostly flattened pieces), overlain by hard, sandy, lodgement till or sparsely pebbly, vertically jointed, silty, clayey, marine glacial sand, or both. These generally grade up into a section of alternating very gravelly till and crudely bedded sandy gravel and gravelly sand, which in turn locally grades up into massive lodgement till. The unit is as much as 60 feet thick and generally near sea level.

Pleistocene Deposits, Undifferentiated (Qup). May include any glacial or nonglacial sediments deposited during the Pleistocene Epoch. Shown where field data are insufficient for more precise differentiation or where steep slopes preclude more detailed delineation at map scale.

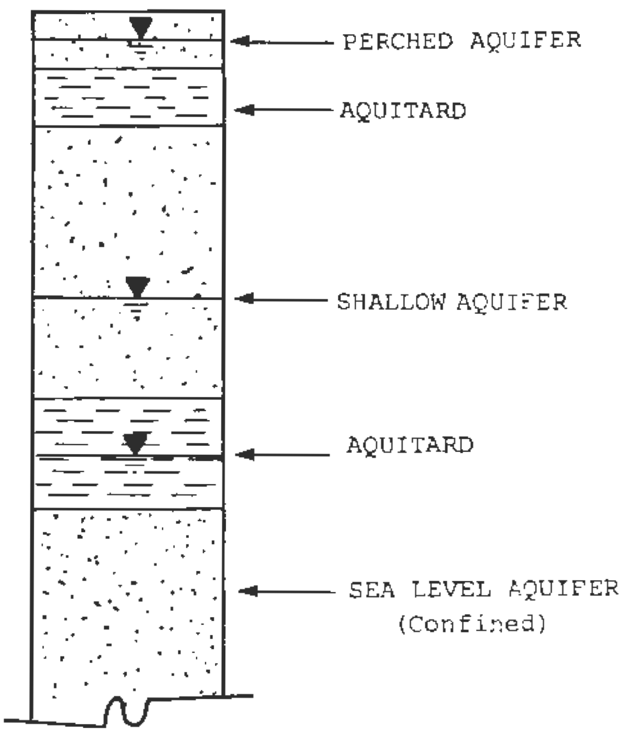
Ground Water Occurrence

Ground water in Island County is typically withdrawn from the coarse grained materials (sand and gravel) described in the previous section on Geology. Recessional and advance outwash as well as the Olympia Gravel and sand layers within the transition beds and Whidbey formation are the primary water producing zones. Till, transition beds and interglacial deposits generally serve as aquitards impeding the movement of ground water.

Perched Aquifer. Water perched on the Vashon till is the first aquifer encountered below the surface. This perched aquifer is limited to local areas and is not developed for beneficial use at any of the sites under investigation (see Figure 6, Hydrostratigraphic Column).

Water Table Aquifer. The next aquifer encountered is the basal portion of the Vashon advance outwash. This is the shallowest major aquifer in use near the sites under investigation and the most likely to be affected by the landfills. Rain water infiltrates through the unsaturated upper portion of the advance outwash, especially where the till is thin or absent, to the low permeability transition beds. Ground water occurs in perched or unconfined condition in this aquifer. In many areas, water is also found perched on silt layers within the outwash in usable quantities.

Sea Level Aquifer. The deepest aquifer identified as being in use in the areas under consideration has been named the "Sea Level Aquifer" by the USGS.[2] The USGS describes this aquifer as occurring between 30 feet above and 200 feet below sea level. Its piezometric level is commonly within 30 feet of sea level and above the level of the overlying transition beds, indicating confining conditions. In some areas near the coast, pumping has drawn the water level down below sea level creating the potential for sea water intrusion. The Sea Level Aquifer is the most heavily exploited in the county because it provides higher yields for water supply and agriculture.



Generally perched in the recessional outwash by the till

Vashon till

Generally advance outwash but can be recessional outwash channels

Transitional beds

Occasionally sand layers in the transition beds but predominantly the coarser parts of the underlying Olympia Gravel, Whidbey formation and Double Bluff Drift.

ISLAND COUNTY

Hydrostratigraphic Column

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	SUM	2/4/85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 6

Beneficial Use

Ground water is the primary source of potable water in Island County. The annual volume of ground water extracted was estimated to be 1.67 billion gallons by the USGS in 1979. Three-quarters of this was used for domestic purposes while most of the remaining volume was used for irrigation. Industrial and other uses accounted for a negligible amount.

Personnel of the Island County Health Department identified 248 wells in use within one mile of the nine sites included in the study. The shallow and perched aquifers are primarily used by wells in upland areas, but the largest volumes are generally withdrawn from the sea level aquifer.

Water Quality

Very little ground water quality information is available for any of the landfill sites. Data obtained by Island County Health Department personnel indicate that in general the chemical quality of regional ground water near the sites under investigation is good. However, ground water quality at several of the sites is significantly degraded.

Most areas of the county appear to have moderate to hard water. Elevated concentrations (often above drinking water standards) of iron and manganese in the ground water are common. Significant differences in the water quality between the deep, shallow, and perched aquifers are not apparent with the available data. Ground water contamination from salt water intrusion does not appear to be a problem near most of the sites at the present time.

Naturally occurring high concentrations of iron and manganese are typical of western Washington.

LANDFILL LEACHATE GENERATION

The first step in evaluating a landfill's potential for contaminating ground water is to estimate the amount of leachate generated by the landfill. As infiltrating precipitation saturates the waste material, high concentrations of inorganic and organic compounds can be leached from the site. The volume of leachate produced is a function of the amount of water percolating through the waste, which, in turn, is dependent on a number of interrelated climatological, vegetative, and soil conditions that are evaluated using the water balance method.

Water Balance Method

For seven of the landfill sites under investigation, the Thornthwaite and Mather method was used to estimate the water balance and subsequent potential leachate generation.[8] Total lack of vegetation at the NAS site negated usefulness of this method. Experience has shown that it is reasonable to estimate a 50 percent infiltration rate in these circumstances. The water balance method is based on the relationship between precipitation, evapotranspiration, surface runoff, and soil moisture storage. Since a precise knowledge of all these factors is rarely available and field measurements is difficult, they have been estimated for this study from known site conditions and published data. Refer to Table 1 for a summary of estimates and calculation results.

Assumptions. For the purpose of analysis, assumed conditions common to all the landfill sites include:

1. The sole source of infiltration is precipitation falling directly on the landfill surface. This ignores any surface runoff from adjacent areas and/or ground water infiltration.

2. The hydraulic conductivity (permeability) is uniform in all directions.

3. The temperature datum is the Coupeville, Washington weather station.

4. The landfill is of uniform thickness and all water movement is downward.

5. Water movement through the compacted waste will act like water movement through a soil layer that has an absorption capacity of 5.9 inches per foot.

In addition to the above, further site-specific assumptions have been made and are discussed later.

Water Balance Parameters. The following parameters were used in determining the water balance for each site:

Temperature (T) and precipitation (P)--depending on the site, the mean monthly values for precipitation (inches) were calculated from data at one of five weather service stations in Island County (refer to Figure 2). Temperature data (^{o}F) are only available for the Coupeville station.

Heat Index (I)--derived from standard tables which relate monthly mean temperatures to a corresponding i' value. Summation of the monthly i' values result in a Heat Index value (I) for the site. The heat index is dimensionless.

Unadjusted Potential Evapotranspiration (UPET)--monthly values obtained from standard tables that relate Heat Index to mean monthly temperature. Unadjusted potential evapotranspiration is dimensionless.

Potential Evapotranspiration (PET)--estimated by taking the product of the monthly unadjusted potential evapotranspiration and a correction factor based on the mean possible monthly duration of sunlight at a latitude of 48 degrees north. Potential evapotranspiration is expressed in inches.

Runoff Coefficient ($C_{R/O}$)--estimated from standard tables (Chow, 1964) assuming a surface condition of "sandy soil" and a 2 to 7 percent surface slope.[9] The runoff coefficient is dimensionless.

Runoff (R/O)--fraction of the incident precipitation estimated to be the product of the runoff coefficient and the mean monthly precipitation. Runoff is expressed in inches.

Infiltration (i)--amount of water entering the "soil", taken to be the difference between the monthly precipitation and runoff. Infiltration is expressed in inches.

Infiltration Minus Potential Evapotranspiration (i-PET)--this value indicates periods of moisture excess and deficiency in the "soil" (positive and negative values respectively). Values are expressed in inches.

Accumulated Potential Water Loss (APWL)--obtained by summation of the negative monthly i-PET values. This is expressed in inches.

Soil Moisture Storage (ST)--the amount of water that can be stored in a given profile will depend on the depth of root zone, soil type, and structure. Standard tables of soil and vegetative types with their corresponding water holding capacities were used to obtain an estimate of the water holding capacity of the soil cover at each site. This value was then used to obtain the monthly water retention (inches) in the "soil" from standard tables.

Change in Soil Moisture (AST)--the monthly increase or decrease (in inches) in soil moisture storage.

Actual Evapotranspiration (AET)--if the monthly i-PET value is positive, the actual evapotranspiration (inches) will essentially be equal to the potential evapotranspiration. If i-PET is negative (indicating a moisture deficit), the actual evapotranspiration will be less and is estimated by determining the difference between i-PET and ST and adding the result to the PET.

Percolation (PERC)--the potential amount of available water is assumed to be zero during deficit months (i-PET is negative) and equal to i-PET during months that the soil moisture storage (ST) is exceeded. Percolation is expressed in inches.

Leachate Quantities. As Table 1, Summary of Annual Leachate Generation, illustrates, all of the landfills generate leachate. In general, sites with the greatest leachate generation are those with little or no vegetated cover and higher annual precipitation.

It should be emphasized that the calculated values for leachate generation represent simplified conditions for the sole purpose of comparing sites.

WASTE CHARACTERIZATION

The information on history, operation, and waste types in this report is based on research by the Island County Health Department. Eight of the facilities are disposal sites where land burial is/was the operation method. Subsurface disposal of electroplating industrial effluent via drainfield was used at the MELCO site. Many of the land burial sites began as burning dumps in the 1950s located for convenience in gravel/sand pits. This was typical waste disposal practice for rural areas at the time. Only the Naval Air Station and Coupeville disposal sites are currently operating, although the Oak Harbor site still has operating sewage sludge lagoons and the Freeland site is used as a restricted landfill and recycling center. However, during this investigation, garbage disposal was observed at the Freeland site.

All of the sites except MELCO have received domestic/municipal types of solid waste. At least four of the sites have reportedly received sewage sludge and/or septic pumpage. Some liquid industrial wastes have been reportedly disposed at several sites including dry cleaning solvents and waste oil.

The Naval Air Station and Coupeville sites are the only ones with estimated data on annual waste volumes received. Since most of the closed sites were burning dumps during much of their history, the in-place waste volumes are generally low at these sites.

TABLE 1

ISLAND COUNTY SUMMARY OF ANNUAL LEACHATE GENERATION

	Calculated Annual Leachate Generation (Gallons)	Leachate Discharge (gal/minute)	Acres Underlain by Waste	Annual Precipitation (in inches)	Leachate Volume (x 10^4) gal. per acre/yr
NAS Landfill	1,660,000	3.2	6.13	20	27
Oak Harbor Landfill	1,373,000	2.6	15.0	20	9.2
Hastie Lake Landfill	220,000	0.4	3.0	18.6	7.3
Coupeville Landfill	905,000	1.7	7.4	18.6	12.2
Camano Island Landfill	241,000	0.5	2.0	18.6	12.0
Freeland Landfill	370,000	0.7	2.4	28	15.4
Langley Landfill	989,000	1.9	2.2	38	45.0
Cultus Bay Landfill	866,000	1.6	2.5	38	34.6

POLLUTION POTENTIAL

Provided limited resources for monitoring and a large number of sites, the first step in developing a ground water monitoring strategy is to determine the pollution potential for each of the nine sites under investigation.

The main factors governing the pollution potential of a specific site include:

- o Leachate discharge
- o Age and type of facility
- o Type of waste
- o Pollutant mobility to saturated zone
- o Beneficial use

Pollutant mobility within the saturated zone is also an important consideration. However, analysis indicates that all of the sites possess sufficiently similar hydrogeologic characteristics to preclude pollutant mobility within the saturated zone as a meaningful criteria.

Due to the number of factors involved, the relative impact of each factor and the variety of site conditions, we have established a numerical ranking system for evaluating the pollution potential of each site. Each of the above factors for each site have been assigned a relative rank; low (1), moderate (2), and high (3,4), based on our experience in similar studies and knowledge of the landfill operating conditions and hydrogeology. Because some pollution potential factors result in greater impact than others, we have also assigned multipliers to each factor. This ranking system does not establish whether or not a site is polluting ground water, but whether or not the pollution potential of the site is greater or lesser than the pollution potential of one of the other nine sites under investigation. No rating system for defining pollution potential is perfect. The objective is to establish an approach for allocating Health Department resources for monitoring. No doubt, with time and additional data, the criteria and priorities set forth here will require modification.

Leachate Discharge

The greater the leachate discharge at a waste disposal facility, the greater the potential for exceeding safe drinking water concentrations. Based on the moisture balance analysis for the sites (refer to Table 1) we have ranked each site as follows:

Rank	Discharge
1	0-1 gpm
2	1-2 gpm
3	greater than 2 gpm

Because leachate discharge is one of the most influential factors, it has been assigned a multiplier of five (5).

Age and Type of Facility

The age of a waste disposal facility, particularly landfills, affects the concentration of contaminants which might be generated and detected by monitoring. Older, inactive landfills often have exceeded their peak potential for leaching contaminants from the waste. Older sites where waste burning was practiced also tend to exhibit lower concentrations of selected contaminants due to the buffering action of burned residue. Some disposal facilities (i.e., MELCO drainfield) provide partial treatment of wastes.

Rank	Age of Facility
1	Old, closed burning dumps
2	Recently active or restricted sites
3	Active

While age is a factor to be considered, it is relatively minor with respect to other pollution potential factors and has been assigned a multiplier of one (1).

Types of Wastes

Not all wastes pose the same hazard to public health. Ideally, waste facility operations should screen and regulate the type of wastes accepted and prevent the improper disposal of dangerous or hazardous waste. In practice this is difficult to achieve. However, small rural facilities which serve small communities and individuals typically take in refuse with less pollution potential than facilities which serve industrial operations or large municipalities.

Waste disposal facilities which are limited to demolition debris and wood waste are less of a hazard that those which receive a wide variety of other wastes. Wood wastes often include treated wood products which might contain preservatives classified as hazardous. Sites which have received both wood wastes and municipal and industrial wastes are of particular concern because the wood disintegration process generates chelates. Chelates increase the subsurface mobility of other contaminants (particularly toxic metals).

All of the sites investigated, with the exception of MELCO, received domestic and municipal wastes. Some of the small rural sites have received limited amounts of industrial waste (i.e., dry cleaning fluid). Sites receiving substantial amounts of dangerous or hazardous waste are of greatest concern. Other sites regularly receive industrial and municipal sludges. Therefore, sites are ranked on the reported portions of industrial effluent, municipal sewage, and hazardous waste received.

Rank	Waste Type
1	Domestic, municipal waste only
2	Domestic, municipal waste with small fraction of industrial/municipal sludge
3	Domestic, municipal waste with large fraction of industrial/municipal sludges
4	Hazardous waste

This pollution potential factor has been assigned a multiplier of three (3).

Pollutant Mobility to Saturated Zone

Geologic materials above the water table (vadose zone) often serve to remove pollutants (attenuate) from downward percolating waters. Pollutant attenuation is affected by numerous mechanical, biological, and chemical processes. Mechanical factors important in mobility of pollutants within the vadose zone include the thickness of unsaturated sediments, filtration, and sorption. Filtration and sorption are functions of the type of soil materials, particularly texture and grain size. All of the sites under study are underlain by similar materials (sand and gravel). Therefore, material type is not an important consideration in the relative pollution potential of the nine sites.

The thickness of unsaturated sediments is important in that the greater the distance the pollutant must travel through unsaturated materials the longer the time of migration and the greater the opportunity for other attenuation processes to affect the pollutants. When the water table is shallow (e.g., 5 or 10 feet deep), there is little opportunity for attenuation before the pollutants reach the ground water. Where the unsaturated zone is thick (e.g., greater than 50 feet) a considerable amount of attenuation can take place, substantially reducing the amount of pollutant reaching the water table.

Rank	Depth to Ground Water
1	greater than 50 feet
2	10 to 50 feet
3	less than 10 feet

This pollution potential factor has been assigned a multiplier of three (3).

Beneficial Use

The distance to and number of wells and surface water near a waste disposal site must be considered when evaluating pollution potential because:

1. Improperly sealed or constructed wells can serve as conduits for contaminants reaching the ground water.

2. Wells provide drinking water supply to the public.

3. Surface waters are a potential source of public exposure to contaminants.

In order to address the full range and degree of beneficial use, we have established a separate ranking system for this pollution potential factor.

Sub-Rank	Beneficial Use Considerations
1	Nearest well >1,000 feet downgradient
2	Nearest well 100 to 1,000 feet downgradient
3	Nearest well <100 feet downgradient
1	Less than 5 wells within 1 mile downgradient
2	5 to 10 wells within 1 mile downgradient
3	More than 10 wells within 1 mile downgradient
1	Perennial surface water body >2000 feet downgradient
2	Perennial surface water body 200 to 2,000 feet downgradient
3	Perennial surface water body <200 feet downgradient

Table 2, Beneficial Use Considerations, presents the assigned sub-ranks for each site and beneficial use consideration. Totals range from 4 to 7 and define the overall rank for beneficial use.

Rank	Total Beneficial Use Subrank
1	<5
2	5-6
3	>6

Due to its importance, beneficial use has been assigned a multiplier of five (5).

TABLE 2

BENEFICIAL USE CONSIDERATIONS

SITE	WELLS DOWNGRADIENT						SURFACE WATER DOWNGRADIENT					
	<100 FT.*	100-1000 FT.*	>100 FT.*	<5 WITHIN 1 MILE	5-10 WITHIN 1 MILE	>10 WITHIN 1 MILE	PERENNIAL BODY <500 FT.	PERENNIAL BODY 500-2000 FT.	PERENNIAL BODY >2000 FT.	TOTAL SUBRANK	RANK	FACTOR RATING (5X MULTIPLIER)
Naval Air Station		2				3			1	6	2	10
Oak Harbor		2				3		2		7	3	15
MELCO			1			3		2		6	2	10
Hastie Lake		2			2				1	5	2	10
Coupeville	3				2				1	6	2	10
Camano Island		2		1					1	4	1	5
Freeland			1			3	3			7	3	15
Langley	3			1					1	5	2	10
Cultus Bay		2			2			2		6	2	10

* Based on interpretation of existing ground water flow data.

Site Summary

Each of the pollution potential factors have been evaluated for each site and is discussed under SITE ANALYSIS AND EVALUATION. Table 3, Pollution Potential Rating, presents the rating for all nine sites under study. The higher the rating, the greater the pollution potential of a given site. Below, we have listed the sites in order of priority for monitoring based on the sites' pollution potential.

Monitoring priority	Site	Pollution Potential rating
1	NAS	43
2	Oak Harbor	40
3	Coupeville	35
4	Freeland	34
5	Langley	33
6	MELCO	32
7	Cultus Bay	27
8	Hastie Lake	25
9	Camano Island	17

MONITORING STRATEGY

The monitoring strategy for this project is an approach for implementing monitoring program(s) at each of the nine sites under study in a cost effective manner. The major factors to be weighed in the development of a monitoring strategy include:

1. Pollution potential
2. Basic data requirements
3. Cost

Pollution potential was discussed in detail in the preceding section. Any monitoring strategy for Island County must first address site priority based on pollution potential.

Basic data requirements refer not only to the data obtained from a monitoring program, but also to data or information necessary to properly interpret the monitoring data. Therefore, in some cases where hydrogeologic data is lacking, the monitoring program for a specific site is, in part, a hydrogeological data collection program.

The direct cost for implementing a monitoring program is heavily influenced by the hydrogeology of a specific site. The depth of monitoring wells, the number of aquifers and ground water flow characteristics, all influence the cost of a monitoring program. For example, a site with a single shallow aquifer and well defined uni-directional ground water flows is relatively inexpensive to monitor, whereas a site with radial

TABLE 3

POLLUTION POTENTIAL RATING

POLLUTION POTENTIAL FACTOR	NAVAL AIR STATION	OAK HARBOR	MELCO	HASTIE LAKE	COUPEVILLE	CAMANO ISLAND	FREELAND	LANGLEY	CULTUS BAY
Leachate discharge	15	10	5	5	10	5	5	10	10
Age and type of facility	3	3	2	1	3	1	2	1	1
Type of waste	12	9	9	6	9	3	3	3	3
Pollutant mobility to saturated zone	3	3	6	3	3	3	9	9	3
Beneficial use	10	15	10	10	10	5	15	10	10
Total rating	43	40	32	25	35	17	34	33	27
Monitoring priority	1	2	6	8	3	9	4	5	7

flow and multiple aquifers at great depth could be orders of magnitude more costly to monitor.

Cost has not been used to establish whether or not a site should be monitored. However, cost in conjunction with the available Health Department resources has been considered with respect to the recommendations for implementing each site monitoring program.

Department of Ecology Minimum Functional Standards (DOE MFS) for monitoring detailed in WAC 173-304-490 are applicable to owners and operators of landfills. The monitoring strategy presented here has been structured for the Health Department for the purpose of most efficiently identifying hazards to public health. The strategy presented does not include all the elements included in the DOE-MFS, however, the strategy is structured to allow incorporation of individual site monitoring programs into DOE-MFS mandated programs with little or no duplication of effort.

Monitoring Program Development

The objectives of a monitoring program are to:

- o Obtain samples representative of in situ ground water quality.
- o Use monitoring and analysis methods that provide reproducible results through quality assurance and training of personnel.
- o Develop a monitoring program consistent with DOE-MFS.

Monitoring programs have been developed for each site incorporating alternatives for well placement. Each program addresses:

- o Where to monitor
- o What to monitor
- o When to monitor
- o How to monitor, and
- o Cost of monitoring

Where to Monitor

Ground water and contaminant flow occur within a three dimensional system and therefore, monitoring locations must be defined both areally (site location) and with depth (aquifer locations).

Site Locations. Proper monitoring site locations are critical to achieving the goals of the monitoring programs. Unfortunately, when sufficient data are lacking, a substantial amount of time and money are at risk regardless of the approach used in selecting site locations.

The principal factor in locating monitor wells is the direction of ground water flow. Monitor wells should be located downgradient and as near to the source as practical. Where possible, drilling through garbage to install a monitoring well should be avoided. Federal Solid Waste Standards (40 CFR 247) dictate a minimum of three monitoring wells downgradient from the waste. The newly promulgated DOE Minimum Functional Standards (WAC 173-304) also require at least three downgradient wells.

In order to adequately determine whether or not ground water quality changes over distance and has been impacted by landfill operations, it is necessary to establish a background monitoring well upgradient of the contaminant source.

Aquifer Locations. To achieve early contaminant detection and minimize pollution impact, it is preferable to monitor the shallow or uppermost aquifer beneath the contaminant source. At some sites the shallow aquifer is perched with little or no beneficial use and/or may be in hydrologic connection with deeper more developed aquifers. In these situations it is necessary to monitor two or more aquifers.

What and When to Monitor

The Minimum Functional Standards for solid waste facilities (promulgated November 1985) specify minimum requirements for testing of ground water samples. Site monitoring wells must be sampled quarterly for the life of the facility including the closure and post-closure periods.

The constituents to be tested quarterly in ground water are specified in WAC 173-304-490. These constituents are listed in Table 4.

Specific procedures for evaluation of water quality data are also included in WAC 173-304-490. The site owner/operator must maintain a water quality database for each site. The water quality data from each quarterly sampling run must be statistically evaluated (Student's t test) to see if there is a significant increase (or decrease for pH) in constituent concentration in any downgradient well(s) as compared to the site background well(s). Note that the database will be too small for valid statistical analysis until at least two, and possibly more quarterly sampling runs have been completed. It is therefore recommended that upgradient wells be sampled in duplicate for the first year.

If there is a significant increase in water quality constituent parameters, all monitoring wells must be resampled within fourteen days. The laboratory testing results from the resampling may confirm the statistical increase in constituent concentration or indicate that the increase was anomalous. If confirmed, the operation will be required to sample for Primary

TABLE 4

DOE - MFS INDICATOR PARAMETERS

PARAMETER	TESTING
Temperature*	Field
Conductivity*	Field and Laboratory
pH*	Field and Laboratory
Chloride*	Laboratory
Nitrate-N	Laboratory
Nitrite-N	Laboratory
Ammonia-N*	Laboratory
Sulfate*	Laboratory
COD (Chemical Oxygen Demand)	Laboratory
TOC (Total Organic Carbon)*	Laboratory
TOX (Total Halogenated Hydrocarbons)* +	Laboratory
Dissolved Iron (Fe)	Laboratory
Dissolved Manganese (Mn)	Laboratory
Dissolved Zinc (Zn)	Laboratory
Total Coliform	Laboratory

NOTES: * - Indicators used in previous testing

+ - Not required under the MFS

TABLE 5

PRIMARY DRINKING WATER STANDARD PARAMETERS

Arsenic	Barium
Cadmium	Chromium
Nitrate (as N)	Copper
Silver	Lead
Endrin	Mercury
Methoxychlor	Selenium
2,4-D	Lindane
Coliform	Toxaphene
	2,4,5-TP Silvex

Drinking Water Standards (WAC 173-304-9901) to determine whether or not the site is in compliance with DOE MFS (refer to Table 5 for specific parameters).

Under the Minimum Functional Standards the County Health Department must decide what further investigation will be needed to resolve instances of apparent ground water contamination including monitoring for organic contaminants. The more common volatile organics associated with waste disposal are listed in Table 6. In most cases a specific sampling program will be required to determine if corrective action is needed to protect public health. The frequency of sampling, constituents to be tested and other technical issues are usually best decided with input from ground water quality experts from regulatory agencies or private consultants. The flow chart (Figure 7) indicates the monitoring steps required under the Minimum Functional Standards (WAC 173-304-490).

In the case of one site, MELCO, where electroplating wastes have been discharged, it is recommended that additional testing be performed during the first year for dissolved heavy metals (refer to Table 7) using field filtration. These results should be evaluated according to the same statistical procedures for comparison of upgradient and downgradient ground water conditions.

How to Monitor

Monitoring ground water requires specialized facilities, equipment and procedures.

Facilities. Access to the ground water system is via wells. Establishing whether or not waste disposal operations are impacting ground water quality generally requires the use of specially constructed monitoring wells. Monitoring wells provide for accurate water level measurements, collection of representative water samples and quality assurance/quality control. Only through the use of properly installed monitoring wells can it be assured as to which aquifer is being monitored and if that aquifer is effectively isolated. A disadvantage with monitoring wells is the high cost of installation.

The use of existing wells in the site vicinity has two advantages: no installation costs and they allow assessment of the quality of water the public is actually consuming. However, existing wells have several major disadvantages including:

- o Inability to relate ground water contamination to landfill operations.
- o If public supplies are contaminated it is often too late to take remedial action.

FIGURE 7
SOLID WASTE SITE
GROUND WATER MONITORING
IMPLEMENTATION FLOW CHART

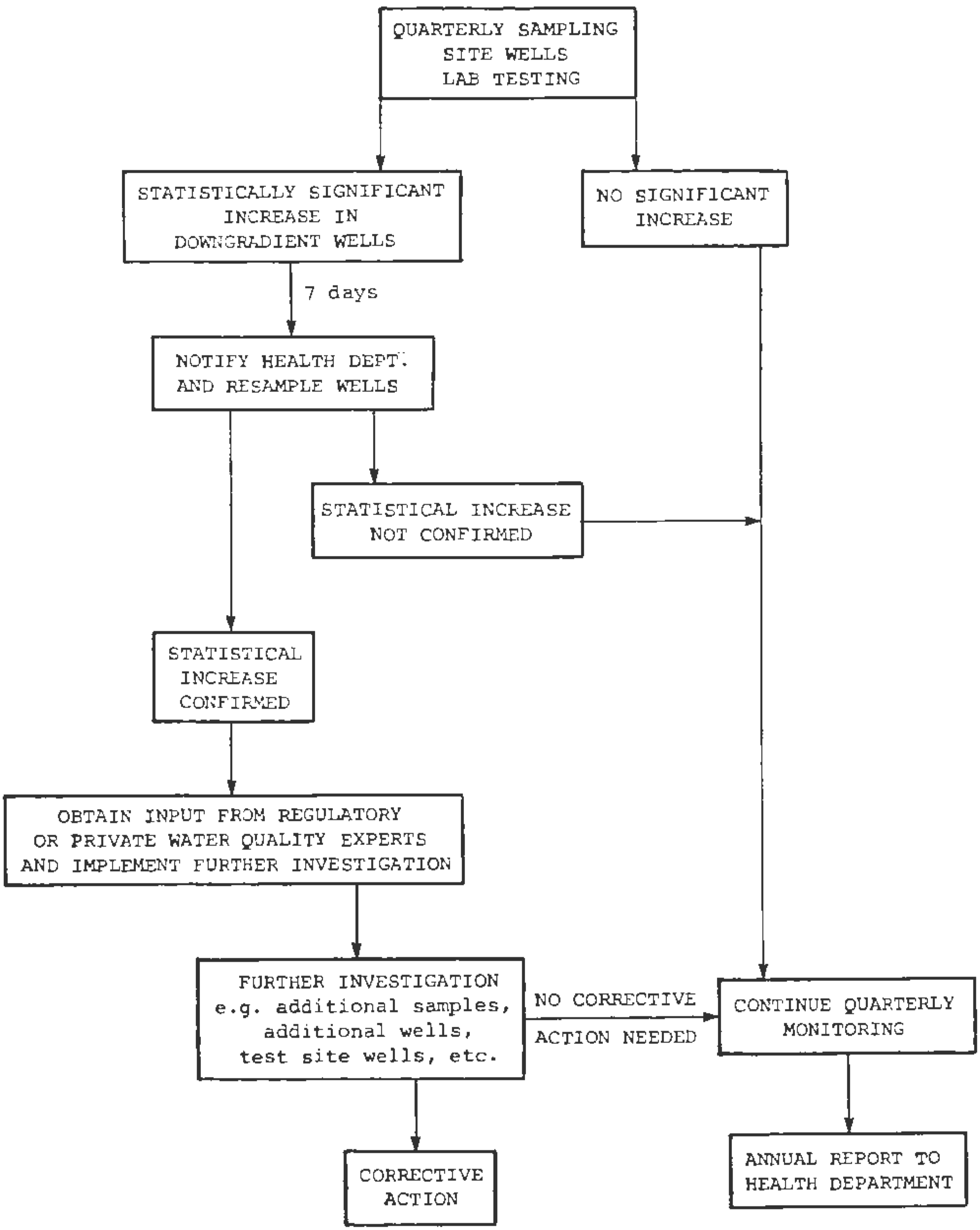


TABLE 6

VOLATILE ORGANICS (EPA 624)

Chloromethane	1,1,2,2-Tetrachloroethane
Bromomethane	1,2-Dichloropropane
Vinyl Chloride	Trans-1,3-Dichloropropene
Chloroethane	Trichloroethene
MEthylene Chloride	Dibromochloromethane
Acetone	1,1,2-Trichloroethane
Carbon Disulfide	Benzene
1,1-Dichloroethene	Cis-1,3-Dichloropropene
1,1-Dichloroethane	2-Chloroethylvinylether
Trans-1,2-Dichloroethene	Bromoform
Chloroform	2-Hexanone
1,2-Dichloroethane	4-Methyl-2-Pentanone
2-Butanone	Tetrachloroethene
1,1,1-Trichloroethane	Toluene
Carbon Tetrachloride	Chlorobenzene
Vinyl Acetate	Styrene
Bromodichloromethane	Total Xylenes

TABLE 7

HEAVY METAL PARAMETERS

	Iron, see Table 4
Arsenic	Manganese, see Table 4
Chromium	Mercury
Copper	(Antimony)
Lead	(Beryllium)
(Nickel)	(Selenium)
Cadmium	Zinc, see Table 4
(-Thallium)	

( ) = Not tested unless contamination is detected.

- o Water levels and water quality results are rarely representative of ground water conditions. Uncertainty exists as to what aquifer is being monitored because of lack of well construction data.

- o Existing domestic wells will not meet DOE MFS for monitoring of landfills.

In addition, the use of existing supply wells for monitoring requires:

1. Access and permission of owner.

2. Drawing sample from tap, before the water has passed through a pressure tank and/or water conditioner. (Samples taken after pressurization or treatment do <u>not</u> represent true aquifer conditions.)

3. Drawing of samples after a long nonpumping period, which must be determined specifically for each well.

Proper installation of specially constructed onsite monitoring wells requires the use of experienced personnel, proper equipment, materials and procedures. For the sites under investigation two types of wells are required: single completion and multiple completion (refer to Figure 8, Monitoring Well Construction Details).

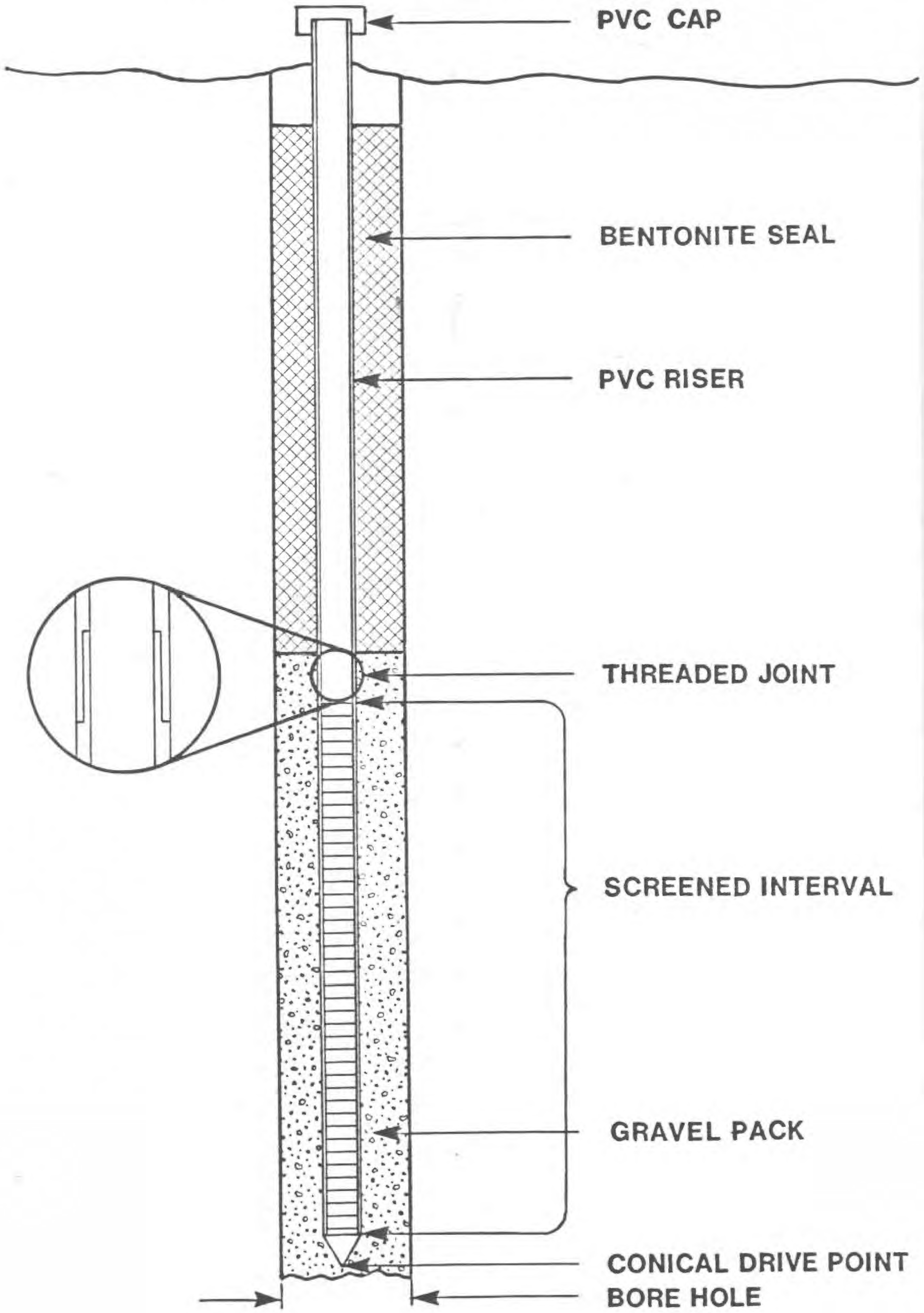
The monitoring wells should be drilled using an air rotary drill rig with casing driver. A minimum 6- to 8-inch diameter hole would be drilled while simultaneously advancing a minimum 6- to 8-inch diameter steel casing (single completion is 6 inches, double completion is 8 inches). The depths of the borings will range from 25 to 200 feet deep or a minimum of 15 feet into water.

Access sufficient to accommodate two 40-foot long rigs (drill rig and pipe truck) is necessary. At some locations road construction will be required. Access to water for drilling will be necessary.

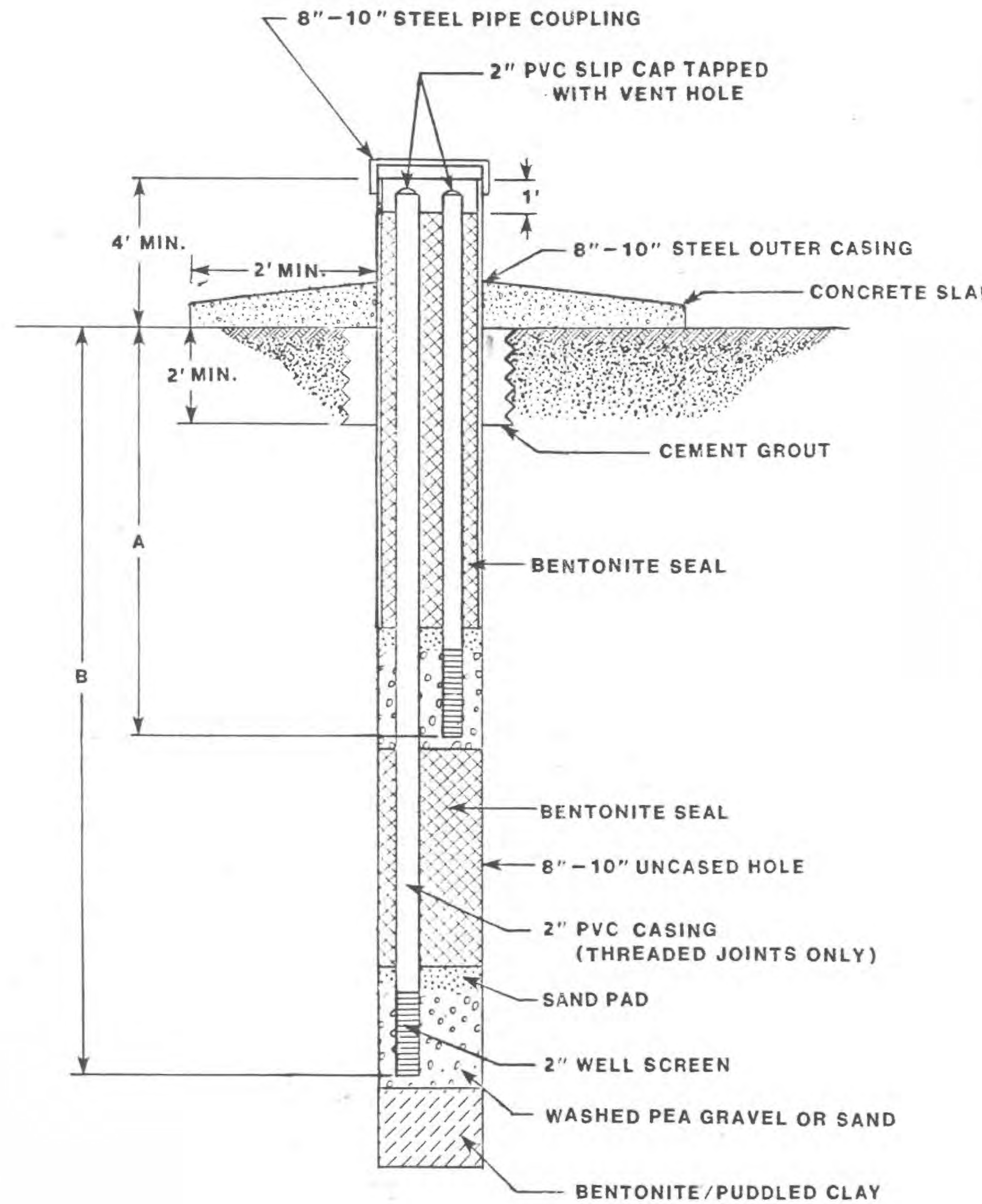
Upon completion of drilling, 2-inch diameter schedule 80 PVC well screen(s) (slot size .010 to .020 inch) should be installed opposite the water-bearing formation. A push point bottom cap will be fixed to the screen. The screen would be attached to the bottom of a 2-inch schedule 80 PVC casing(s) rising 1 to 2 feet above ground surface. A top cap would be provided with an air vent hole. Only threaded couplings should be used. No solvent welded or slip couplings should be used.

After the screen and casing have been installed a 1/4- to 3/8-inch sand or gravel filter should be placed from the bottom

SINGLE COMPLETION MONITORING WELL



DOUBLE COMPLETION MONITORING WELL



ISLAND COUNTY

Single & Double Completion Monitoring Wells

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	3/6/85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 8

of the hole to a depth designated by the geologist. A minimum 2-foot thick plug using bentonite pellets would be placed on top of the filter pack. For single completion wells the remainder of the hole would be filled with a bentonite slurry. For double completion wells an isolating plug (bentonite pellets) should be placed below the upper screen and above the lower screen at depths designated by the geologist.

Simultaneously with the installation of the gravel pack and bentonite, the steel casing should be removed from the hole. Upon removal of the steel casing a 6-inch diameter locking security casing should be cemented into place to protect the monitoring well from vandalism (refer to Figure 9, Security Casing).

After completion the well is developed for two to four hours using a bailer filtered air to remove fines from within the casing and screen and ensure hydraulic continuity with the water-bearing formation. All well construction must be performed by a licensed water well contractor and meet Washington well construction standards. An experienced geologist should log the holes and supervise the placement of screen, casing the gravel pack, well seal, and development.

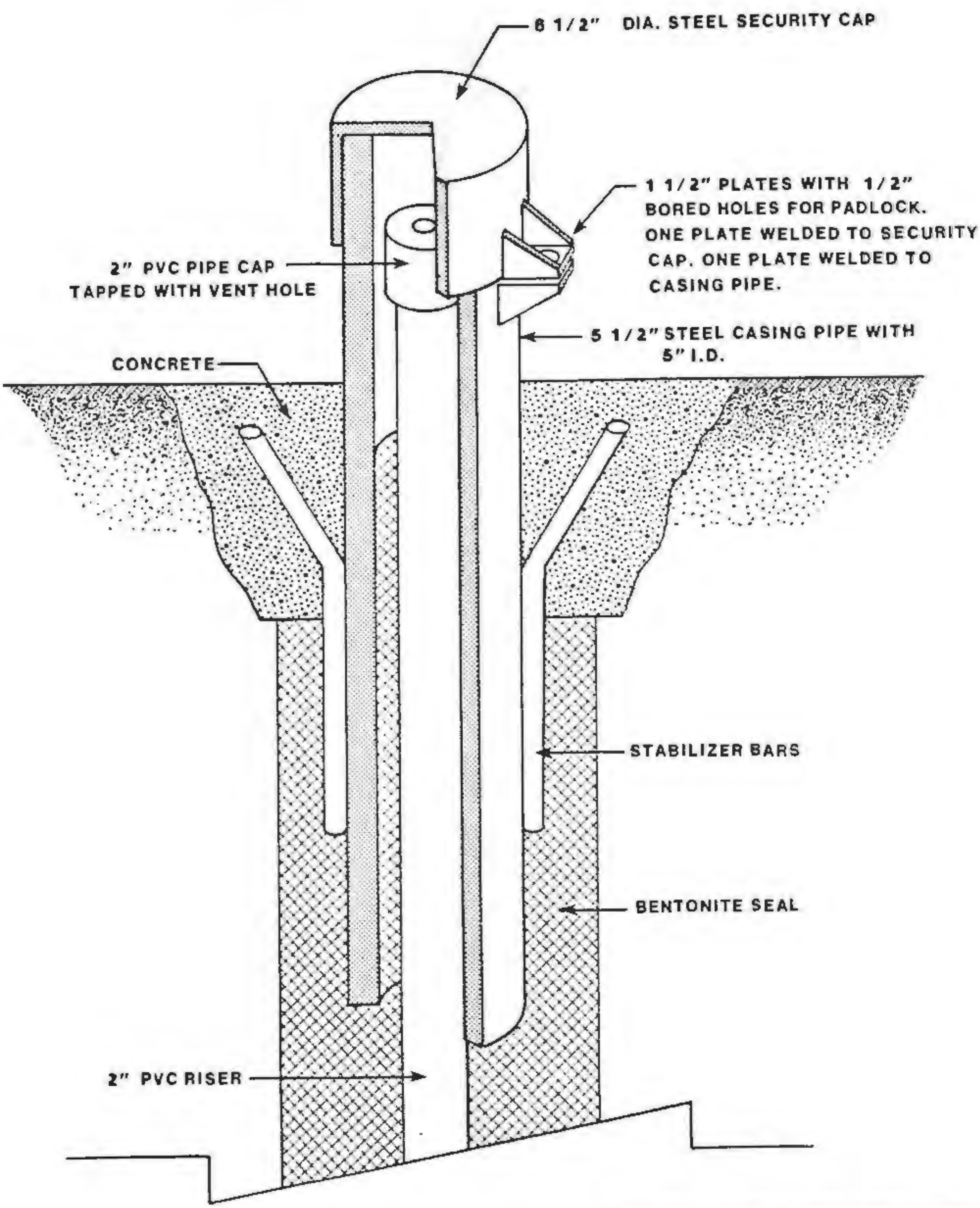
Monitoring Equipment. Proper sampling and field testing equipment are critical for effective monitoring. SEA supplied and trained Health Department staff in the use of the following monitoring equipment:

1 double check valve bailer
1 Teflon bailer
1 pH meter
1 well wizard automatic controller
2 well wizard pumps--stainless steel
with Teflon pump bladder
1 peristaltic pump
1 field filter apparatus
100 0.45 micron filters
100 prefilters
1 conductivity meter
1 flow-through cell

In addition, miscellaneous support equipment and supplies (i.e., meter calibration standards, wash bottles, etc.) were provided.

Similar equipment should be used on all additional monitoring sites with exact purchase needs dependent on the number and depth of sites.

Monitoring Procedures. Adherence to proper monitoring procedures are an absolute necessity to obtain consistent and reliable results. Appendix IV is a procedure manual developed to assist the Health Department in their monitoring program.



ISLAND COUNTY

Monitoring Well Security Casing

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	3/6/85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 9

Monitoring Costs. In order to efficiently allocate the Health Department's available resources a cost estimate for implementing the monitoring program has been developed for each site based on the following unit costs:

Mobilization/demobilization	$ 500
Drill 6-inch diameter hole and remove casing/ft	19
Drill 8-inch diameter hole and remove casing/ft	23
Materials, 25 ft single completion well	410
Materials, 50 ft single completion well	475
Materials, 100 ft single completion well	650
Materials, 200 ft single completion well	975
Materials, 150-100 ft double completion well	1,425
Materials, 200-100 ft double completion well	1,975
Well installation-development/hour	75
Access (road building, etc.)/hour	55
Coordination and supervision/hour	45
Sampling (Health Department personnel/hour)	22
Drilling contingency	10%
Minimum Functional Standards Constituents/sample	225
Metals testing (MELCO)/sample	280
Volatile organics/sample	225
Drinking Water Standards constituents/sample	375

Table 8, Monitoring Costs, presents the cost of implementing a monitoring program at each of the sites. Program A assumes installation of monitoring wells and Program B assumes use of existing wells only. Table 8 takes into account the double completion well drilled at Coupeville and the three single completion wells drilled at Freeland.

TABLE 8
ISLAND COUNTY - ESTIMATED MONITORING COSTS*

SITE	MONITORING PRIORITY	WELL DEPTHS (FT)	INSTALLATION COSTS $	PROGRAM A TOTAL FIRST TWO YEARS $	PROGRAM B TOTAL FIRST TWO YEARS $
NAS	1		0	0	51,000
OAK HARBOR	2	150 100 100 100	27,000	40,000	8,600
Coupeville[a]	3	200/100 200/150 200/150 200/100 200/100	69,000	88,400	---
Freeland[a,b]	4	100 100 150	18,600	38,000	
Langley	5	50 50 50 150	22,000	35,000	6,900
MELCO	6	25 25 25	12,000	23,00	---
Cultus Bay	7	150/100 150/100 150/100	34,000	**	**
Hastie Lake	8	200 200 200	28,900	38,600	9,700
Camano Island	9	150 150 150	20,600	29,700	18,500

NOTES:

* Testing costs will decrease somewhat with increasing volume of laboratory analyses.
** Insufficient data to recommend monitoring approach.
--- Insufficient existing downgradient wells to monitor.
a Suitable dedicated monitoring wells already exist onsite. Well depths in this table are for additionally required wells.
b Program B not recommended for this site.

Naval Air Station, Oak Harbor and MELCO Manufacturing

The Naval Air Station (NAS) Landfill, Oak Harbor Landfill and MELCO Manufacturing are immediately adjacent to each othe and share the same climate and hydrogeology.

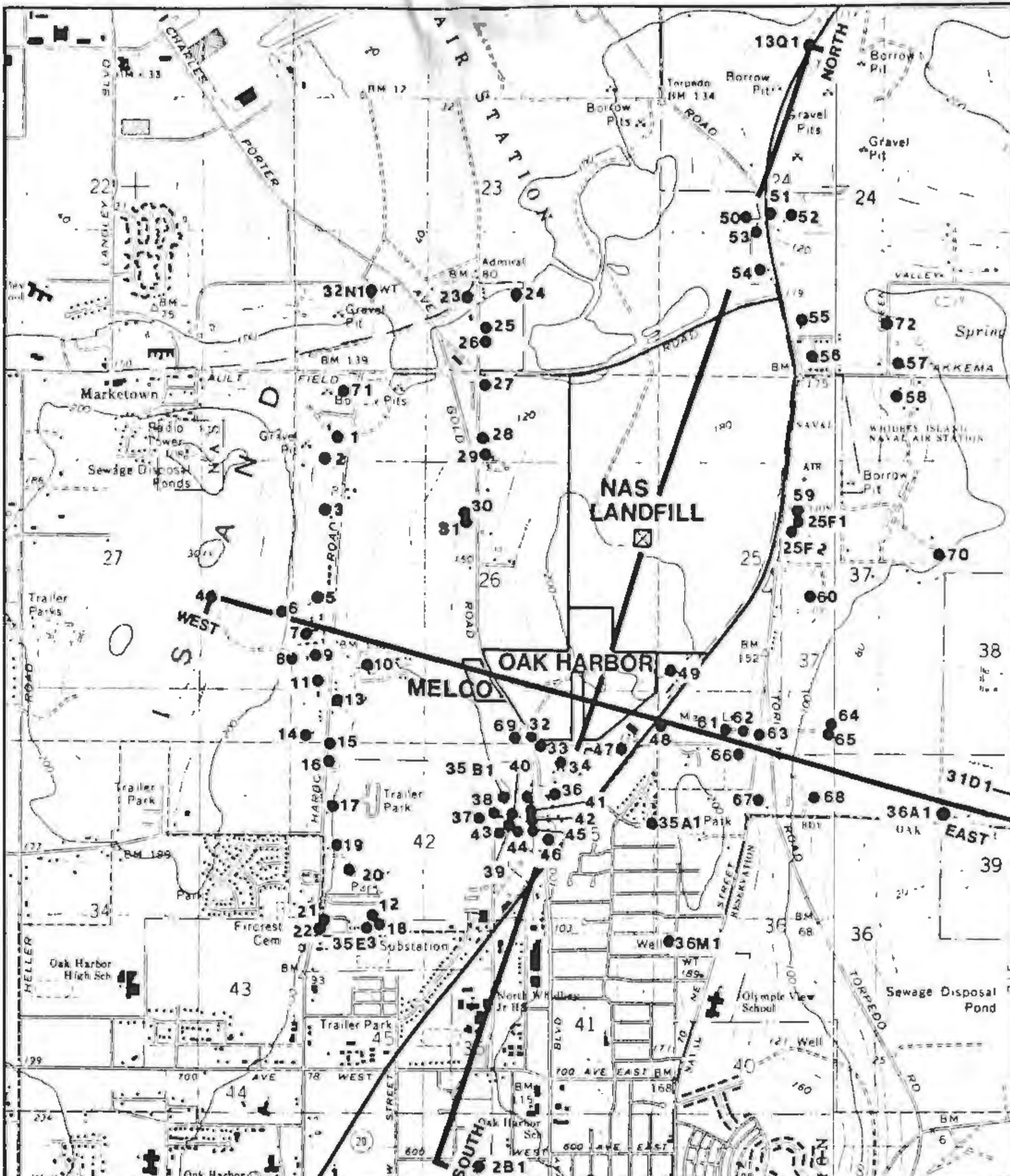
All three sites are located north of Oak Harbor an southeast of Ault Field in an area of rolling wooded uplands refer to Figure 10, Site Location Map. The Oak Harbor and NA landfills are located on a subdued hill at an elevation about 20 feet above sea level. MELCO is low on the southwest flank c this hill at about 130 feet above sea level. The northeaster portion of the hill, which is owned by the Navy, has bee cleared of vegetation and used for gravel borrow. With th exception of the landfill and developed areas, the remainde of the hill is wooded with mostly young trees. The Oak Harbo Landfill has been closed except for the disposal of dewatere sewage sludge and demolition debris. MELCO has stopped sit plating operations and the NAS landfill is still active.

Climate. Precipitation at Ault Field averages 20 inches pe year and is estimated to be the same as the other three sites Temperature data is available only for Coupeville where i averages 40° F in the winter and 60° F in the summer with a annual mean temperature of 50° F. Winds blow from the Strait o Juan de Fuca over the northern part of Whidbey Island and th sites.

Geology. All three sites are located on Vashon glacia materials, predominantly advance outwash sand and gravel covere by till layer, refer to Figure 11, Surficial Geology.

Both the till and recessional outwash have been remove before or during operation of the two landfills. The advanc outwash is underlain by clay and sand of the transitional bed which in turn is underlain by undifferentiated sand and gravel refer to Figures 12 and 13, Geologic Cross-Sections. Metamorphi bedrock crops out west and north of the site (off map). Hill and ridges in the bedrock may be in part responsible for th apparent rise in elevation to the west and north of th transition beds.

Hydrogeology. Available well data indicate that two aquifer are in use in the vicinity of these three sites. A shallc aquifer in the advance outwash and the sea level aquifer in ar below the transition beds. Although no information is availabl it is likely that a near-surface perched aquifer may be preser in the recessional outwash.



EXPLANATION

Base Map: U.S.G.S. 7½' quads. Oak Harbor & Crescent Harbor

60 ● Well With Number

WEST EAST

Cross Section Location

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

N

NAS, Oak Harbor and MELCO Sites

Sites Location Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-25-85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 10

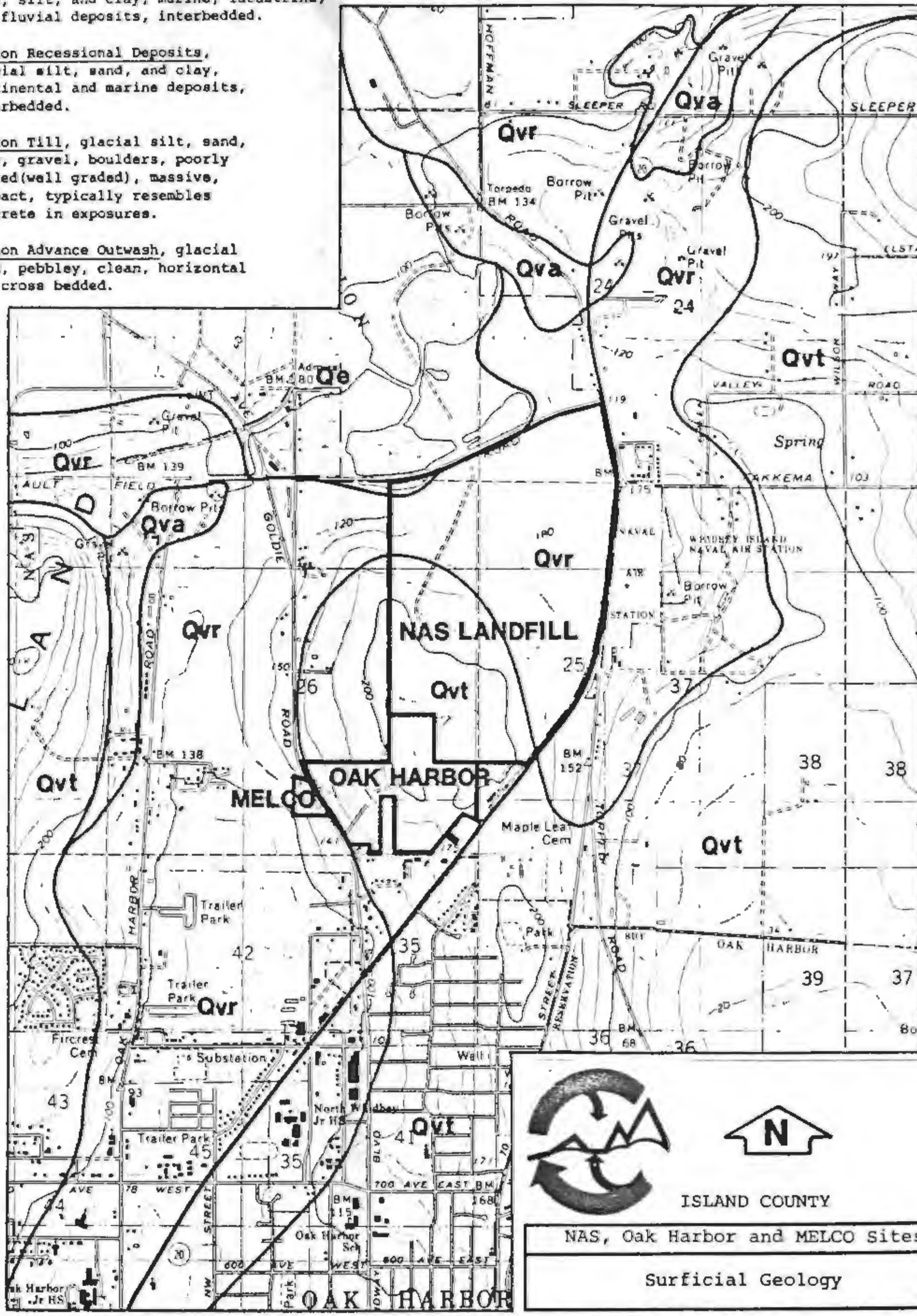
EXPLANATION

Qe .. Everson Age Deposits (undifferentiated), sand, silt, and clay, marine, lacustrine, and fluvial deposits, interbedded.

Qvr .. Vashon Recessional Deposits, glacial silt, sand, and clay, continental and marine deposits, interbedded.

Qvt .. Vashon Till, glacial silt, sand, clay, gravel, boulders, poorly sorted (well graded), massive, compact, typically resembles concrete in exposures.

Qva .. Vashon Advance Outwash, glacial sand, pebbley, clean, horizontal and cross bedded.



Base Map: U.S.G.S. 7½' quad. Oak Harbor and Crescent Harbor

Geologic Contact

0 2000 4000

ISLAND COUNTY

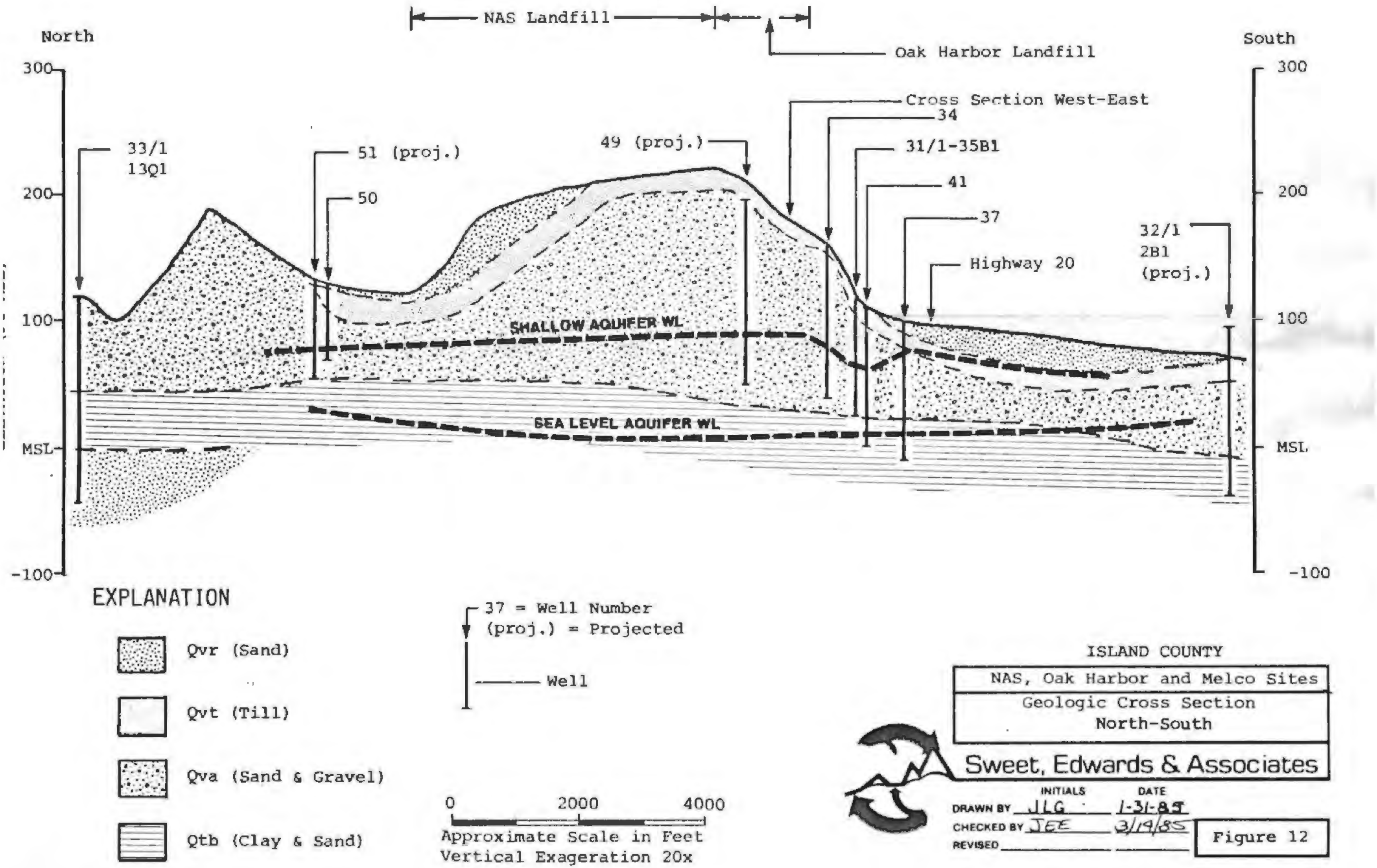
NAS, Oak Harbor and MELCO Sites

Surficial Geology

Sweet, Edwards & Associates

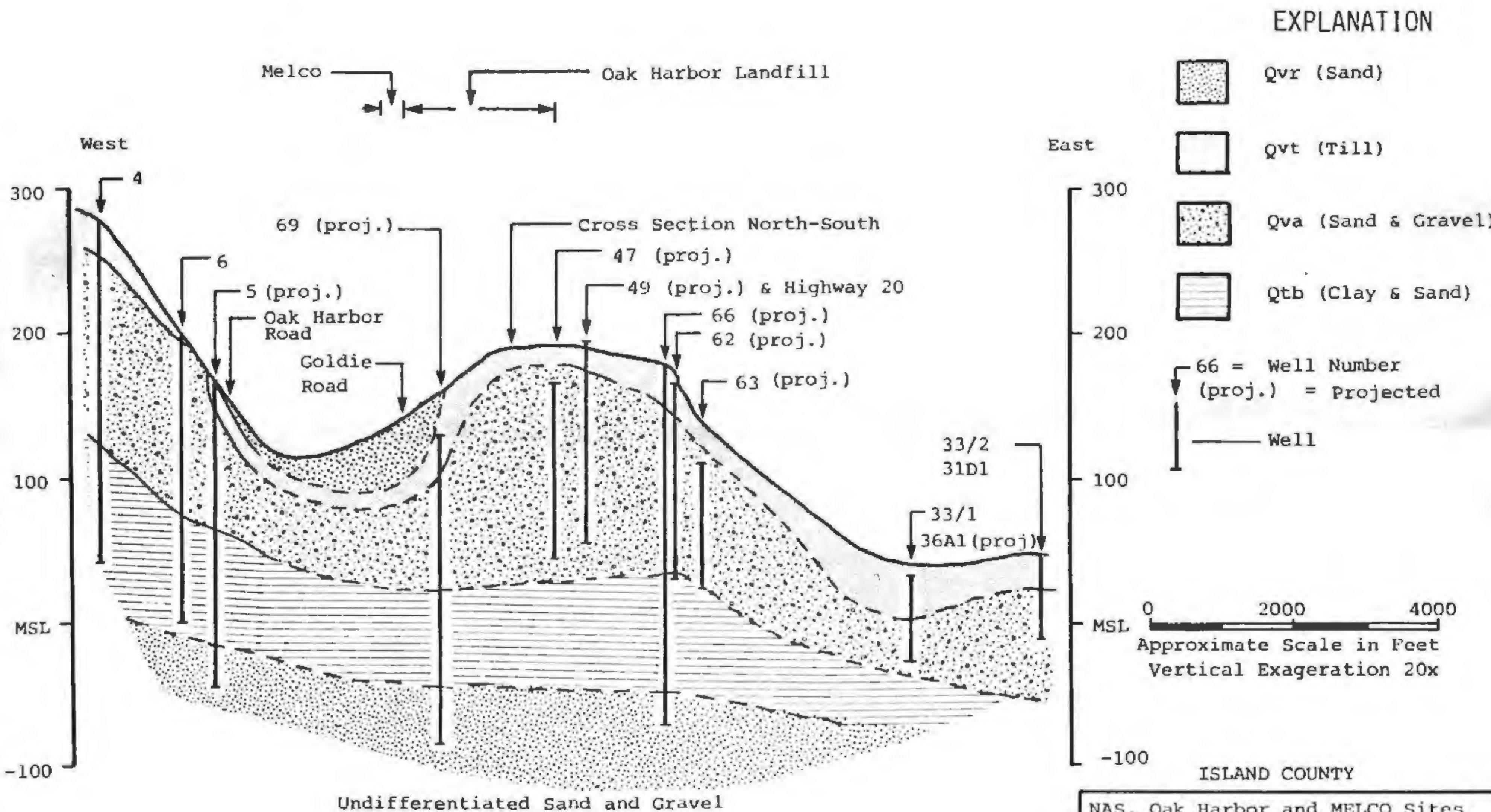
	INITIALS	DATE
DRAWN BY	JLG/sim	2-1-85
CHECKED BY	JEE	3/19/85
REVISED		

Figure 11



North
South
NAS Landfill
Oak Harbor Landfill
Cross Section West-East
300
200
100
MSL
-100
33/1
13Q1
51 (proj.)
50
49 (proj.)
34
31/1-35B1
41
37
Highway 20
32/1
2B1
(proj.)
SHALLOW AQUIFER WL
SEA LEVEL AQUIFER WL
EXPLANATION
Qvr (Sand)
Qvt (Till)
Qva (Sand & Gravel)
Qtb (Clay & Sand)
37 = Well Number
(proj.) = Projected
Well
0
2000
4000
Approximate Scale in Feet
Vertical Exageration 20x
ISLAND COUNTY
NAS, Oak Harbor and Melco Sites
Geologic Cross Section
North-South
Sweet, Edwards & Associates
INITIALS
DATE
DRAWN BY JLG 1-31-85
CHECKED BY JEE 3/19/85
REVISED

Figure 12



ISLAND COUNTY

NAS, Oak Harbor and MELCO Sites

Geologic Cross Section
West-East

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-31-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 13

Water levels define a broad, apparently low, ridge existing in the shallow aquifer under both the NAS and Oak Harbor landfills, refer to Figure 14.

Flow in the shallow aquifer is roughly radial from the NAS site, but to the south and west under the Oak Harbor site. Recharge is probably highest in areas of thin or absent till. The swampy area located to the southwest also serves as a recharge area. Between the hill and the swamp, a trough exists in the water table which may direct the flow from under the Oak Harbor site to the southwest and then south under the town of Oak Harbor.

Fewer wells have penetrated the deeper sea level aquifer in this area. Water level data in this aquifer define a broad basin that drains to the south and underlies all three sites. Flow under MELCO and the Oak Harbor Landfill appears to be due south while flow under the NAS Landfill may be to the southeast (see Figure 15, Water Level Map, Sea Level Aquifer). Studies by the Navy indicate a NE-SW ground water ridge with flow to the northwest and southeast.[10]

Beneficial Use. A total of 79 wells have been identified from Department of Ecology and Health Department records within a mile of the three sites. Seventy-three of these wells were located in the field by Health Department personnel who noted that at least 70 are currently used, refer to Table 9, Well Inventory. Ground water is used primarily for domestic potable supply, but some water is used to water stock and wash gravel. Total use of ground water has been kept down by importation of Skagit River water for the Naval Air Station and Oak Harbor's water supply system. Available well data indicate that the shallow aquifer is utilized by two-thirds of the wells. One-third tap the sea level aquifer. The shallow wells generally yield less water and supply smaller systems. The deeper wells were generally developed for higher yields to augment the city water supply, for the Navy, or to wash gravel (see Figure 10, Site Location Map for well locations).

Water Quality. Available data show generally good ground water quality in both the shallow and sea level aquifers, although limited data is present for the sea level aquifer. Elevated concentrations of iron and manganese have been reported in a number of wells throughout the area. Most ground water is quite hard and slightly elevated in dissolved solids. A sulfureous smell is reported at a few wells in the northeast part of the area. Monitoring wells at the NAS landfill exhibit elevated levels of chromium and iron.

Electrical conductivities (EC) of surface waters were taken at the NAS and Oak Harbor sites during the course of this investigation (see Figures 16 and 17). EC at the NAS were 135 micromhos immediately south of the solid waste disposal site

TABLE 9
NAS - OAK HARBOR - MELCO WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
1	Greentree	33/1/26D	120	--	120?	---	---	---	
2	Concrete Nor'West	33/1/26E	145	10	202	-27- -57	yes	---	heavy use day of W.L. measurement
3	Trask Construction	33/1/26E	140	22	185	---	yes	---	
4	Whidbey Island Sportsmens Club	33/1/27S	275	56*	236	39 - 43	yes	---	
5	Sheer	33/1/26M	160	12*	203	---	yes	---	
6	Sheer	33/1/27S	215	45	200		yes	---	
7	Gun Club Road Water System	33/1/26M	170	--	165	---	---	yes	
8	Traylor	33/1/26N	180	15	189	-4- -9	yes	---	
9	Traylor	33/1/26N	155	5*	178	-18- -23	yes	---	
10	Valley High Mobile Home Park	33/1/26N	100	74	---	---	---	yes	pumping during W.L. measurement
11	Faber	33/1/26N	140	92*	52	---	---	---	
12	Carder	33/1/35E	72	64	44	28 - 36	yes	---	open hole 28-36'/2nd well said nearby
13	Wildwood	33/1/26N	111	80	67	44 - 49	yes	---	
14	Odell	33/1/26N	130	83*	67	---	yes	---	
15	Hilberdink	33/1/35D	110	86*	38	---	---	---	
16	Eelkema	33/1/35D	105	31	123	---	yes	---	
17	Oak Hollow	33/1/35D	105	25	146	-30- -46	yes	yes	
18	Faber	33/1/35E	80	69*	40	---	yes	---	
19	Matthews	33/1/35E	95	18*	139	---	yes	---	
20	Hoffelt	33/1/35E	90	18	138	---	yes	---	
21	Hoffelt	33/1/35E	95	-11	157	-57- -62	yes	---	2 wells/includes #22
22	Hoffelt	33/1/35E	--	--	---	---	---	---	no Field Well Record sheet
23	Christian	33/1/23P	95	--	---	---	---	---	went dry Summer 1983
24	Barnard	33/1/23Q	100	77	58	---	---	---	
25	Sharp	33/1/23Q	110	--	56	---	---	---	
26	Hanson	33/1/23Q	115	--	---	---	---	---	
27	Eelkema	33/1/26B	110	69	58	---	---	---	
28	Lindel	33/1/26B	120	--	---	---	---	yes	
29	Lane	33/1/26B	130	12	---	---	---	---	
30	VFW	33/1/26F	140	82	75	---	---	yes	used a Hernately w/31
31	VFW	33/1/26F	140	68	144	---	yes	---	
32	Cash Auto Parts	33/1/26Q	140	--	---	---	---	---	
33	Vance (Jacks)	33/1/35B	135	61*	135	0 - 10	yes	---	

See last page of this table for footnotes

TABLE 9
NAS - OAK HARBOR - MELCO WELL INVENTORY

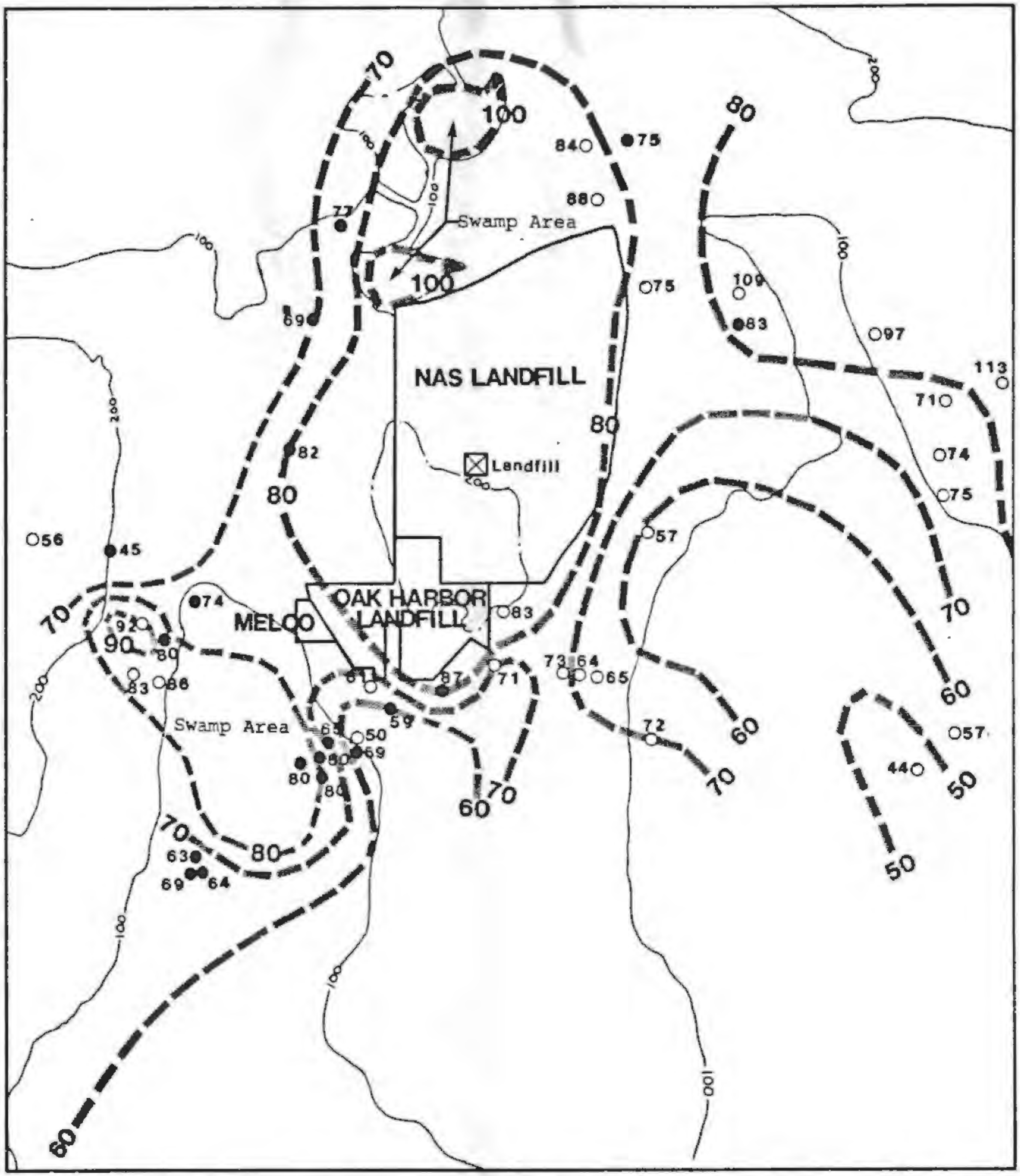
Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
34	Hartman	33/1/35B	117	59	96	21 - 31	yes	---	
35	Evergreen Mobile Home Park	33/1/35B	100	65	66	---	yes	yes	
36	Mattson	33/1/35B	120	--	---	---	---	---	
37	Fiske	33/1/35B	80	80	34	46 - 56	yes	---	
38	Howard	33/1/35B	80	80	45	---	---	---	
39	Bergdoll	33/1/35B	90	--	---	---	---	---	
40	Wiley	33/1/35P	90	--	50	---	---	---	
41	Nicole	33/1/35B	100	62*	102	3 - -2	yes	---	
42	Sullivan	33/1/35B	90	69	48	---	---	---	
43	Church of Christ	33/1/35B	80	80	47	---	yes	---	
44	Bergdoll	33/1/35B	90	--	---	---	---	---	
45	Bergdoll	33/1/35B	90	--	---	---	---	---	
46	Riksen/Mattson	33/1/35G	100	--	---	---	---	---	water not used for drinking
47	Patterson Water System	33/1/35A	175	87	120	50 - 55	yes	yes	
48	Flowers Boats	33/1/25N	180	71*	142	---	yes	---	
49	Auld Holland Inn	33/1/25N	200	83	144	57 - 67	yes	yes	pumping during W.L. measurement
50	Midget Market	33/1/24L	120	84*	61	74 - 79	yes	yes	pump test available
51	Thunderbird Mobile Home Park	33/1/24L	94	35*	77	---	yes	---	
52	Thunderbird Mobile Home Park	33/1/24L	130	75	58	72 -82	yes	yes	USGS K = 345
53	Van Vorst	33/1/24L	120	--	45	---	---	---	
54	Auvil	33/1/24L	120	88*	40	---	---	---	
55	Lang	33/1/24P	130	--	---	---	---	---	
56	Eastgate	33/1/24P	160	75*	136	---	yes	yes	2nd well on site/no log/sulphur smell
57	Lindsey	33/1/24Q	125	109*	44	---	yes	---	
58	Jaeger Water System	33/1/25B	140	83	91	49 - 55	yes	yes	pump test available
59	Westgate	33/1/25L	170	--	---	---	---	---	reported over 500' deep/old NAS well
60	Link	33/1/25L	130	57*	84	---	yes	---	
61	Brinkerhoff	33/1/25N	180	73*	127	---	---	---	
62	Lighthouse Tabernacle	33/1/25N	160	64*	124	36 - 41	yes	yes	
63	McDonald	33/1/25P	110	65*	83	27 - 37	yes	---	
64	Saari	33/1/25P	70	--	25	---	---	---	
65	Saari	33/1/25P	70	--	25	---	---	---	
66	Maple Leaf Cemetery	33/1/36D	183	5	253	-70 - -60	yes	---	USGS K = 430

See last page of this table for footnotes

TABLE 9
NAS - OAK HARBOR - MELCO WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
67	Wojciechowski	33/1/36C	140	--	110?	---	---	---	
68	Wardenaar	33/1/36C	75	72*	20	---	---	---	
69	City of Oak Harbor	33/1/26Q	130	14	214	---	yes	yes	no pump in well
70	Case Farm	33/1/25G	94	14	137	---	yes	---	
71	Dept. of Ecology	33/1/26G	130	25	682	W.L.@160'	yes	yes	USGS test hole #2/sev. levels
72	Freer	33/1/24Q	100	--	32	---	---	---	water bearing strata 28-32'
WSB-25	NAS Ault Field (Well 5)	33/1/23N1	48	--	122	---	yes	---	reported destroyed WSB-25
WSB-25	Lake City Contractors	33/1/25F1	162	4*	253	-65 - -49	yes	---	not in use - WSB-25, 8 gpm
WSB-25	Curtis Construction Co.	33/1/25F2	157	8*	252	-94 - -52	yes	---	not in use - WSB-25, 250 gpm
WSB-25	Decker	33/1/35B1	103	50*	104	---	yes	---	dd reported WSb-25, 8 gpm
WSB-25	Town of Oak Harbor (#7)	33/1/35A1	185	11*	300	---	---	---	100 gpm w/74'dd
WSB-25	Carder	33/1/35E3	77	63*	44	---	yes	---	open hole 36-44'
WSB-25	Town of Oak Harbor (#6)	33/1/36M1	178	11*	263	---	---	yes	WSB-25, 540 gpm w/54' dd

Notes: Site Well Number is used to designate wells on the Site Location Map.
All elevations are in feet above mean sea level.
All measurements are in feet.



EXPLANATION

Base Map: U.S.G.S. 7.5' quads. Oak Harbor & Crescent Harbor

Elevation Contour (Ft MSL)

84 ○ Well with old or reported water level measurement

80 ● Well with recent water level measurement

60 — Water level elevation

0 1000 2000 3000

N

ISLAND COUNTY

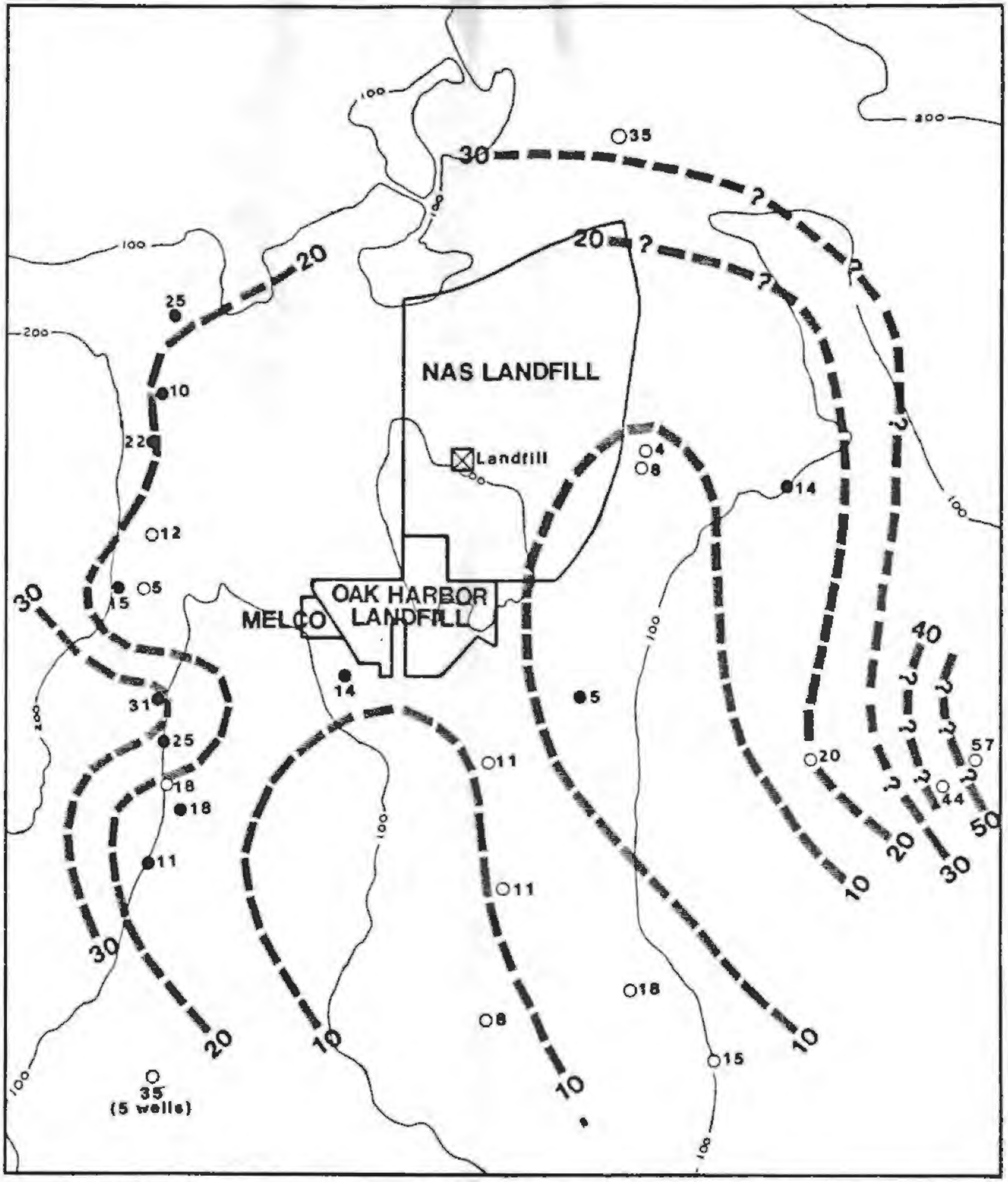
NAS, Oak Harbor and MELCO Sites

Water Level Elevation Map
Shallow Aquifer

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-22-85
CHECKED BY	JEE	3/14/85

Figure 14



EXPLANATION

Base Map: U.S.G.S. 7.5' quads. Oak Harbor & Crescent Harbor

Elevation Contour (Ft MSL)

Well with old or reported water level measurement

Well with recent water level measurement

10 — Water level elevation

0 1000 2000 3000

N

ISLAND COUNTY

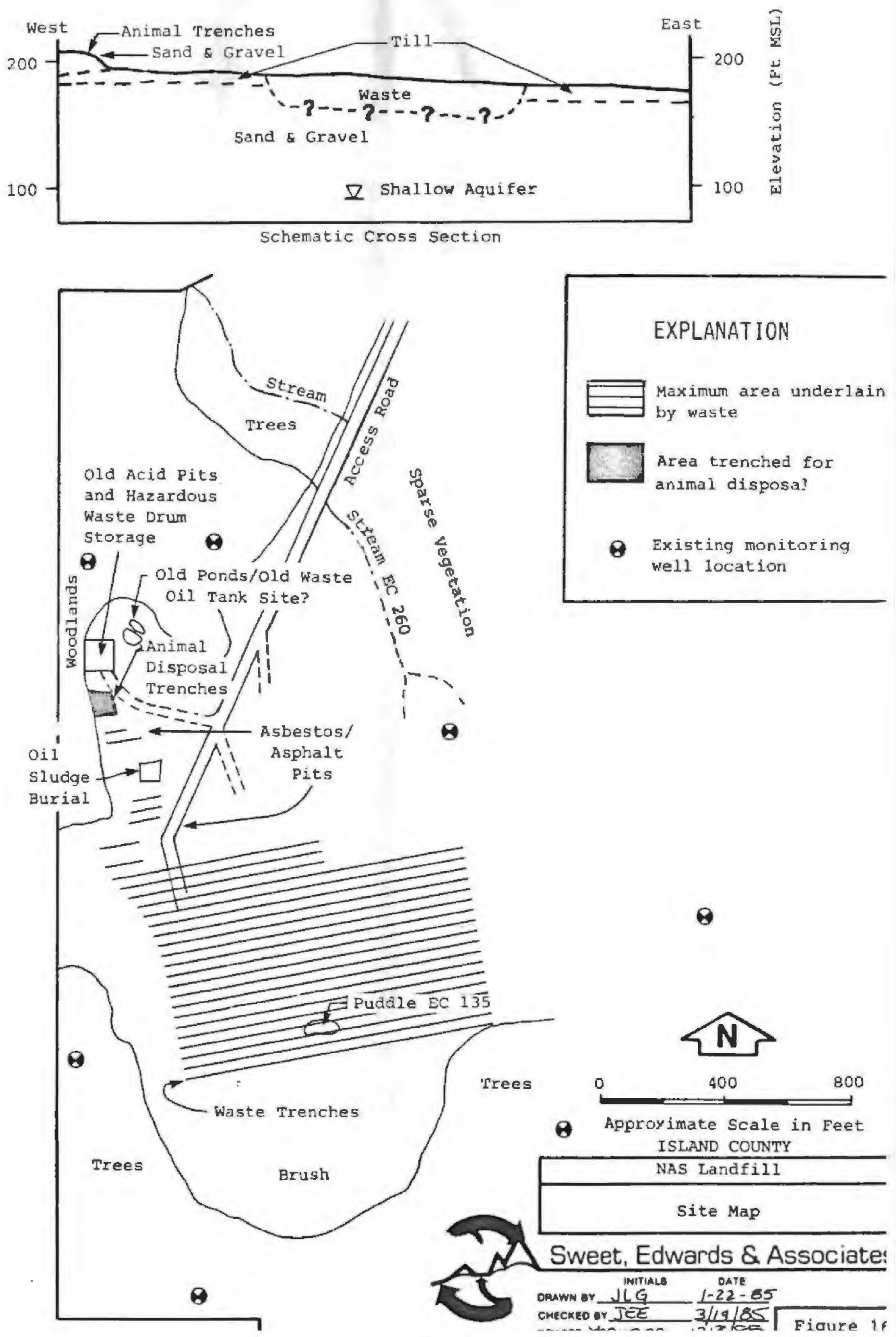
NAS, Oak Harbor and MELCO Sites

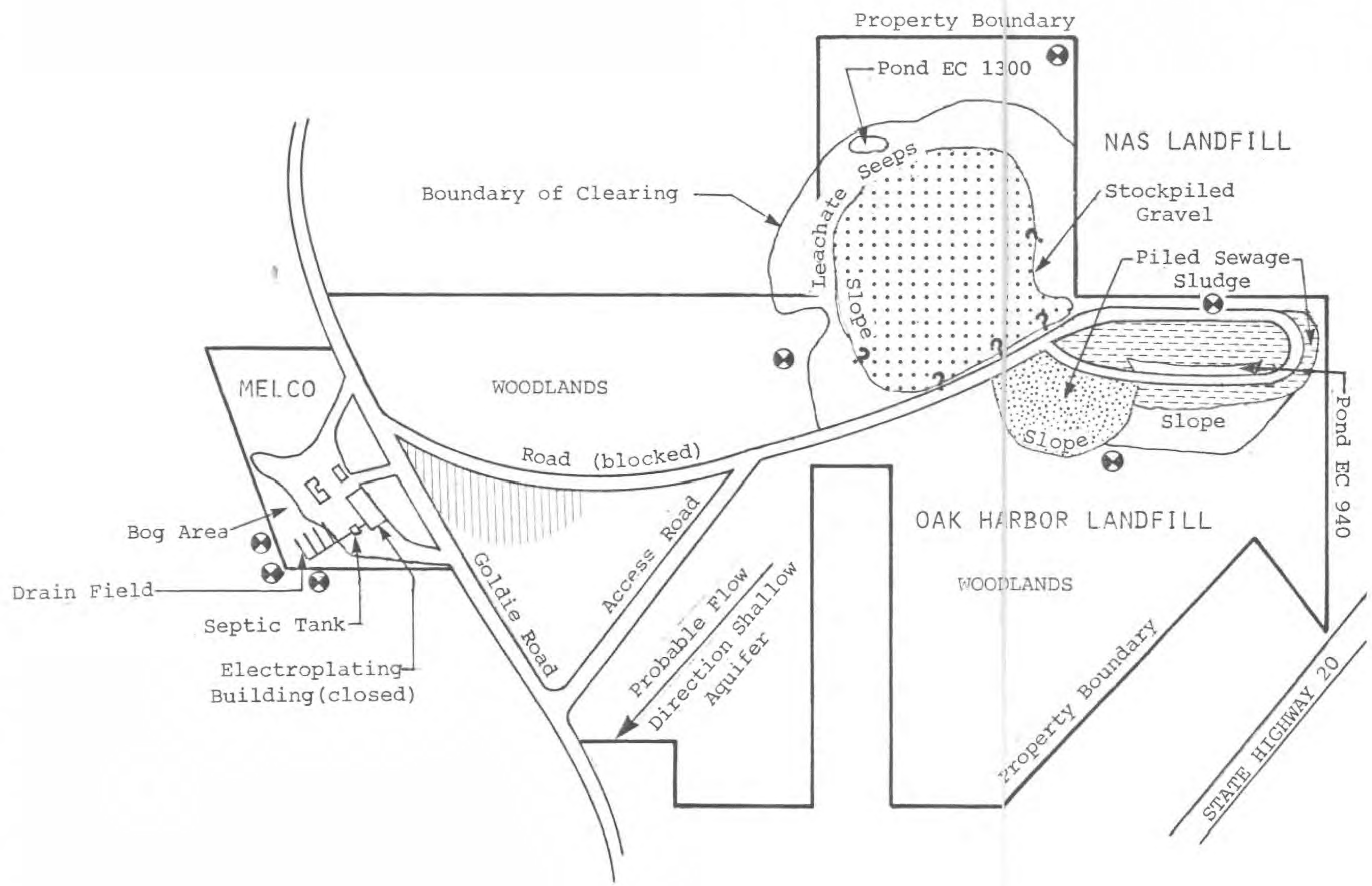
Water Level Elevation Map
Sea Level Aquifer

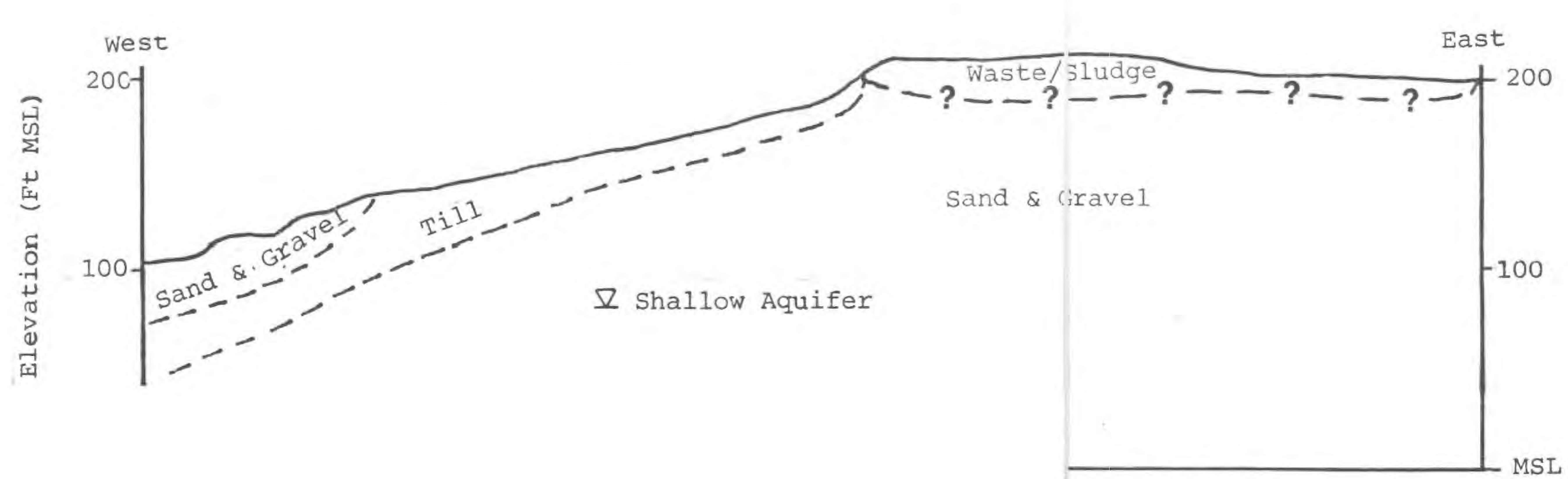
Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-22-85
CHECKED BY	JEE	3/19/85

Figure 15

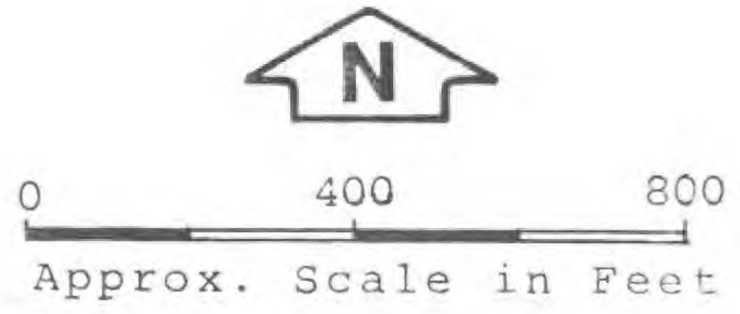

West
Animal Trenches
Sand & Gravel
Till
East
200
Waste
Sand & Gravel
100
Shallow Aquifer
Elevation (Ft MSL)
Schematic Cross Section
EXPLANATION
Maximum area underlain by waste
Area trenched for animal disposal
Existing monitoring well location
Stream
Trees
Access Road
Old Acid Pits and Hazardous Waste Drum Storage
Sparse Vegetation
Stream EC 260
Old Ponds/Old Waste Oil Tank Site?
Woodlands
Animal Disposal Trenches
Asbestos/ Asphalt Pits
Oil Sludge Burial
Puddle EC 135
Trees
Waste Trenches
Trees
Brush
N
0
400
800
Approximate Scale in Feet
ISLAND COUNTY
NAS Landfill
Site Map
Sweet, Edwards & Associates
INITIALS
DATE
DRAWN BY JLG 1-22-85
CHECKED BY JEE 3/19/85





EXPLANATION

- Areas underlain by waste
- Areas underlain by uncertain material
- Areas underlain by sewage sludge
- Demolition disposal area
- Proposed Monitoring Well location



ISLAND COUNTY

NAS, Oak Harbor and MELCO Sites

Oak Harbor Landfill and MELCO Sites Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-22-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 17

and 260 micromhos in a stream about 600 feet to the north. Ponds in the immediate vicinity of the Oak Harbor site had conductivities ranging from 940 to 1,300 micromhos. Conductivities in excess of 500 micromhos are indicative of potential landfill contamination.

NAS Landfill. The NAS landfill is a 6-acre existing site located on the eastern portion of a large tract of land which has been mostly cleared of vegetation. Access is via a gravel road entering the property from Ault Field Road which forms the northern boundary of the property, refer to Figure 16, Site Map. Surface gravels appear to have been removed from much of the area, but grasses are beginning to reestablish vegetative cover. The property consists of a gentle swale that drains to the north through an intermittent stream. Waste has been buried in a series of trenches dug in a relatively flat lying area above the southwest portion of the swale.

A hazardous waste storage area and trenches used for animal disposal are located near the central portion of the west property line. Ponds are present near the hazardous waste storage area on old areal photographs. A band of young trees and a fence separate this landfill from the Oak Harbor Landfill. All fill trenches are covered with native material, primarily sand and gravel, after placement of the waste.

Waste Characterization--The Naval Air Station (NAS) site consists of several disposal areas, both active and abandoned. Land disposal at the NAS has been ongoing since 1956. The domestic and demolition waste is placed in trenches and covered with the excavated soil. Trench disposal is reported to be 5,000 tons/year. An estimated 10,000 to 40,000 gallons of sewage sludge has also reportedly been disposed of in the trenches. Studies by the Navy indicate up to 160,000 gallons/year of hazardous waste were disposed of in the landfill and adjacent area between 1969 and 1983. Hazardous materials included: paints, Stoddard solvent, MEK, trichloroethylene, trichloroethane, thinners, pesticides, and oil wastes.

A fenced storage area is also on site for hazardous materials in drums. No details are available for the types of materials in the drums. Approximately 5,000 gallons of waste oil have been pumped into a pit onsite. A disposal pit for dead animals is located onsite. The locations of the solid waste trench fills, the drum storage area, oil disposal sites, and the animal waste pit are shown on Figure 16.

Leachate Generation--The maximum area underlain by waste is estimated to be 6.13 acres. Cover consists of sand and gravel and some till removed during excavation of the trench. Rainfall was assumed to be the same as measured at Ault Field or 20 inches per year. The waste cover is unvegetated and 50 percent of rainfall is assumed to infiltrate to and through the approximately 25-foot thickness of waste. Leachate production from the NAS site was estimated to be equal to infiltration or 1.66×10^6 gallons per year.

Pollution Potential--The NAS landfill has the highest rated pollution potential. This rating results primarily from the relatively high leachate discharge potential at the site and the reported disposal of substantial quantities of hazardous waste.

Monitoring Strategy--The Navy has installed seven monitoring wells around the site (refer to Figure 16, Site Map). Available well logs indicate the wells range from 77 to 102 feet deep with water levels 67 to 90 feet deep.[10] Insufficient data are available to determine direction of flow. Based on the available data, there are sufficient number of wells for a Program A type of monitoring program. We do not know the current status of monitoring at the site. Future monitoring by the Navy should include volatile organic and heavy metal constituents in addition to DOE-MFS parameters.

Program B includes the use of existing wells to surround the ground water ridge on which the NAS landfill is located. Candidate wells for the shallow aquifer include: numbers 49, 60, 56, 54, 61, 48, 47, 33, 30, or 31, and 27, (refer to Figure 10, Site Location Map). Candidate wells for the deep aquifer are limited to number 69, and possibly 59. Sampling and testing should include DOE-MFS indicator parameters as well as volatile organics parameters and Drinking Water Standards. First year monitoring costs will be about $31,000. Subsequent year monitoring costs will be $20,000. Clearly, there is incentive for site-specific monitoring and close coordination between the Navy and the Health Department.

<u>Oak Harbor Landfill</u>. This site covers 15 acres immediately south of the NAS Landfill. Access is from Goldie Road on the southwest corner of the property (see Figure 17, Site Map). The northeast portion of this irregularly shaped property has been used for mining of gravel and subsequent waste disposal. Demolition debris is located on the western property boundary. The area underlain by solid waste is located on the highest part of the site and has been covered. This area is basically flat, but slopes steeply on the southern and western sides of the waste mound. The remainder of the property slopes to the southwest. Current disposal dumping is restricted to dewatered sewage sludge on the central and far eastern edge of the waste mound. A gravel stockpile exists on the north central part of the mound. Grass seed has been spread over the western and southern portions of the waste mound where sewage sludge has been spread to act as fertilizer. Most of the remainder of the property is wooded.

Waste Characterization--The Oak Harbor site is shown on Figure 17 and consists of active and closed disposal areas.

The areas, which received domestic/municipal and demolition wastes from 1953 to 1980, are closed. The sewage sludge disposal area is still active.

In 1980, an estimated 12,000 to 13,000 cubic yards of domestic/municipal waste were disposed at the site. Since 1958, hundreds of gallons of dry cleaning solvents and 200,000 to 300,000 gallons of DARCO dry cleaning sludge have reportedly been disposed at the site. It is not clear whether the solvents and DARCO sludges were placed exclusively in the sewage sludge ponds or that the landfill also received some of the liquid wastes.

Leachate Generation--Waste covers approximately 15 acres of the site and an average 10- to 12-foot thickness of waste was assumed for the site. Based on field inspection, the minimal cover observed, and the site moisture balance, infiltration was assumed to be 17 percent of the annual precipitation or 3.4 inches (refer to Table 10, Moisture Balance). The annual volume of leachate generated is estimated to be approximately 1.37×10^6 gallons (4.21 acre-feet).

Pollution Potential--The Oak Harbor Landfill received the second highest pollution potential rating due to the intensive beneficial use of ground water nearby and the high volumes of municipal and industrial sludges the site receives. The site also generates relatively large quantities of leachate.

Monitoring Strategy--Ground water flow at the Oak Harbor Landfill is likely to be southerly. However, due to its presence on the same ground water ridge as the NAS Landfill, and the irregular shape of the landfill, we recommend that Program A include four initial monitoring wells as located on Figure 16, Site Map. Cost of installation will be about $27,000. Based on the data obtained from the initial borings, the monitoring program should be expanded to include a minimum of one well upgradient and three downgradient, or to meet DOE MFS. Sampling and testing should include the DOE-MFS indicator parameters as well as one sequence of volatile organics testing at each site (see Table 4). First year monitoring will cost about $5,500 and $3,800 annually thereafter if only four wells are monitored.

Program B includes the use of existing wells No. 47, 34, and 33 for the shallow aquifer, and well No. 69 for the deep aquifer. Sampling and testing should include the parameter listed above. First year monitoring costs will be about $5,200 with costs of about $3,400 annually thereafter.

<u>MELCO Manufacturing</u>. MELCO is a small manufacturing facility that produces printed circuit boards. It consists primarily of three buildings and a drainfield with associated access roads and parking lots. All structures are located on the southern half of the property. Much of the property is wooded

TABLE 10

MOISTURE BALANCE FOR OAK HARBOR LANDFILL

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1.	T	38.6	41.0	44.2	49.0	53.2	57.6	61.0	61.1	56.5	50.9	44.2	41.5	49.9
2.	P	2.3	2.5	1.8	1.4	1.2	1.0	0.6	0.8	1.0	2.1	2.4	2.7	19.8
3.	I	0.26	1.00	1.58	2.62	3.65	4.86	5.88	5.91	4.55	3.08	1.58	1.08	
4.	UPET	0.02	0.03	0.04	0.06	0.07	0.09	0.11	0.11	0.09	0.07	0.04	0.03	
5.	PET	0.45	0.71	1.22	2.05	2.75	3.59	4.42	4.06	2.83	1.95	0.92	0.65	
6.	$C_{R/O}$	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	
7.	R/O	0.30	0.32	0.23	0.18	0.15	0.13	0.07	0.10	0.13	0.27	0.31	0.35	2.54
8.	i	2.0	2.18	1.57	1.22	1.05	0.87	0.53	0.70	0.87	1.83	2.09	2.35	
9.	i-PET	1.55	1.47	0.35	-0.83	-1.70	-2.72	-3.89	-3.36	-1.96	-0.12	1.17	1.70	
10.	APWL	0	0	0	-0.83	-2.53	-5.25	-9.14	-12.5	-14.46	-14.58	0	0	
11.	ST	3.00	3.00	3.00	2.26	1.25	0.49	0.13	0.13	0.13	0.13	3.00	3.00	
12.	ΔST	0	0	0	-0.74	-1.01	-0.76	-0.36	0	0	0	2.87	0	
13.	AET	0.45	0.71	1.22	1.96	2.06	1.63	0.89	0.70	0.87	1.83	0.92	0.65	13.89
14.	PERC	1.55	1.47	0.35	0	0	0	0	0	0	0	0	0	3.37

SYMBOLS: T = mean air temperature; P = precipitation; I = heat index; UPET = unadjusted potential evapotranspiration; PET = potential evapotranspiration; $C_{R/O}$ = runoff coefficient; R/O = surface runoff; i = infiltration; i-PET = infiltration minus the potential evapotranspiration; APWL = accumulated potential water loss; ST = storage; ΔST = change in soil moisture storage; AET = actual evapotranspiration; PERC = percolation.

and slopes to the southwest. Benches have been constructed in the slope for the facility. Access is from Goldie Road which forms the site's eastern boundary. The drainfield is located in a wooded area in the southwest corner of the property below the electroplating building. A bog is reported to exist below the drainfield (see Figure 17, Site Map).

Waste Characterization--The MELCO industrial site is shown on Figure 17. WESTON Consultants conducted a Preliminary Site Assessment (August 1984) for EPA and their assessment is the primary data base for this report.

During the period 1980 to 1983, the company discharged approximately 12,000 gallons per day of treated effluent from a now closed electroplating facility onsite. The effluent was pumped to the subsurface drainfield shown on Figure 17.

The EPA/WESTON investigation included sampling and testing of shallow soils from the areas of the drainfield and bog. Water samples from the site trench drain and nearby municipal well were also tested. The study concluded that the heavy metals in the effluent are held in the site soils and are not a significant environmental threat. No mention was made of the possible presence of solvents used in the electroplating process.

Pollution Potential--The MELCO site was rated sixth in terms of pollution potential. The site no longer serves as a waste disposal operation. While the type of facility and waste warrant concern, the partial treatment by the drainfield and the adsorption characteristics of the contaminants relegate this site to a lesser status than some of the other sites under investigation.

Monitoring Strategy--The ground water flow direction at the MELCO site is assumed to be topographically controlled. Three 25-foot deep downgradient wells are recommended as shown on Figure 16, Site Plan. Access problems may warrant road building. Monitoring an upgradient well at MELCO does not warrant the additional cost until the ambiguities associated with ground water flow direction are resolved at the nearby NAS and Oak Harbor landfills. Once these issues are resolved, a program to include three downgradient wells and one upgradient well may be warranted. Initial cost for well installation will be about $12,000. Sampling and testing should include the DOE-MFS indicator parameters as well as heavy metals for the first two years. First year monitoring would be about $7,032. Second year monitoring would be about $4,300.

Hastie Lake Landfill

This 3-acre closed landfill is located 5 miles southwest of Oak Harbor in an area of rolling wooded uplands (see Figure 18, Site Location Map). Infiltration of rain water is impeded by the till creating swamps and marshes in the shallow depressions and flat land common in this area. Hastie Lake is also perched on the till. The landfill is on a gentle slope that drains west to the shore of the island. Elevations at the site range from 160 to 180 feet above mean sea level (see Figure 19, Surficial Geology).

The Hastie Lake Landfill occupies a rectangular property (refer to Figure 20, Site Map). Access is from Hastie Lake Road, south of the site. The covered waste mound occupies the central part of the site and slopes steeply on the east, west, and southern sides. The upper surface of the waste is flat and has been covered with till and tree stumps. Grass and brush is also growing on this surface.

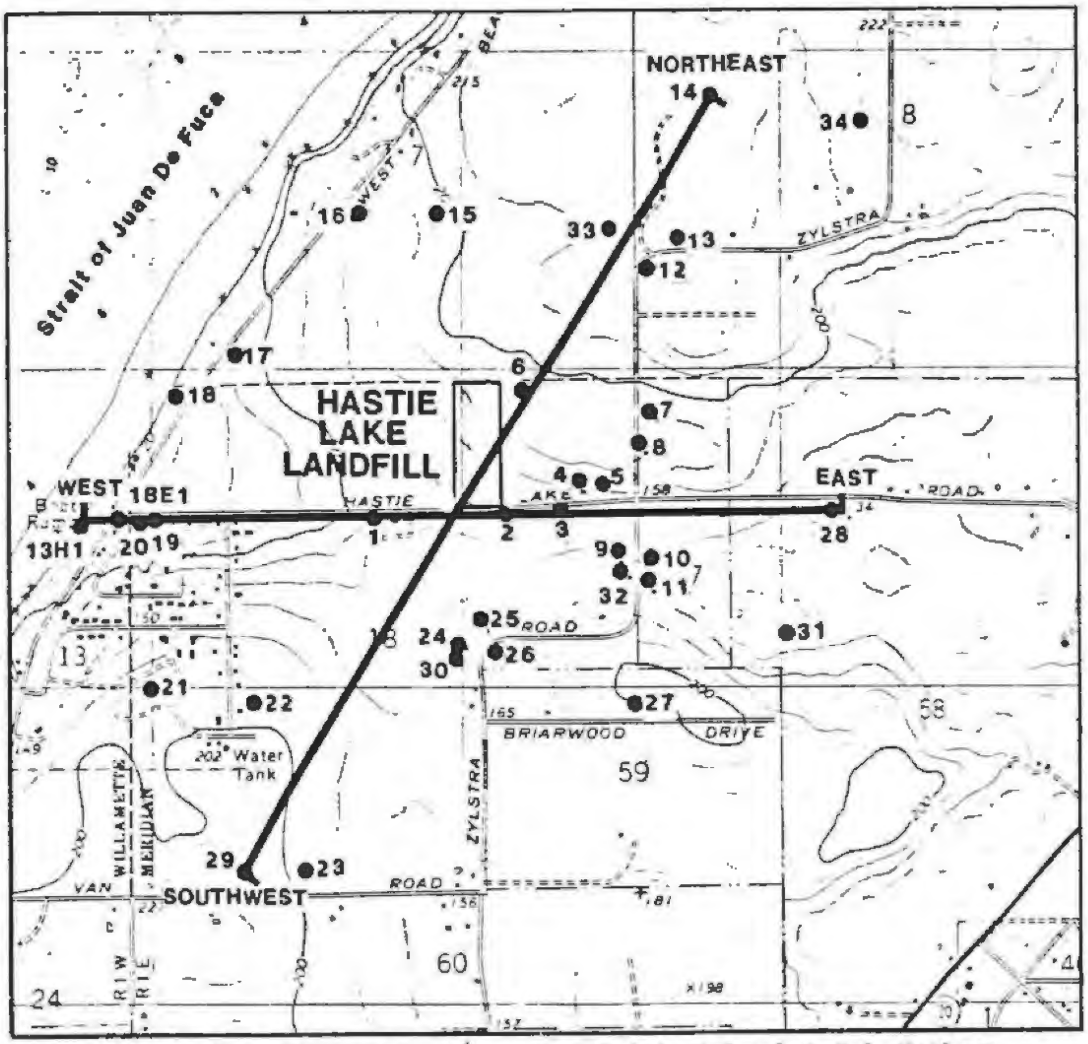
A stockpile of till is located on the northern part of the site. About half of the northern area has been cleared of vegetation and the near surface gravel removed.

Climate. The climate at this site is expected to be similar to that described for the NAS-Oak Harbor-MELCO sites. Precipitation is about 19 inches per year and falls primarily in the winter. Temperature averages about 40° F in the winter and 60° F in the summer with an annual mean of 50° F.

Geology. The landfill is underlain by the Vashon glacial sequence to about elevation 40 feet. A thin layer of recessional outwash sand and gravel was present under the northern two-thirds of the site, but has been removed (see Figure 21, Geologic Cross Section). The till appears to have been thin at the site and partially removed to allow mining of the underlying advance outwash gravels. The advance outwash sand and gravel are underlain by the transition beds. These beds are in turn underlain by sand and gravel which were probably deposited during the Olympia interglaciation.

Hydrogeology. Both the shallow and sea level aquifers are used in this area. The shallow aquifer (advance outwash sand and gravel) is used primarily east of the site. Available water level data define a westward slope to the shallow aquifer water table, refer to Figure 22. Flow under the site appears to be west or southwest toward the Strait of Juan de Fuca.

The sea level aquifer potentiometric surface defines a northeast trending trough west and north of the site (see Figures 23 and 24). It is unclear how this trough is maintained at elevations below sea level. Water levels below sea level were reported for seven wells, most of which are for domestic



Base Map: U.S.G.S. 7½′ quads. Smith Island & Oak Harbor

EXPLANATION

14 ● Well With Number

WEST EAST ⊔ Cross Section Location

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

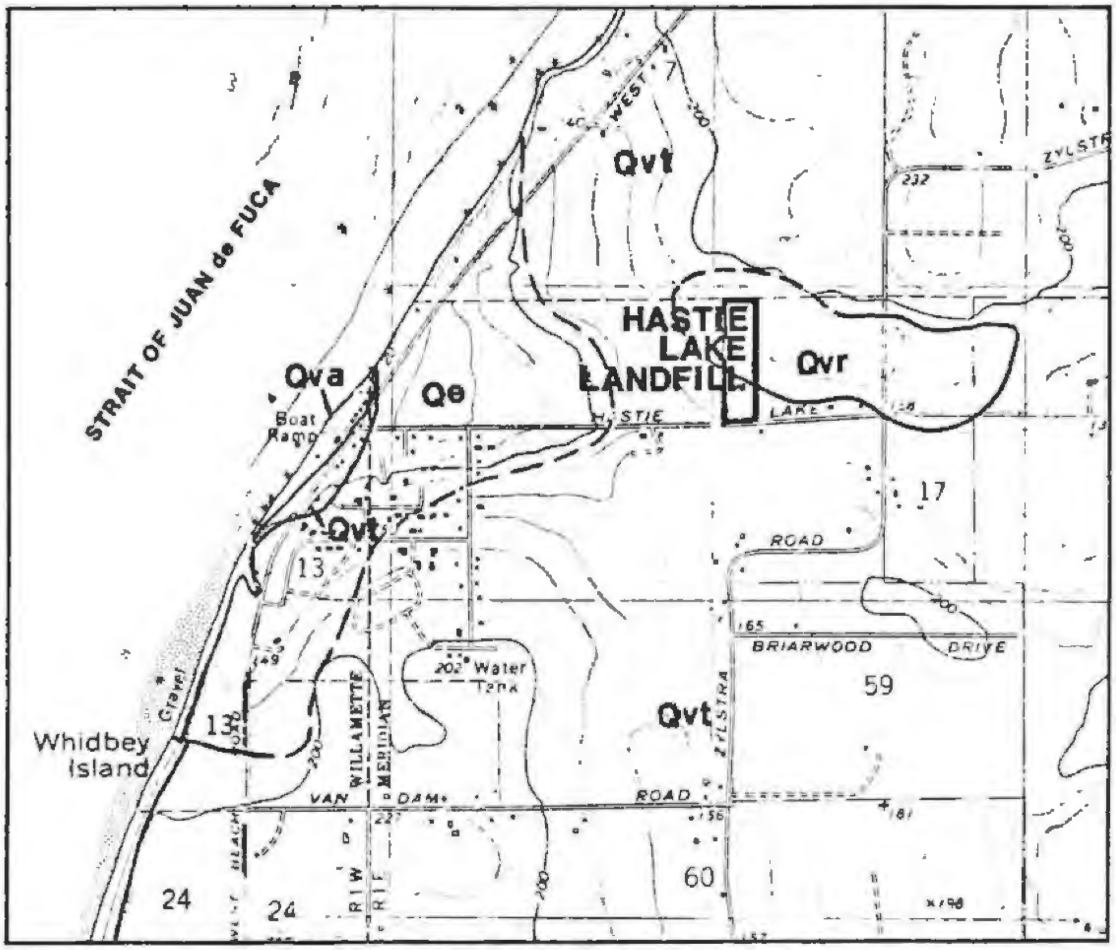
Hastie Lake Landfill

Site Location Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SIm	1-28-85
CHECKED BY	JEE	3/19/85
REVISED		

Figure 18



Base Map: U.S.G.S. 7½' quads. Smith Island & Oak Harbor

EXPLANATION

Geologic Contact, Dashed where Approximate

Qe .. Everson Age Deposits (undifferentiated), sand, silt, and clay, marine lacustrine, and fuvial deposits, interbedded glacial.

Qvr .. Vashon Recessional Deposits, glacial silt, sand, and clay, continental and marine deposits, interbedded.

Qvt .. Vashon Till, glacial silt, sand, clay, gravel, boulders, poorly sorted(well graded), massive, compact, typically resembles concrete in exposures.

Qva .. Vashon Advance Outwash, glacial sand, pebbely, clean, horizontal and cross bedded.

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

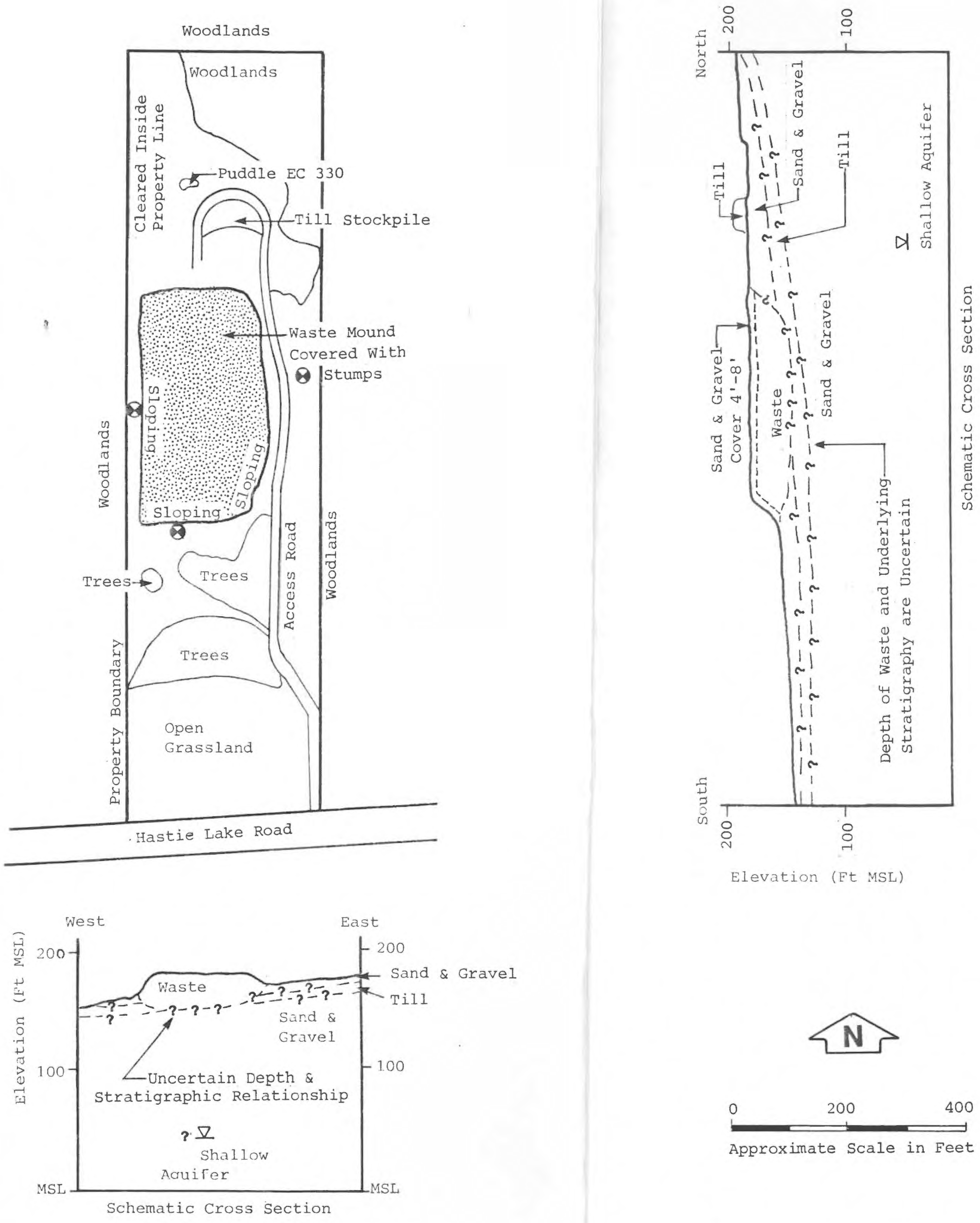
Hastie Lake Landfill

Surficial Geology

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/sim	2-1-85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 19



EXPLANATION

Area underlain by waste

Proposed Momitoring well location

ISLAND COUNTY

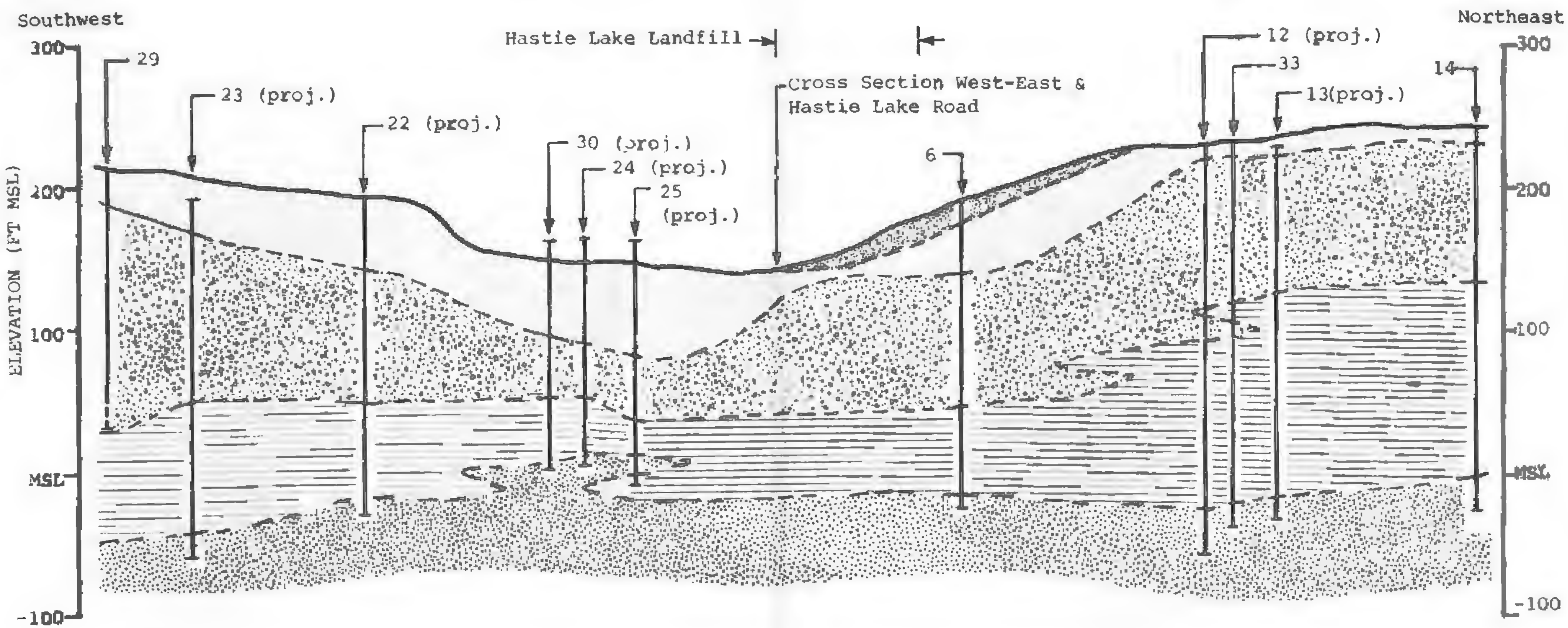
Hastie Lake Landfill

Site Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-28-85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 20



EXPLANATION

Qvr (Sand & Gravel)

Qvt (Till)

Qva (Sand & Gravel)

Qtb (Clay & Sand)

25 = Well Number
(proj.) = Projected

— Well

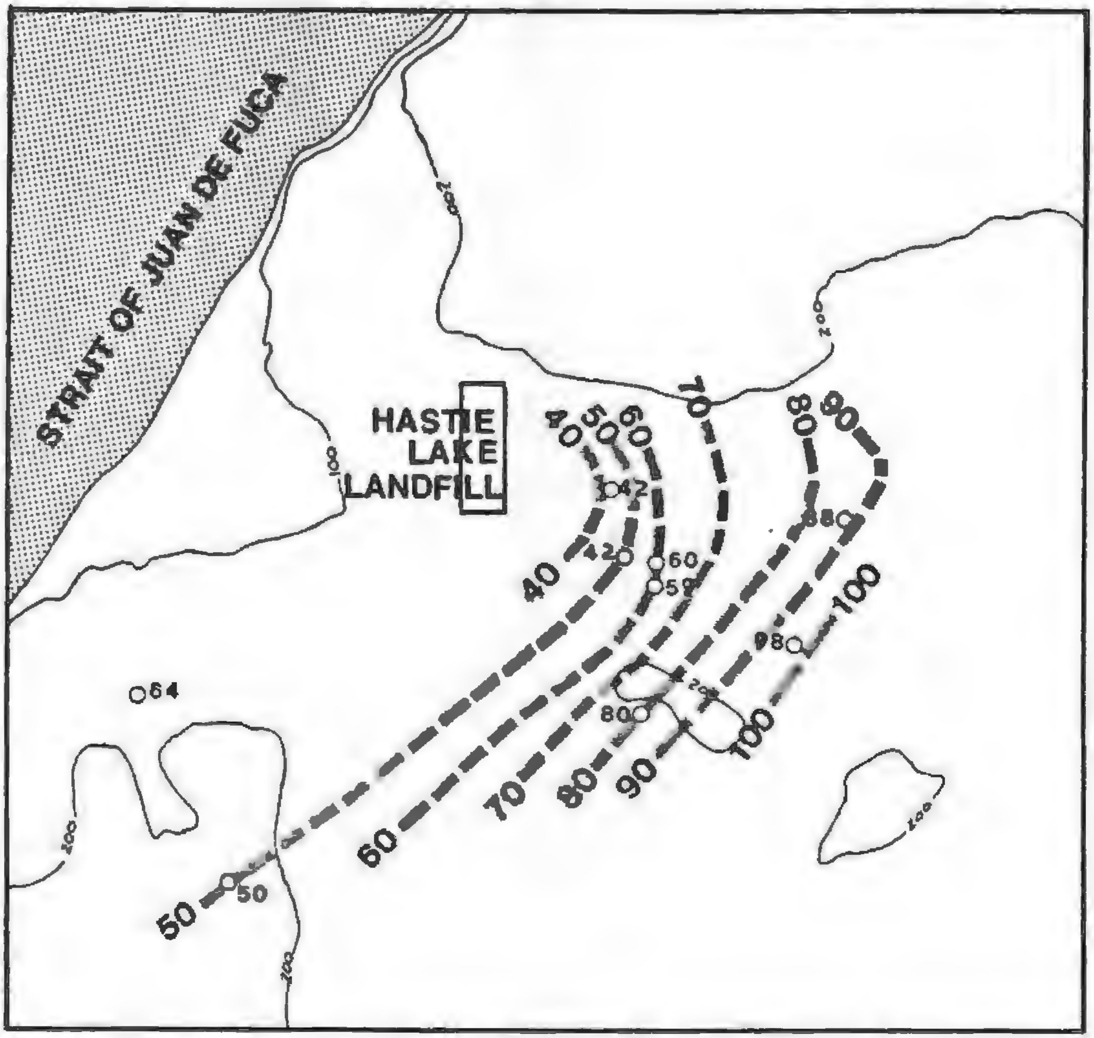
0 1000 2000
approximate Scale in Feet
Vertical Exageration 10x

ISLAND COUNTY

Hastie Lake Landfill

Geologic Cross Section
Southwest-Northeast

Sweet, Edwards & Associates



Base Map: U.S.G.S. 7.5' quads. Smith Island & Oak Harbor

EXPLANATION

—100— Elevation Contour (Ft MSL)

64O Well with old or reported water level measurement

40 — Water level elevation

N

0 2000 4000

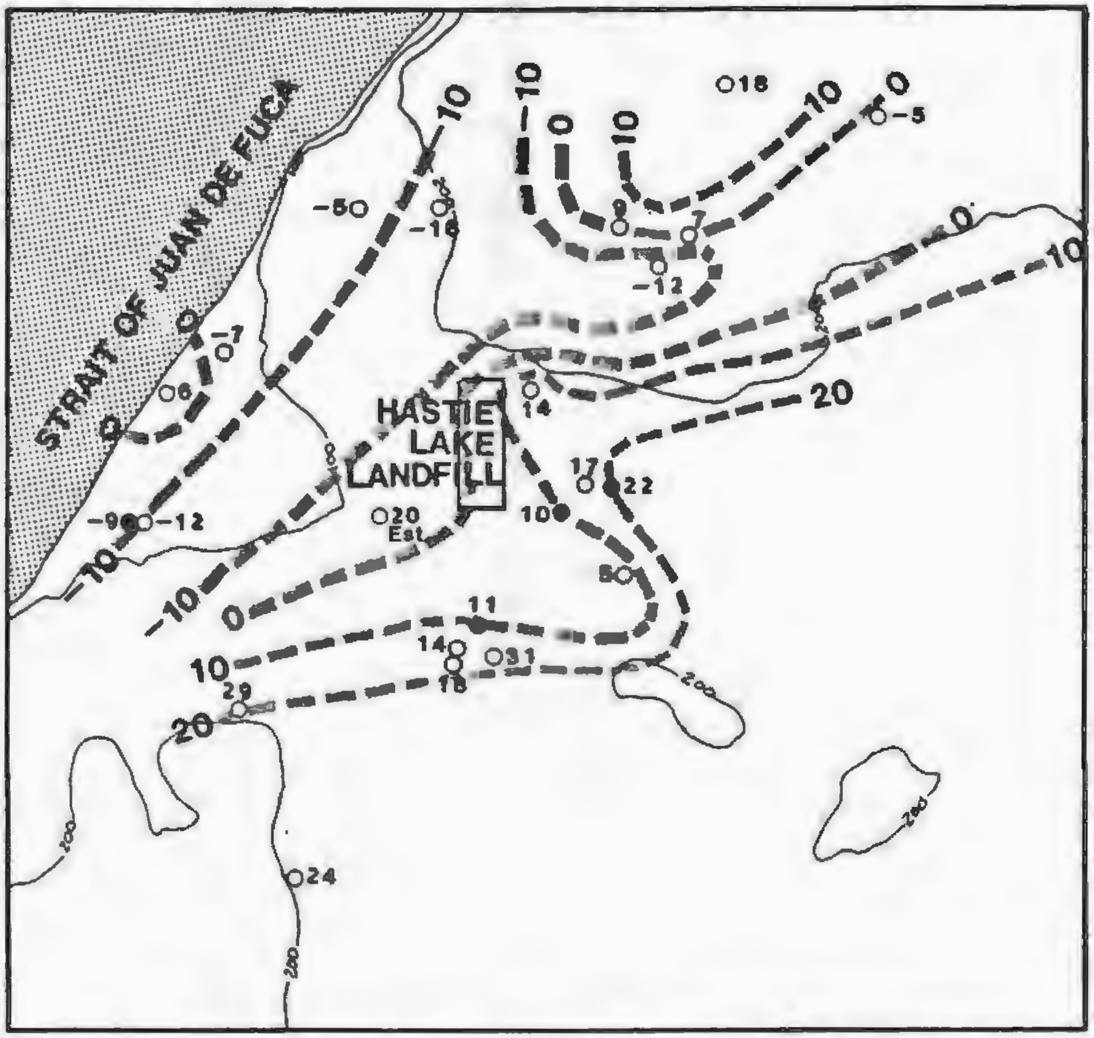
Approximate Scale in Feet

ISLAND COUNTY

Hastie Lake Landfill
Water Level Elevation Map Shallow Aquifer
Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-30-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 22



Base Map: U.S.G.S. 7.5' quads. Smith Island & Oak Harbor

EXPLANATION

—100— Elevation Contour (Ft MSL)

O14 Well with old or reported water level measurement

●10 Well with recent water level measurement

10 — Water level elevation

N

0 2000 4000

Approximate Scale in Feet

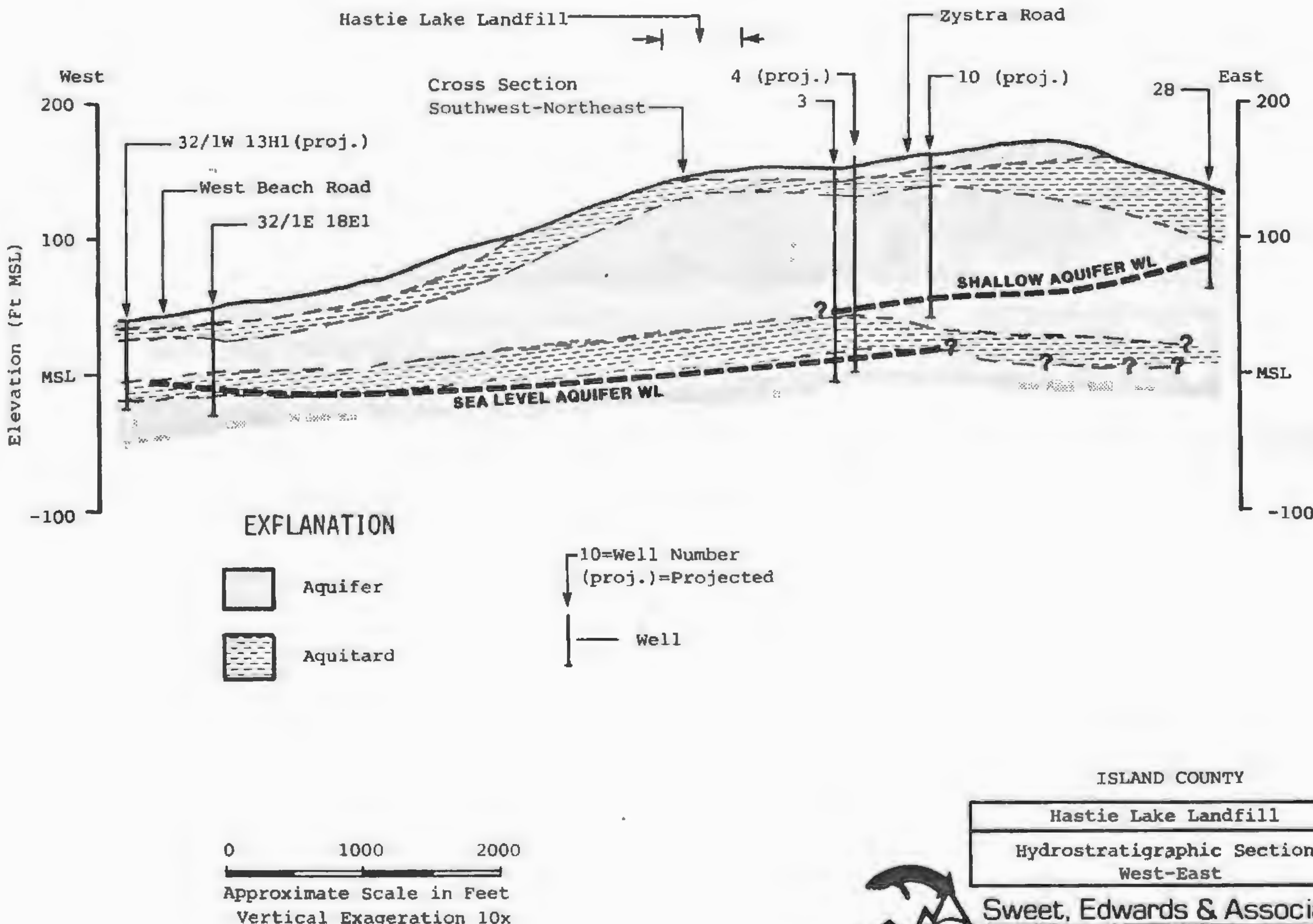
ISLAND COUNTY

Hastie Lake Landfill
Water Level Elevation Map Sea Level Aquifer

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-30-85
CHECKED BY	TEE	3/14/85
REVISED		

Figure 23



ISLAND COUNTY

Hastie Lake Landfill

Hydrostratigraphic Section
West-East

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-30-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	121385

Figure 24

use. Additional water level data are required to adequately define the potentiometric surface. Most wells in the sea level aquifer are completed below the base of the transition beds, but a few obtain their supplies from sand layers within the transition beds.

Beneficial Use. Thirty-four domestic wells have been located within a mile of Hastie Lake Landfill, refer to Table 11 - Well Inventory. The majority of these wells serve only one or two single family dwellings, although two neighboring wells (well nos. 19 and 20 on Figure 18, Site Location Map) are used by 93 homes.

Based on drilling records, approximately two-thirds of the wells pump from the sea level aquifer and one-third use the shallow aquifer. Average well yields are generally greatest from the sea level aquifer even though specific capacity does not differ significantly from that in the shallow aquifer (see Figure 24).

Water Quality. Water quality data are available primarily for wells penetrating the sea level aquifer. Ground water in both aquifers is generally hard and high in dissolved solids. Five wells reported elevated concentrations of iron (>12 mg/L) and manganese, with three above drinking water standards. The maximum contaminant level (MCL) for iron is .3 mg/L). There does not appear to be any specific areal distribution of wells with elevated levels of these metals. Although natural ground water quality in western Washington tends to exhibit high concentrations of iron and manganese, the high levels around Hastie Lake are atypical and may be due to contamination by the landfill. A deep U.S.G.S. test well (well 35) indicates the absence of brackish water to a depth of 565 feet below sea level.

Waste Characterization. The Hastie Lake site began as a rural disposal site in a gravel pit which was a burning dump prior to 1969. The site received domestic solid waste with possible small quantities of dry cleaning solvents until closure in 1976.

Leachate Generation. The estimated volume of leachate generated by the 30-foot thick Hastie Lake Landfill is 2.2×10^5 gallons/year (0.67 acre-feet/year). About 14 percent of the annual precipitation (Coupeville, Washington rain gauge) falling on the 3-acre site infiltrates through the sparsely vegetated sandy till cover, refer to Table 12, Moisture Balance.

Pollution Potential. The Hastie Lake Landfill received the second lowest rating for pollution potential. This is primarily due to the site's age and use, the low level of downgradient beneficial use, great depth to ground water, and relatively low levels of leachate discharge. However the elevated iron concentrations are significant and warrant attention.

TABLE 11
HASTIE LAKE - WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
1	Palmer	32/1/18G	120	20*	---	---	---	---	
2	Walton	32/1/18G	140	--	---	---	---	yes	
3	Palmer	32/1/18H	150	10	154	---	yes	---	
4	Linson	32/1/18A	165	17	156	-9 - -14	yes	---	
5	Tenants	32/1/18A	160	42	---	---	---	---	
6	Weibly	32/1/18A	190	14*	215	---	yes	---	
7	Love	32/1/17D	160	--	---	---	---	---	
8	DeGraffe	32/1/17D	180	--	278	---	---	---	
9	Martin VanRensum	32/1/18H	160	92*	79	---	partial	---	
10	Korrn	32/1/17E	155	60*	128	---	partial	---	High Fe content in well
11	Lohse	32/1/17E	165	59*	125	---	yes	---	
12	Knuckles Estates	32/1/8N	240	-12*	284	-35 - -44	yes	---	
13	Jacobs	32/1/8M	240	7*	262	-17 - -22	yes	---	
14	Brideck Meadows	32/1/8E	240	18*	265	-15 - -25	yes	yes	
15	Norcliffe	32/1/7K	195	-16*	283	-78 - -88	yes	yes	
16	Hetherington	32/1/7L	145	-5*	195	-45 - -50	yes	---	
17	Goulter	32/1/7N	80	-7*	212	-122 - -132	yes	yes	pump test
18	Williams	32/1/18D	30	6*	112	---	yes	---	
19	Pattons Hide Away	32/1/18E	40	-12	114	---	---	yes	
20	Pattons Hide Away	32/1/18E	40	-9	110	---	---	yes	
21	Raineri	32/1/18M	190	64*	150	40 - 45	yes	---	
22	Shirona	32/1/18L	195	19*	227	-22 - -32	yes	yes	
23	Swap	32/1/18P	195	24*	248	-48 - -53	yes	---	
24	Owen	32/1/18K	165	14*	160	5 - 10	yes	---	
25	Shrum	32/1/18G	165	11	171	---	yes	---	
26	Owen	32/1/18K	170	31*	158	15 - 18	yes	---	
27	Briarwood	32/1/18J	200	80*	151	49 -54	yes	---	pump test
28	Bethel	32/1/17F	140	88*	79	---	yes	---	
29	Wittig	32/1/18N	210	50*	180	---	yes	---	
30	Semler	32/1/18K	163	18*	162	---	yes	---	
31	Steel	32/1/17F	140	98	60	80 - 85	yes	---	
32	Ed VanRensum	32/1/18H	168	5*	189	---	yes	---	
33	Allen	32/1/7J	220	9*	267	-42 - -47	yes	---	
34	Metcalfe	32/1/8F	240	-5*	298	-53 - -58	yes	---	
35	D.O.E./U.S.G.S.	32/1/9M	180	13	1005	---	yes	yes	USGS TH #3

Note: Site Well Number is used to designate wells on Site Location Map
All elevations are in feet above mean sea level. All measurements are in feet.

TABLE 12

MOISTURE BALANCE FOR HASTIE LAKE LANDFILL

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1.	T	38.6	41.0	44.2	49.0	53.2	57.6	61.0	61.1	56.5	50.9	44.2	41.5	49.9
2.	P	2.18	1.67	1.76	1.38	1.39	1.16	.59	.74	1.24	1.66	2.19	2.68	18.64
3.	I	0.62	1.00	1.58	2.62	3.65	4.86	5.88	5.91	4.55	3.08	1.58	1.08	36.23
4.	UPET	0.02	0.03	0.04	0.06	0.07	0.09	0.11	0.11	0.09	0.07	0.04	0.03	
5.	PET	0.45	0.71	1.22	2.05	2.75	3.59	4.42	4.06	2.83	1.95	0.92	0.65	25.6
6.	$C_{R/O}$	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	
7.	R/O	0.22	0.16	0.17	0.14	0.14	0.12	0.06	0.07	0.12	0.16	0.22	0.27	1.85
8.	i	1.96	1.51	1.59	1.24	1.25	1.04	0.53	0.67	1.12	1.50	1.97	2.41	16.79
9.	i-PET	1.51	0.81	0.37	-0.81	-1.50	-2.55	-3.89	-3.39	-1.71	-0.45	1.05	1.76	
10.	APWL	0	0	0	-0.81	-2.31	-4.86	-8.75	-12.14	-13.85	-14.30	0	0	
11.	ST	3.00	3.00	3.00	2.27	1.35	0.56	0.14	0.13	0.13	0.13	1.18	2.94	
12.	ΔST	0	0	0	-0.73	-0.92	-0.79	-0.42	-0.01	0	0	1.05	1.76	
13.	AET	0.45	0.71	1.22	1.97	2.17	1.83	0.95	0.68	1.12	1.50	0.92	0.65	14.17
14.	PERC	1.51	0.81	0.37	0	0	0	0	0	0	0	0	0	2.69

SYMBOLS: T = mean air temperature; P = precipitation; I = heat index; UPET = unadjusted potential evapotranspiration; PET = potential evapotranspiration; $C_{R/O}$ = runoff coefficient; R/O = surface runoff; i = infiltration; i-PET = infiltration minus the potential evapotranspiration; APWL = accumulated potential water loss; ST = storage; ΔST = change in soil moisture storage; AET = actual evapotranspiration; PERC = percolation.

Monitoring Strategy. The general direction of ground water flow is to the west at the Hastie Lake Landfill. However, insufficient data exist to establish flow direction immediately beneath the site. Under Program A, three 200-foot wells should be located as shown on Figure 20, Site Map. Access problems may require road building. Initial cost for well installation will be about $28,900. Based on the data from the initial borings, the monitoring program should be modified to meet DOE MFS. Sampling and testing should cover the DOE-MFS indicator parameters. First year monitoring costs will be $6,200 and about $3,500 annually thereafter.

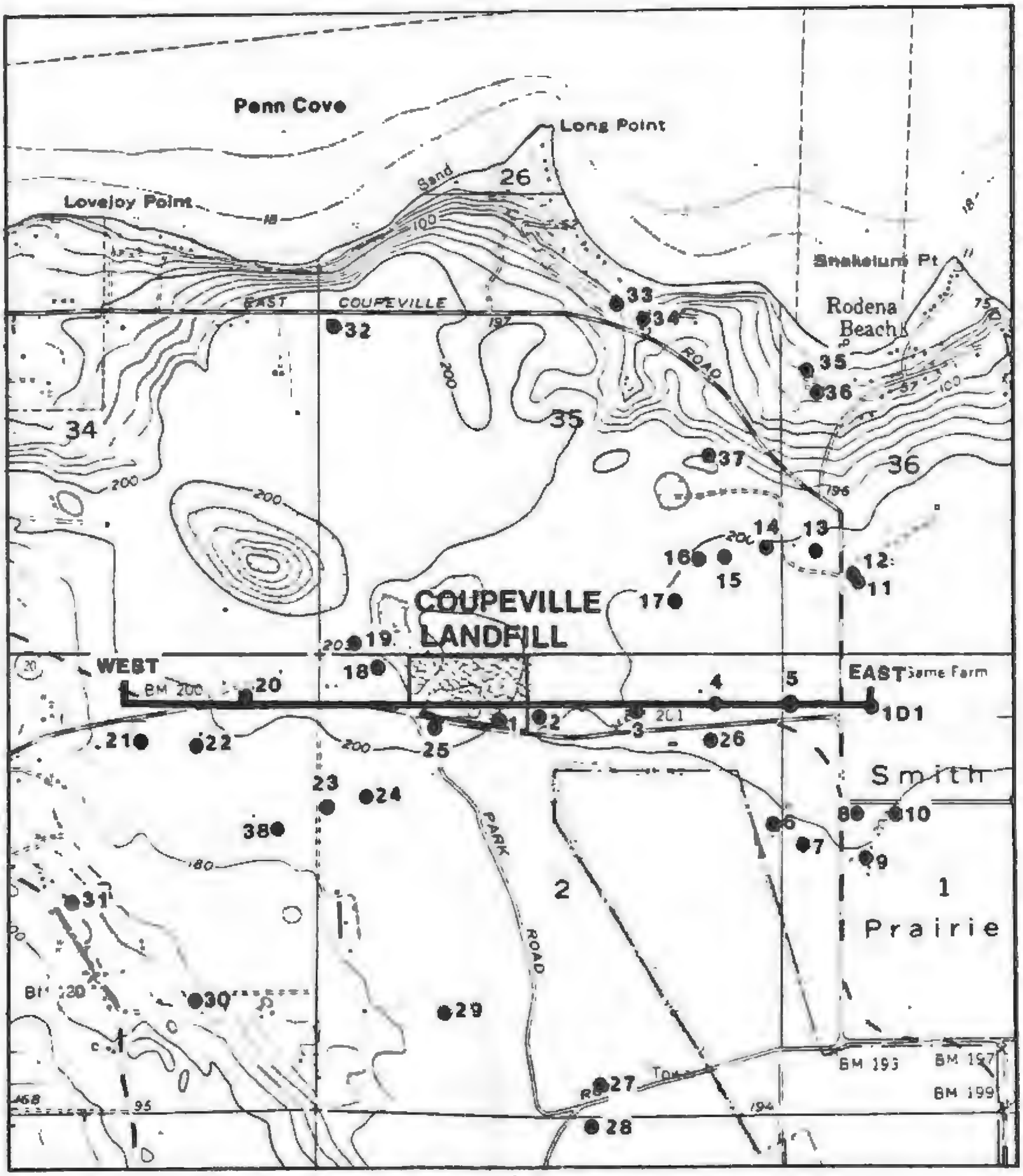
Program B includes monitoring existing wells No. 2, 1, and 6 in the sea level aquifer. No wells are reported downgradient for the shallow aquifer. First year monitoring will cost about $6,200 and about $3,500 annually thereafter. Any new wells drilled within 2,000 feet downgradient and 500 feet upgradient should be added to the program.

Coupeville Landfill

The landfill is located two miles southeast of Coupeville in Smith Prairie, refer to Figure 25, Site Location Map. The area is a generally level glacial terrace with an elevation about 200 feet above sea level. The terrace is wooded around the site, but opens to agricultural grassland to the east and west. Several depressions or kettle holes, one over 100 feet deep, are present north of the site. No surface drainage or ponded water is evident, indicating that rainfall infiltrates rapidly. Steep slopes and sea cliffs border the terrace on all sides.

The Coupeville Landfill is bounded on the south by State Highway 20 from which access is provided at several points, refer to Figure 26, Site Map. This is the primary waste disposal site for the county. Operations are conducted in a large gravel pit that is being backfilled with waste. Sand is used for cover material. The southern two-thirds of the pit has been filled except for the eastern area where the current working face is located. A solid waste box station for small quantity dumping is located above the pit in the southeast corner of the property. The northwest corner of the site is occupied by the now closed and covered city of Coupeville Landfill which is a partially filled kettle hole. Much of the area between the old city landfill and the county landfill is covered with sand stockpiles. A green belt has been preserved between the landfill and the highway. An animal shelter is located in this green belt.

The Coupeville Landfill is one of two sites selected for initial groundwater monitoring during Phase II of this study. Two wells were installed in one boring (MW-1) located at the



Base Map: U.S.G.S. 7½′ quad. Coupeville

EXPLANATION

27 ● Well With Number

WEST EAST ⊔ Cross Section Location

N

0 2000 4000

Approximate Scale in Feet

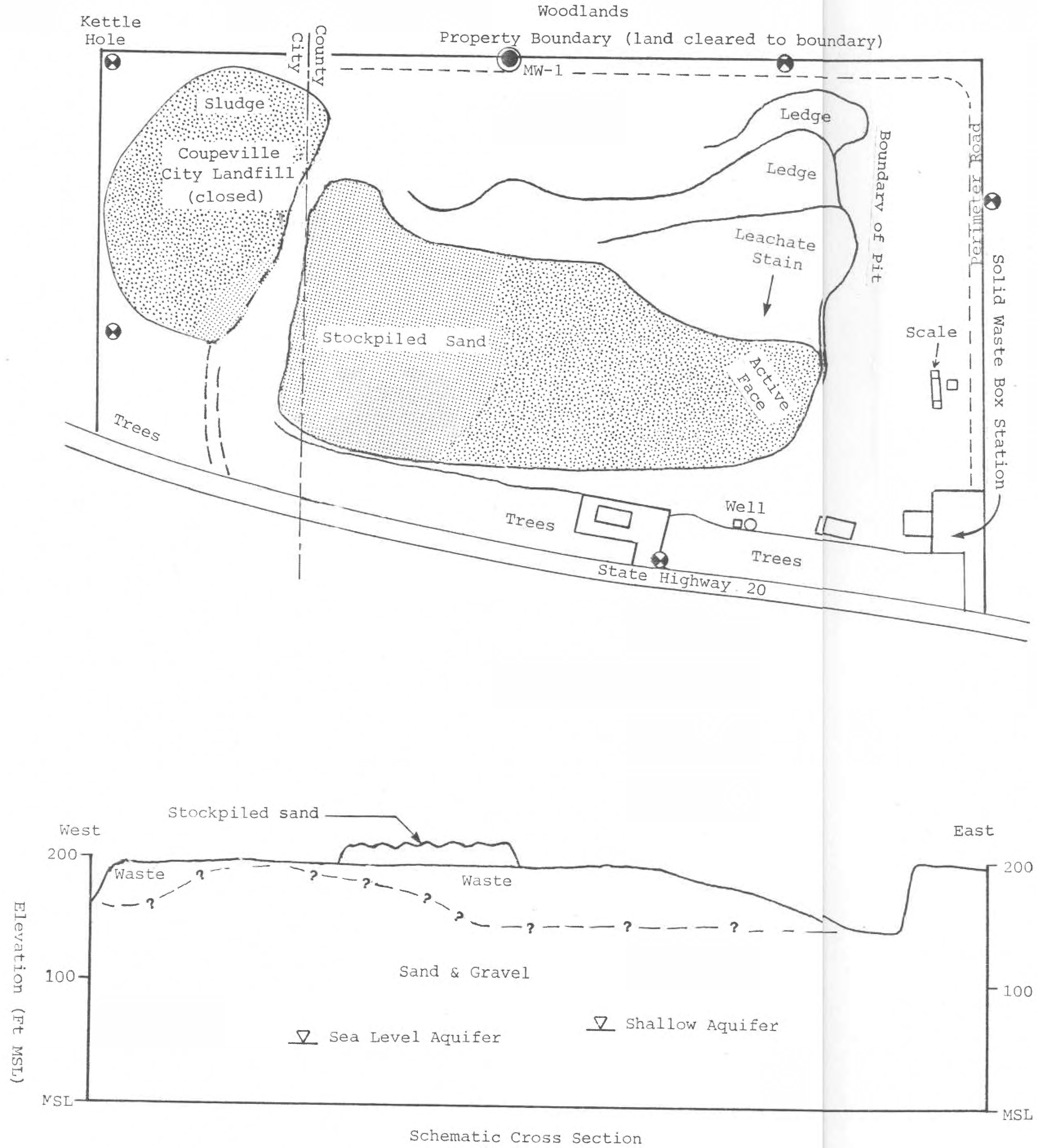
ISLAND COUNTY

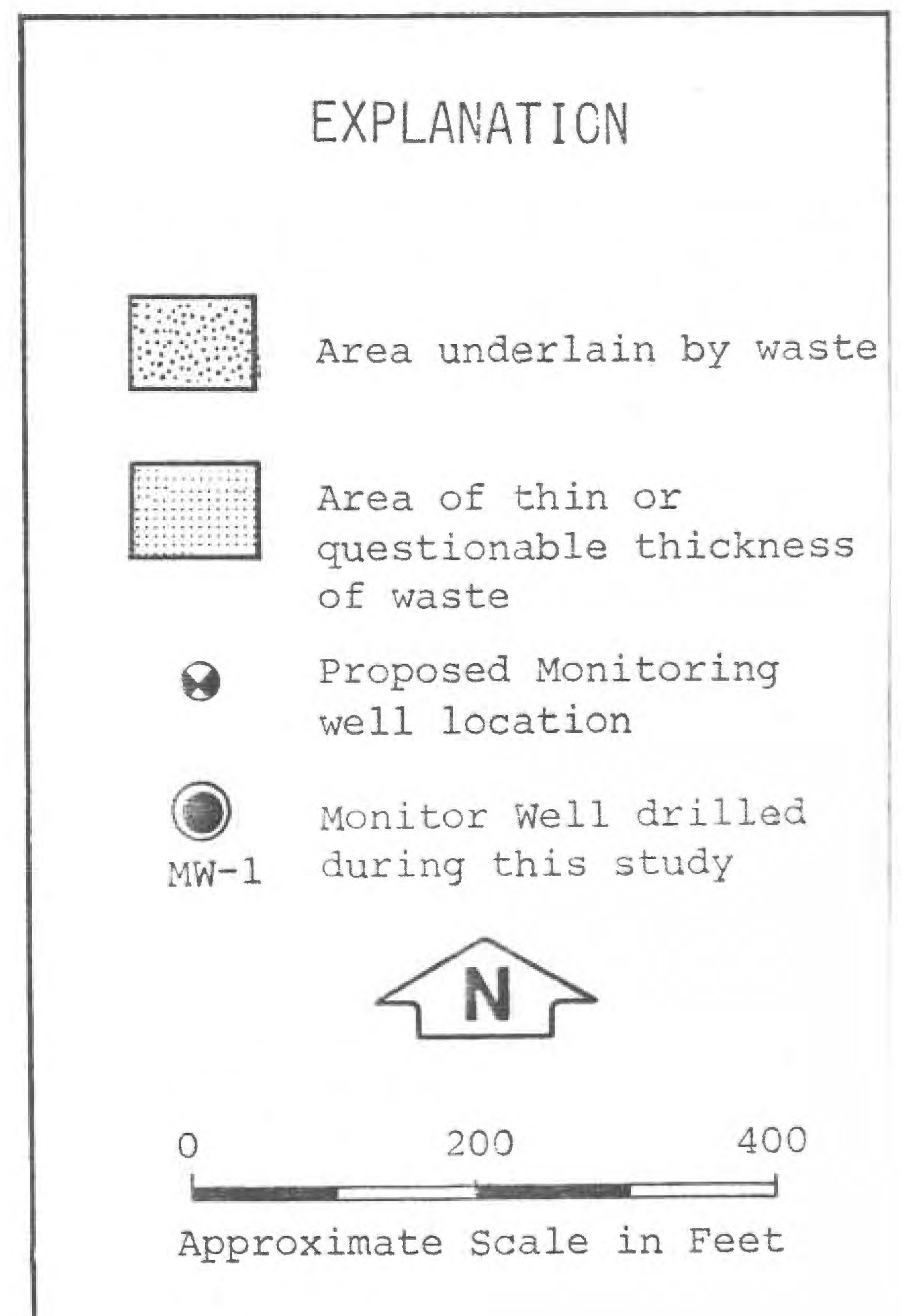
Coupeville Landfill
Site Location Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJM	1-28-85
CHECKED BY	JEE	3/19/85
REVISED	mmm	12/3/85

Figure 25





ISLAND COUNTY
Coupeville Landfill
Site Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJM	1-28-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 26

center of the northern boundary of the site. See Appendix 5, Site Drilling and Sampling Description for drilling procedures and lithologic log.

Climate. Annual precipitation averages 18.6 inches, but can vary from less than 11 inches to nearly 28. The coldest month is January when temperature averages 38.2° F while the warmest month is July with an average temperature of 61.1° F. The annual mean temperature is 49.7° F. Winds are primarily from the west and northwest though winter southwesterlies are common.

Geology. The Coupeville Landfill is located in a glacial channel that crosses Whidbey Island in a north-south direction. The channel is filled with Vashon recessional outwash (refer to Figure 27, Surficial Geology). The channel was cut to levels below sea level east and west of the landfill (refer to Figure 28, Geologic Cross-section West-East).

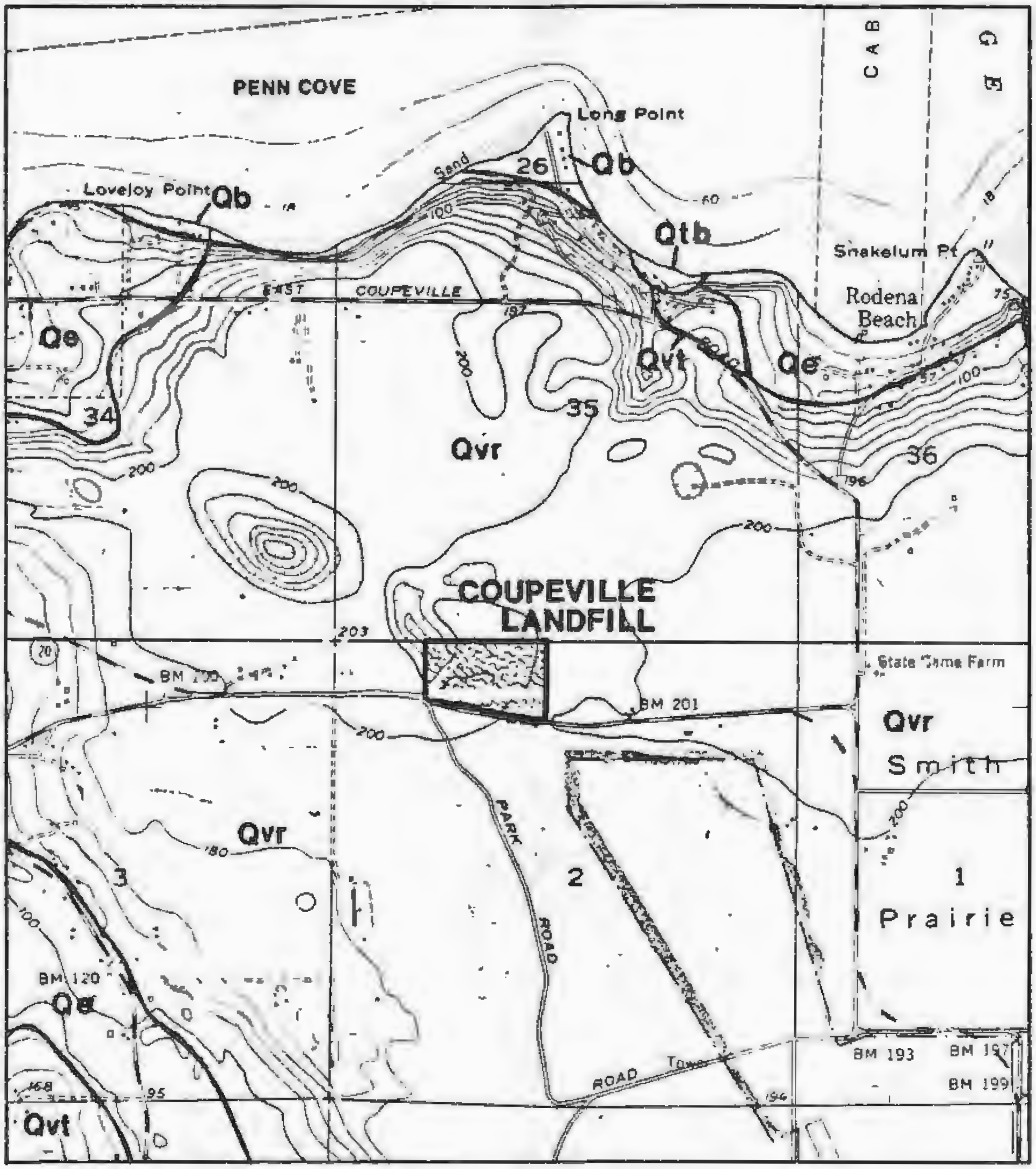
A kettle is located in the northwest corner of the site. A larger kettle 1,000 feet northwest of the site is 100 feet deep.

Data from monitor well drilling indicates that the landfill is located over approximately 40 to 100 feet of Vashon recessional outwash (Qva). The Vashon till and possibly the upper portions of the advance outwash appear to have been eroded and replaced with the recessional outwash. The advance outwash overlies approximately 60 feet of transition beds which are underlain by the Whidbey Formation. Data from monitor well MW-1 indicate that pockets or discontinuous strata of the Olympia Gravels may be sandwiched between the transition beds and the Whidbey Formation.

Hydrogeology. A shallow aquifer is perched on top of the Transition Beds immediately beneath the landfill. This aquifer is low yielding and the only known well accessing the shallow aquifer is the monitor well constructed for this investigation.

Most of the wells in the vicinity of the landfill produce from the sea level aquifer. The sea level aquifer is confined beneath the transition beds under the landfill. East and west of the landfill, the sea level aquifer occurs as a water table or unconfined system in the deeper cuts of the glacial outwash channel.

A northwest trending ridge exists in the potentiometric surface south and west of the site, refer to Figure 29, Flow beneath the site appears to be to the north toward Penn Cove. Insufficient data are available to adequately define the potentiometric surface north of the site. The potentiometric



EXPLANATION

Base Map: U.S.G.S. 7½' quad. Coupeville

Qb .. Beach Deposit, sand and gravel along shorelines.

Qe .. Everson Age Deposits (undifferentiated), sand, silt, and clay, marine, lacustrine, and fluvial deposits, interbedded.

Qvr .. Vashon Recessional Deposits, glacial silt, sand, and clay, continental and marine deposits, interbedded.

Qvt .. Vashon Till, glacial silt, sand, clay, gravel, boulders, poorly sorted (well graded), massive, compact, typically resembles concrete in exposures.

Qtb .. Transitional Beds, glacial and non-glacial clay, silt, and fine sand, thick beds underlying Qva.

Geologic Contact

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

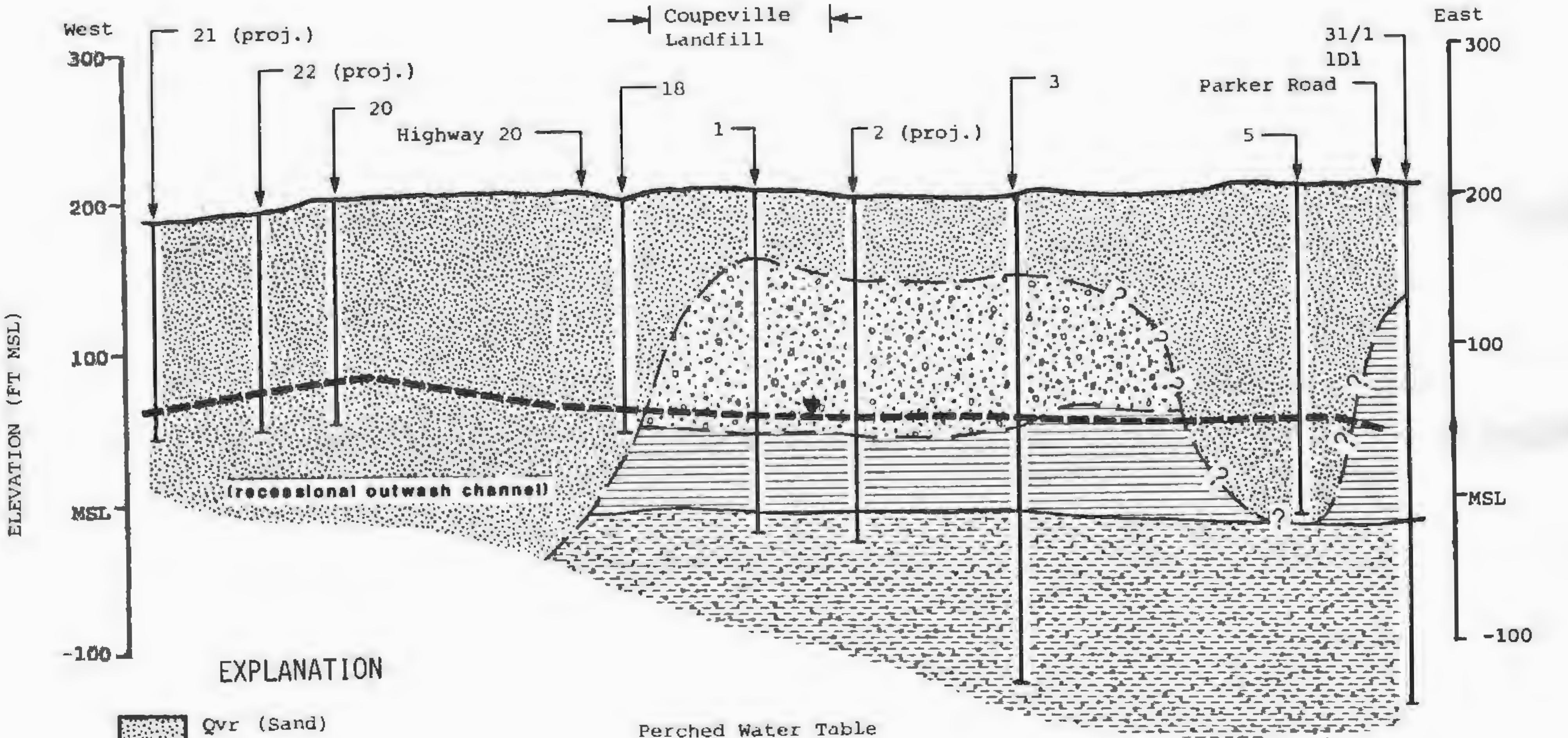
Coupeville Landfill

Surficial Geology

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJm	2-1-85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 27



EXPLANATION

Qvr (Sand)

Qva (Sand & Gravel, Clay & Sandy Clay)

Qtb (Clay & Sand)

Qw (Sand & Clay)

Potentiometric Surface Sea Level Aquifer

Perched Water Table

2 = Well Number
(proj.) = Projected

Well

0 1000 2000
Approximate Scale in Feet

ISLAND COUNTY

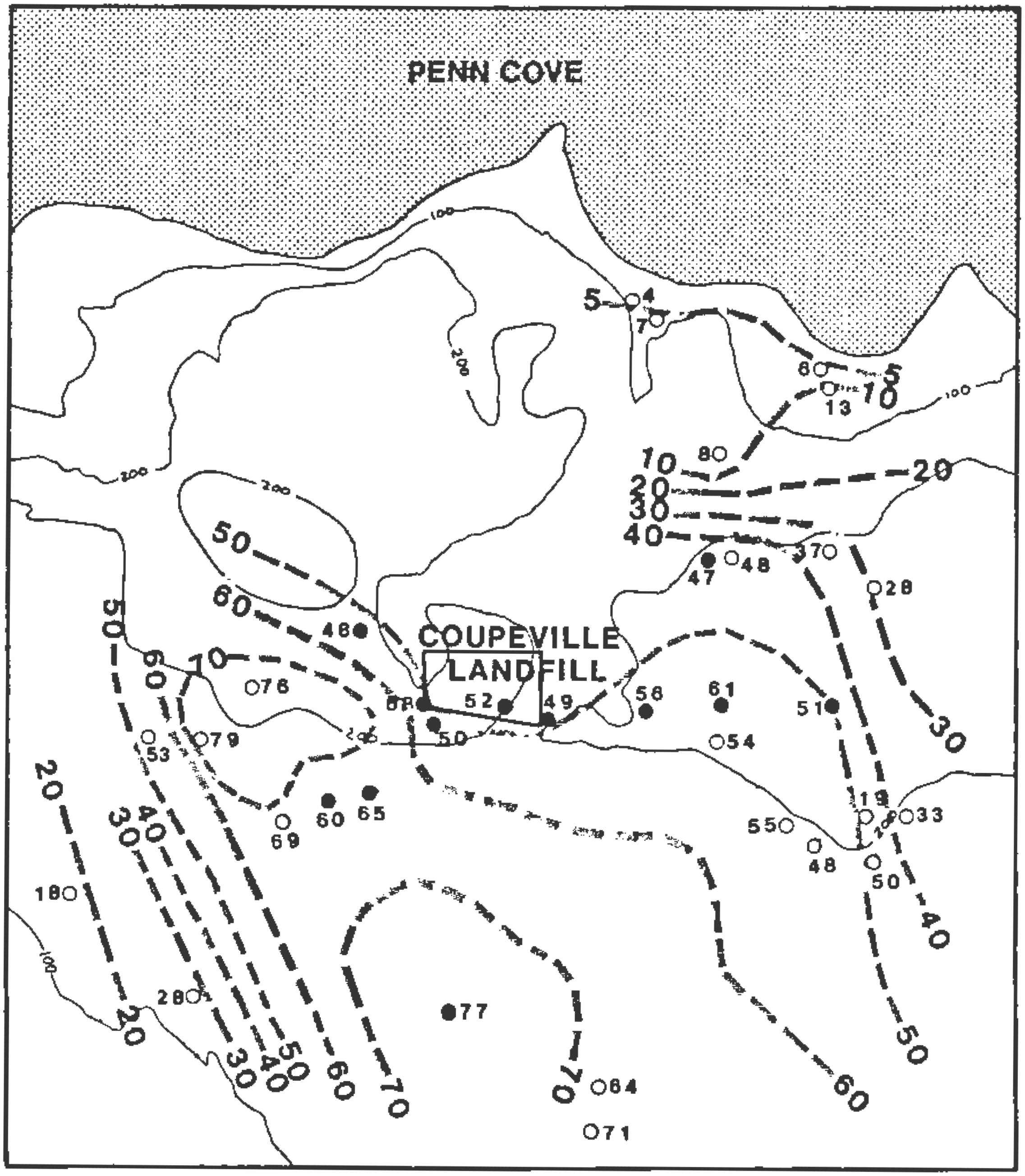
Coupeville Landfill

Geologic Cross Section
West-East

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-31-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 28



Base Map: U.S.G.S. 7.5' quad. Coupeville

EXPLANATION

—100— Elevation Contour (Ft MSL)

O71 Well with old or reported water level measurement

●51 Well with recent water level measurement

20 Water level elevation

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

Coupeville Landfill

Water Level Elevation Map
Sea Level Aquifer

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-30-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 29

surface, where better defined, appears to reflect the topography. This supports the idea of northward flow toward Penn Cove. Several wells near the coast northeast of the site appear to withdraw from sand lenses within the transition beds.

Beneficial Use. A total of 41 wells are located within 1 mile of the Coupeville Landfill, refer to Table 13, Well Inventory. At least 38 of these are currently being used, primarily for domestic purposes, according to records furnished by the Island County Health Department. Existing well logs and analysis of Department of Water Resources (currently Department of Ecology) data indicate the average well yield is approximately 32 gallons per minute and the specific capacity averages about 6 gallons per minute per foot of drawdown.[1]

Water Quality. Existing regional data indicate relatively poor ground water quality in this aquifer. The ground water is comparatively hard and average conductivity readings exceed 700 micromhos/cm. Water from wells 25, 33, and 37 (see Figure 25) also contain elevated concentrations of manganese and iron. Water samples taken from a U.S.G.S. test hole less than two miles southeast of the landfill indicate that brackish water is present at 168 feet below sea level.

During this investigation the double completion monitor well (MW-1), constructed on the northern boundary of the site and the dog pound well (MW-2), were sampled and tested. MW-1 accessed both the shallow perched aquifer (MW-1S) and the deeper sea level aquifer (MW-1D), therefore MW-1 is discussed below as two separate wells.

In general, the test results are consistent with the existing regional data. Iron and manganese concentrations are elevated in both the wells (refer to Appendix 6, Ground Water Quality Testing Data). Manganese concentrations in the perched aquifer (MW-1S = .18) are above the maximum contaminant level (MCL = .05) defined in 40 CFR 257 and the State of Washington Drinking Water Standards.

Quadruplicate sampling and analysis for indicator parameters provided relatively consistent values. Electrical conductivities (EC) for all three wells were in the range of 600 to 660 micromhos/cm. EC values are slightly higher in the sea level aquifer than the perched aquifer. Chlorides are also slightly higher in the sea level aquifer (38-45 mg/l) than in the perched aquifer (22 to 30 mg/l).

Sulfate concentrations in MW-1 both deep and shallow (presumed downgradient monitoring wells 14 to 33 mg/l) were more than double the sulfate concentrations (<2-19 mg/l) in MW-2

TABLE 13
COUPEVILLE LANDFILL - WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
1	Island County Dog Pound	31/1/2C	205	52	224	0 - -9	yes	yes	
2	Wash. State Dept. of Transp.	31/1/2B	200	49	221	-11 - -21	yes	---	
3	Island Disposal	31/1/2B	200	56	204	---	yes	yes	Drilled to 320 ft.
4	Island Auto Rebuild	31/1/2A	205	61	230	---	---	---	pump test
5	Burlington North'rn Timberlnds	31/1/1D	205	51*	200	10 - 20	yes	---	
6	Brown	31/1/2H	200	55*	203	-3 - -2	yes	---	
7	Karlinsey	31/1/1E	200	48*	281	-77 - -81	yes	---	
8	Kinneth	31/1/1E	202	19	248	---	---	---	
9	Kinneth	31/1/1E	198	50	210	---	---	---	
10	Dance	31/1/1E	200	33*	316	-111 - -116	yes	---	
11	Wash. State Dept. of Game	31/1/36N	205	28	200	11 - 57	yes	---	
12	Wash. State Dept. of Game	31/1/36N	205	60*	210	-4 - 6	yes	---	
13	Bridge	32/1/36N	200	37*	198	2 - 12	yes	---	
14	Brown	32/1/35R	200	--	190	---	yes	---	
15	Glover	32/1/35R	200	48*	178	---	yes	---	
16	Boyer	32/1/35R	200	47	180	---	yes	---	
17	Hansen	32/1/35R	200	--	---	---	---	---	
18	Little	31/1/2D	200	68	151	---	yes	yes	
19	Hillcrest Homestead Tracts	32/1/35N	202	48	171	---	yes	yes	
20	Argent	31/1/3A	200	76*	146	---	yes	---	
21	Libbey	31/1/3B	170	53*	142	28 - 33	yes	---	
22	Youderian	31/1/3B	198	79*	144	54 - 60	yes	---	
23	Jacobs Road Water System	31/1/2E	194	60	246	---	yes	---	
24	Bainbridge	31/1/2E	190	65	173	17 - 23	yes	---	
25	D.N.R. Rhododendron Park	31/1/2D	202	50*	170	32 - 37	yes	yes	
26	Countryside Inn	31/1/2A	202	54*	220	---	yes	---	
27	Is. County Rhododendron Park	31/1/2Q	190	64*	283	-88 - -93	yes	yes	
28	Gabryrsh	31/1/11B	192	71*	165	---	---	---	
29	Bailey	31/1/2P	190	77*	172	18 - 28	yes	---	
30	Barrett	31/1/3K	140	28*	339	-194 - -199	yes	---	
31	Engle	31/1/2L	120	18*	373	-248 - -253	yes	---	
32	Seiger	32/1/35E	205	--	222	---	---	---	
33	Long Point Manor Water Co.	32/1/35G	99	4	201	-91 - -102	yes	yes	
34	Long Point Manor Water Co.	32/1/35G	105	7	192	---	---	---	
35	Reeder	32/1/36E	20	6*	32	---	---	---	
36	Whelan	32/1/36E	22	13*	44	---	---	---	
37	Kinneth Point Woods	32/1/35J	203	8	201	-63 - -98	yes	yes	pump test
38	Kenworthy	31/1/3H	185	69*	144	41 - 46	yes	---	
39	D.O.E./U.S.G.S.	31/1/11H	190	68	1000	---	yes	yes	USGS TH-4

Note: Site Well Number is used to designate wells on Site Location Map. All elevations are in feet above mean sea level. All measurements in feet.

(presumed upgradient monitoring well). TOC was also higher in the downgradient well (1.4 to 20.1 mg/l) than in the upgradient well (1.3 to 1.5 mg/l). Although TOC is relatively high in all three wells sampled, TOX is relatively low, ranging from <.008 mg/l to .019 mg/l. However, the TOX concentrations in the shallow downgradient well are higher than either the deep downgradient well or the upgradient well.

Because indicator parameters are consistently higher in the downgradient well than the upgradient well it is reasonable to conclude that the ground water regime has been impacted by landfill operations. However, it is important to note that volatile organics analysis did not indicate the presence of priority pollutants above the detection limit.

Waste Characterization. The Coupeville site is an active regional disposal site which primarily receives domestic/municipal solid waste and some demolition waste. The site receives an estimated 18,000 tons of solid waste annually. Some dry cleaning solvents were reportedly taken to the site during the period 1980-1984. A sewage sludge disposal area is also located onsite and reportedly received 90,000 gallons in 1984.

Leachate Generation. It is estimated that 9.05×10^5 gallons/year (2.78 acre-feet/year) of leachate enter the Coupeville ground water system, refer to Table 14. Approximately 24 percent of the yearly rainfall falling on the 7.4-acre site percolates through the sparsely vegetated, sand-gravel cover.

Pollution Potential. The Coupeville Landfill received the third highest rating for pollution potential. This rating is based on the relatively high estimated leachate discharge potential, the type of wastes, the site's activity, and the presence of a well onsite. An additional concern is the lack of, or conflicting, subsurface data for such a large active site as this.

Monitoring Strategy. Insufficient data exist to design an adequate monitoring program at the Coupeville Landfill. One double completion monitoring well was installed at the site during Phase II of this study. However five additional double completion wells may be needed at this site. The existing onsite supply well may be adequate as a monitoring well, reducing the number of new wells pending the drilling results of the first wells installed. Access problems will require some road building. Assuming six wells are required, cost of installation would be approximately $69,000.

TABLE 14

MOISTURE BALANCE FOR COUPEVILLE LANDFILL

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1.	T	38.6	41.0	44.2	49.0	53.2	57.6	61.0	61.1	56.5	50.9	44.2	41.5	49.9
2.	P	2.18	1.67	1.76	1.38	1.39	1.16	.59	.74	1.24	1.66	2.19	2.68	18.64
3.	I	0.62	1.00	1.58	2.62	3.65	4.86	5.88	5.91	4.55	3.08	1.58	1.08	36.23
4.	UPET	0.02	0.03	0.04	0.06	0.07	0.09	0.11	0.11	0.09	0.07	0.04	0.03	
5.	PET	0.45	0.71	1.22	2.05-	2.75	3.59	4.42	4.06	2.83	1.95	0.92	0.65	25.6
6.	$C_{R/O}$	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	
7.	R/O	0.22	0.16	0.17	0.14	0.14	0.12	0.06	0.07	0.12	0.16	0.22	0.27	1.85
8.	i	1.96	1.51	1.59	1.24	1.25	1.04	.53	.67	1.12	1.50	1.97	2.41	16.79
9.	i-PET	1.51	0.80	0.37	-0.81	-1.50	-2.55	-3.89	-3.39	-1.71	-0.45	1.05	1.76	
10.	APWL	0	0	0	-0.81	-2.31	-4.86	-8.75	-12.14	-13.85	-14.30	0	0	
11.	ST	1.00	1.00	1.00	0.40	0.08	0.01	0.01	0.01	0.01	0.01	1.00	1.00	
12.	ΔST	0	0	0	-0.60	-0.32	-.07	0	0	0	0	0.99	0	
13.	AET	0.45	0.71	1.22	1.84	1.57	1.11	0.53	0.67	1.12	1.50	0.92	0.65	12.2
14.	PERC	1.51	0.80	0.37	0	0	0	0	0	0	0	0.06	1.76	4.5

SYMBOLS: T = mean air temperature; P = precipitation; I = heat index; UPET = unadjusted potential evapotranspiration; PET = potential evapotranspiration; $C_{R/O}$ = runoff coefficient; R/O = surface runoff; i = infiltration; i-PET = infiltration minus the potential evapotranspiration; APWL = accumulated potential water loss; ST = storage; ΔST = change in soil moisture storage; AET = actual evapotranspiration; PERC = percolation.

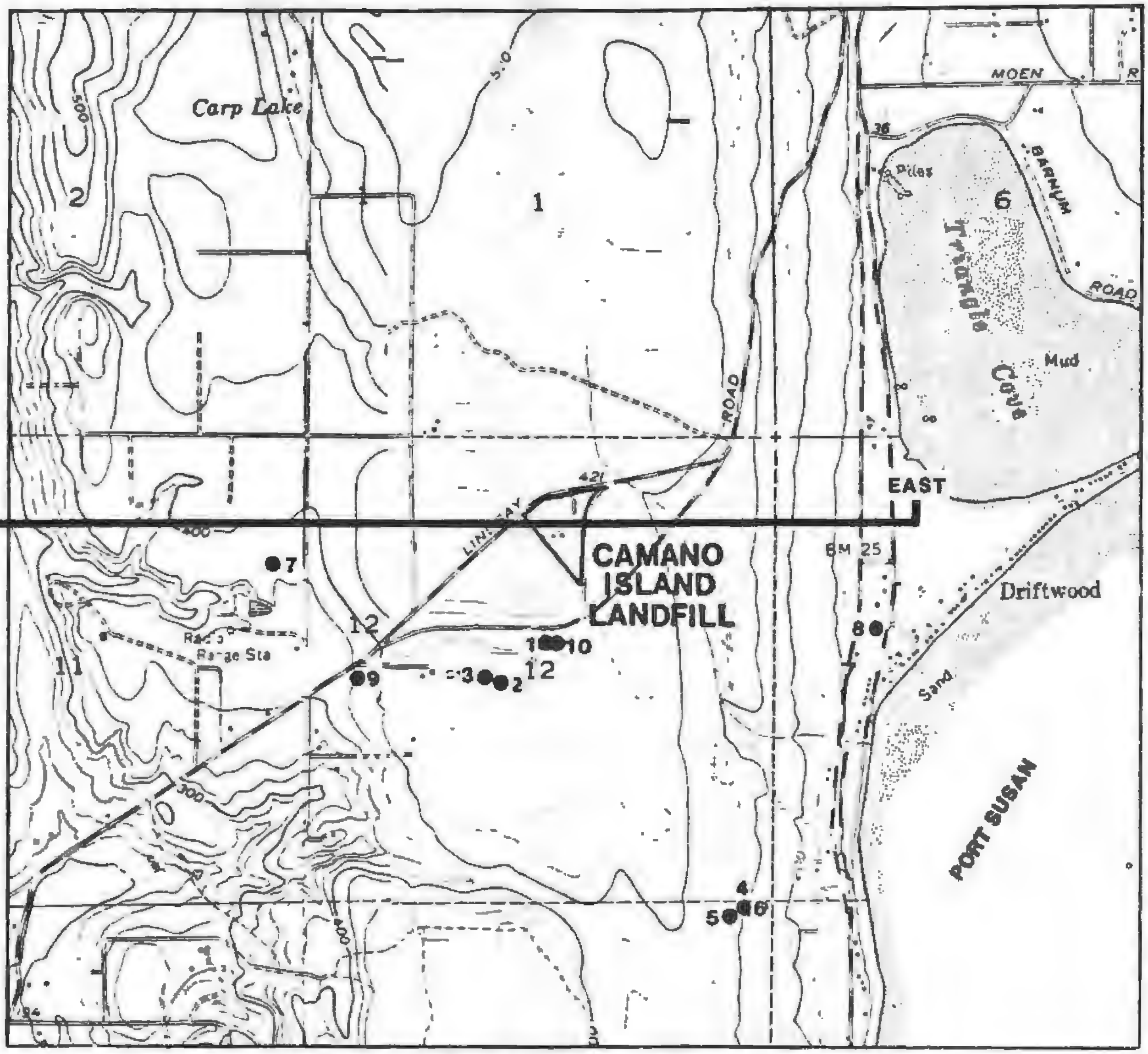
During this investigation tests were run for volatile organics, Primary Drinking Water Standards and indicator parameters. The volatiles and Primary Drinking Water Standards were not detected or below the MCL (iron and manganese excepted), therefore future sampling should be limited to DOE-MFS standards until an adequate data base is established. First year monitoring costs will be about $12,400, followed by $7,000 annually thereafter. The final monitoring program should be expanded to meet DOE MFS. There are no existing wells within a reasonable distance for monitoring downgradient of the Coupeville Landfill. Any new wells drilled within 2,000 feet downgradient and 500 feet upgradient should be monitored. Because sampling and testing during this investigation indicated potential impacts to ground water quality from landfill operations, a complete monitoring program should be implemented as soon as possible.

Camano Island Landfill

This closed landfill (primarily demolition waste) is located in the central portion of Camano Island west of Triangle Cove (see Figure 30, Site Location Map). Rolling wooded uplands characterize the area. Drainage courses are evident though actual flow appears to be rare indicating high infiltration rates. The site is located in a small ravine at an elevation of 440 feet above mean sea level. Access is from the old Camano Hill Road. Upland elevations are generally much higher on Camano Island when compared to Whidbey Island. Camano Island is also quite narrow at the site creating a steep rise from sea level to the upland.

The site was originally developed as a gravel pit (Figure 31). Waste disposal operations filled the gravel pit and most of a preexisting gully before the landfill was closed prior to November 1, 1985. Most of the waste has been dumped on the west side of the gully where removal of gravel left a steep slope below a small hill. The surface of the mound is flat and covered with silty gravel except in a small area on its north side where dumping occurs sporadically. The south and east sides of the waste mound are steep.

Climate. The DOE reports average annual precipitation to be 19 inches at the site. This low level indicates that the Olympic rain shadow extends over this portion of Camano Island. The nearest weather station reporting temperature is at Coupeville where the annual mean is 50^{o} F. The winter average temperature is 40^{o} F and in summer 60^{o} F.



Base Map: U.S.G.S. 7½' quad. Camano & Juniper Beach

EXPLANATION

5 ● Well With Number

WEST EAST Cross Section Location

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

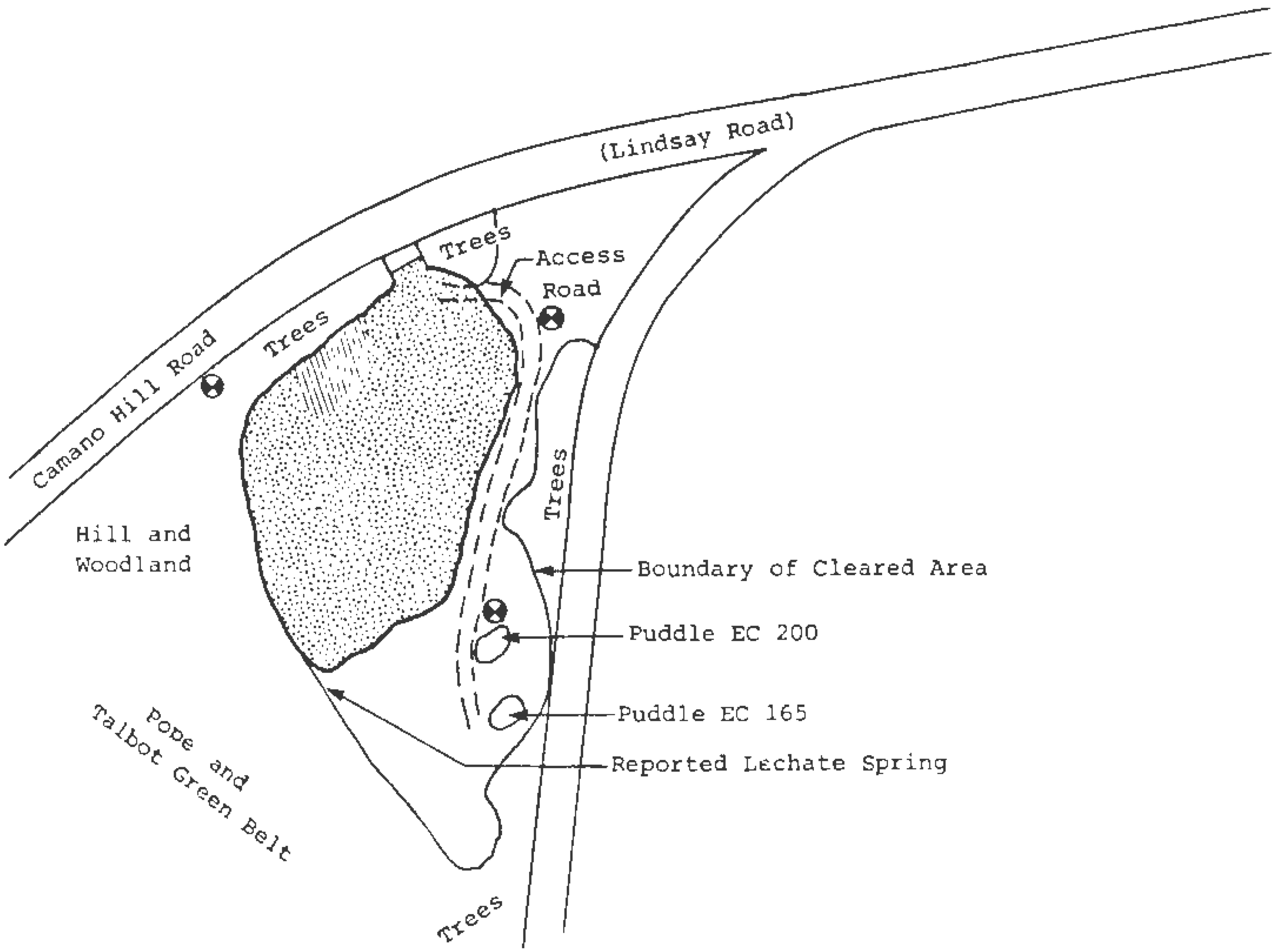
Camano Island Landfill

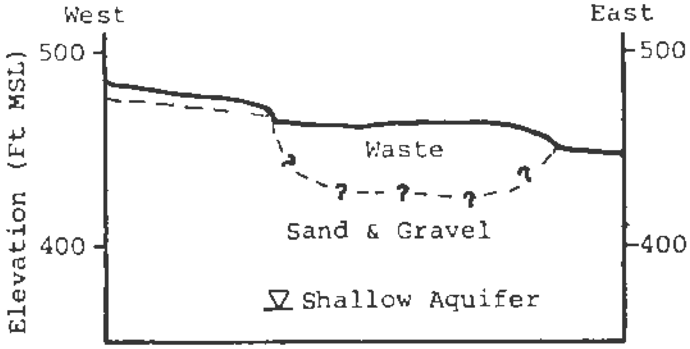
Site Location Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJm	1-28-85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 30





Schematic Cross Section

EXPLANATION

Area underlain by waste

Active demolition disposal area

Proposed Monitoring well location

N

0 200 400

Approximate Scale in Feet

ISLAND COUNTY

Camano Island Landfill

Site Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-28-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 31

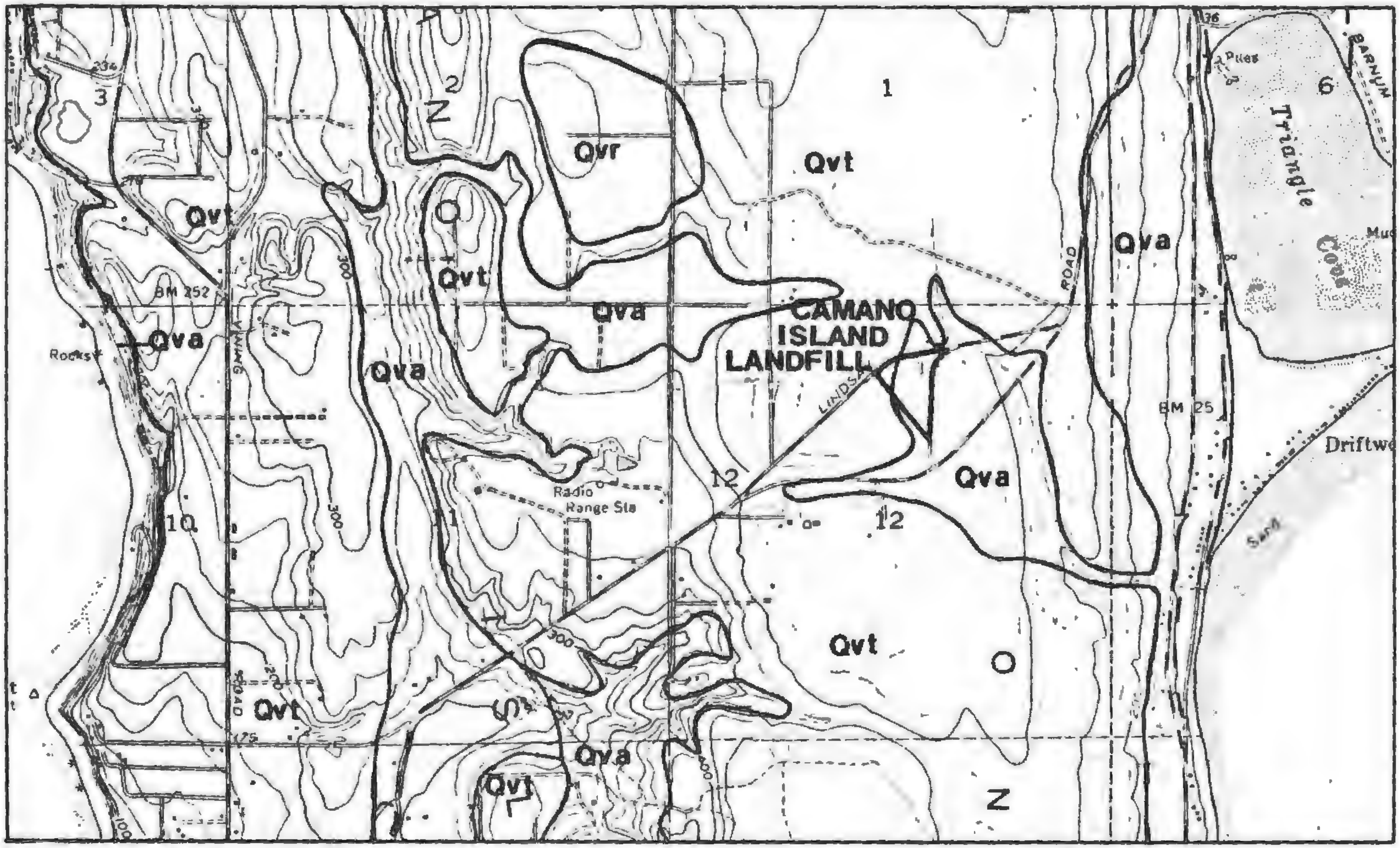
Geology. Very few well logs are available to aid in defining the geology under the site. Only one well identified within one mile of the site penetrated below sea level, but no log was located. Detailed geologic field mapping was performed to provide a basis for subsurface interpretation. The geologic sequence appears to be similar to that of Whidbey Island (refer to Figure 32, Surficial Geology and Figure 33, Geologic Cross Section). The till thins to the east in the vicinity of the site and was removed to facilitate mining of the gravels below. The advance outwash consists of sand and gravel in outcrop, but clay layers are reported in well logs. Below the advance outwash is a sequence of silt, clay and fine sand layers. This sequence was not well enough exposed to identify the unit with certainty, but it appears to belong to the transition beds and/or Whidbey Formation. One well may have penetrated this material and is extracting water from gravels (Double Bluff Drift) found below.

Hydrogeology. Ten wells were identified within one mile of the site, and water levels reported on seven. The ground water system appears to be complex and insufficient data are available to adequately map the potentiometric surface for ground water systems beneath the site. There may be several perching clay layer(s) in the advance outwash. Existing well log data suggest about two-thirds of the wells are using water from the perched aquifers while one-third are probably drawing from the deeper, sea level aquifer.

Recharge to the ground water system is through direct infiltration of rainwater. The lack of till cover and surface drainage east of the site probably indicate that a greater volume of water reaches the aquifers on this side. If this is correct, then a ground water mound could be expected, causing westward flow under the site. It is unclear what effect the perching clay layers have on this system.

Beneficial Use. Twelve wells have been identified within one mile of the Camano Island Landfill. At least ten are in current use for domestic purposes with six of these multi-family or community wells, refer to Table 15, Well Inventory.

Water Quality. The limited existing data show generally good ground water quality exists in these aquifers. Ground water is moderately hard and there does not appear to be any significant differences in the water quality between the deep and shallow or perched aquifers. Concentrations of iron and manganese in water from well 1 (see Figure 30) have been found to exceed current drinking water standards. Water in well 4 also contained elevated iron concentrations in the past; however, recent analysis indicate iron concentrations are presently down.



Base Map: U.S.G.S. 7½' quads. Camano & Juniper Beach

EXPLANATION

Qvr .. Vashon Recessional Deposits, glacial silt, sand, and clay, continental and marine deposits, interbedded.

Qvt .. Vashon Till, glacial silt, sand, clay, gravel, boulders, poorly sorted(well graded), massive, compact, typically resembles concrete in exposures.

Qva .. Vashon Advance Outwash, glacial sand, pebbley, clean, horizontal and cross bedded.

—— Geologic Contact

N

0 2000 4000

Approximate Scale in Feet

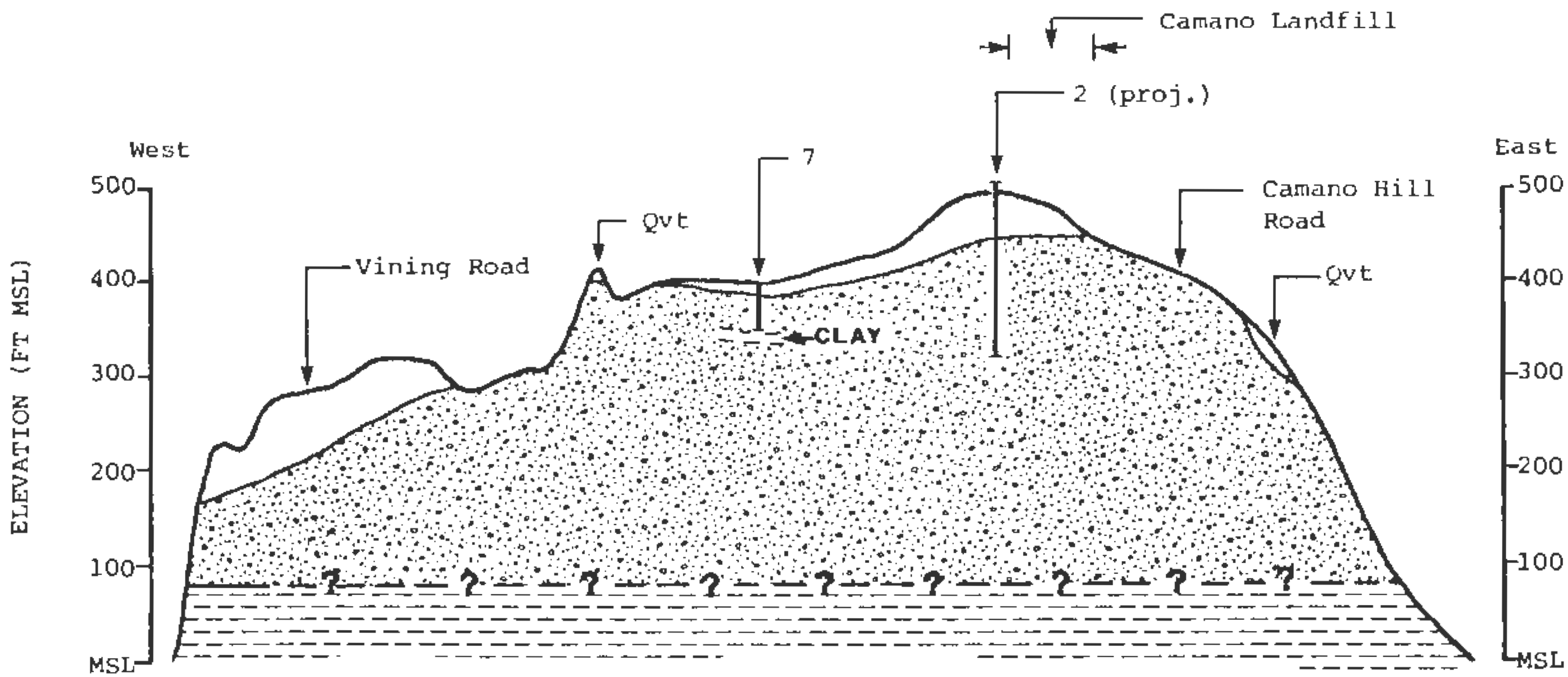
ISLAND COUNTY

Camano Island Landfill

Surficial Geology

Sweet, Edwards & Associates

INITIALS DATE



EXPLANATION

Qvt (Till)

Qva (Sand & Gravel)

Qtb/Qw (Silt & Sand)

2 = Well Number
(proj.) = Projected

Well

0 2000 4000

Approximate Scale in Feet
Vertical Exageration 10x

ISLAND COUNTY

Camano Island Landfill

Geologic Cross Section
West-East

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-31-85
CHECKED BY	JEE	3/19/85
REVISED		

Figure 33

TABLE 15
CAMANO ISLAND LANDFILL - WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
1	Green Island Hills Comm Assn.	31/2/12G	480	---	554	---	---	yes	
2	General Telephone	31/2/12L	470	352*	161	309 - 314	yes	---	
3	Statch	31/2/12F	470	364*	150	---	---	yes	
4	Driftwood Hts., Water Assoc. No. II	31/2/13A	300	219*	188	112 - 127	yes	yes	
5	Camano Sunrise	31/2/13A	330	247	212	118 - 128	yes	---	
6	Driftwood Hts., Water Assoc. No. I	31/2/13A	260	179*	180	---	---	yes	
7	McMillan	31/2/11H	263	325*	49	---	---	---	
8	Driftwood Shores	31/3/7E	50	---	201	---	---	yes	
9	Binckley	31/2/12M	380	100	426	---	---	---	
10	Green Island Hills Comm Assn.	31/2/12G	460	---	152	---	---	---	

Note: Site Well Number is used to designate wells on Site Location Map
All elevations are in feet above mean sea level.
All measurements are in feet.

Despite the close proximity of this area to sea water, there does not appear to be any problem with saltwater intrusion at the present time.

Waste Characterization. The Camano Island disposal site received domestic solid waste from 1958 through 1977 (see Figure 31). Since 1977, disposal has been restricted to demolition waste/white goods in a designated area in the northwest corner of the site. An animal disposal pit was also reported at the site. Since 1982 the site has been further restricted to demolition waste only.

Leachate Generation. The annual volume of leachate entering the ground water system from the Camano Landfill is estimated to be 2.41 x 10^5 gallons (0.74 acre-feet), refer to Table 16, Water Balance. A 30-foot thickness for the refuse was assumed. About 24 percent of the annual rainfall on the 2-acre site infiltrates through the sparsely vegetated silty gravel cover.

Pollution Potential. The Camano Island Landfill was rated as the lowest pollution potential of the nine sites studied. Low leachate discharge and beneficial use, the depth to ground water, and the type of facility and waste, all indicate that the pollution potential of this site is relatively lower than any of the other sites.

Monitoring Strategy. There is a severe lack of data at the Camano Island site. Under Program A, two wells approximately 150 feet deep and one well approximately 100 feet deep should be located as shown on Figure 31, Site Plan. Initial cost for well installation is $20,600. Based on the data obtained, additional wells may be required to meet DOE MFS. Sampling should be limited to DOE-MFS parameters. First year monitoring costs will be about $5,900 and about $3,200 annually for subsequent years.

Program B includes existing wells 1, 2, 3, 9, and 10, plus any additional new wells drilled within 2,000 feet of the site. First year monitoring under Program B would be about $9,900 and $8,600 annually thereafter.

Freeland Landfill

The site is located 2 miles northwest of Freeland. It is near the edge of rolling wooded uplands with elevations ranging from about 140 to 200 feet above mean sea level, refer to Figure 34, Site Location Map. West of the site is a broad north-south trending valley which drains to Mutiny Bay. To the east is Holmes Harbor.

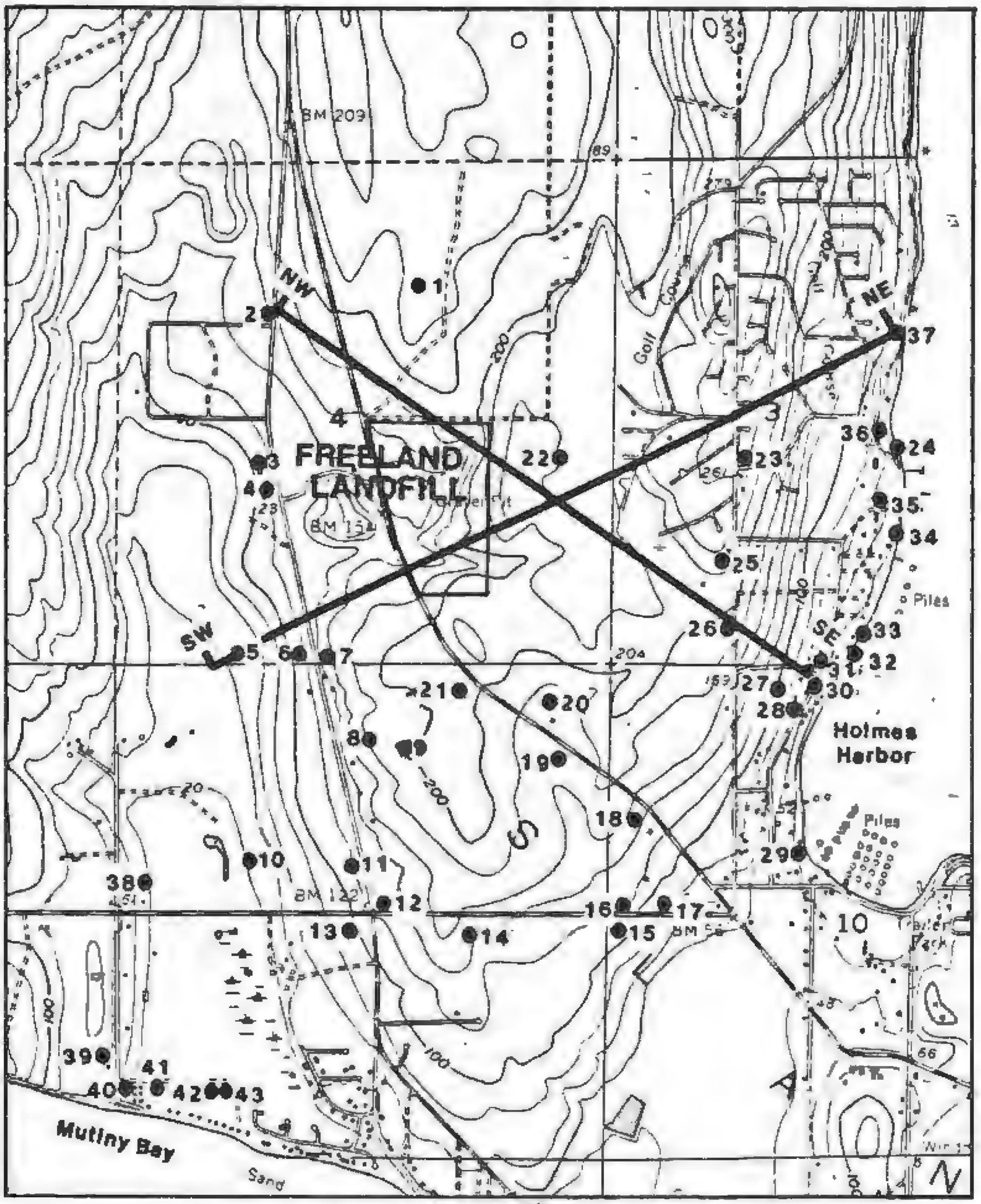
The landfill occupies a small part of the area cleared during the gravel mining operations. Most of the property

TABLE 16

MOISTURE BALANCE FOR CAMANO ISLAND LANDFILL

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1.	T	38.6	41.0	44.2	49.0	53.2	57.6	61.0	61.0	56.5	50.9	44.2	41.5	49.9
2.	P	2.18	1.67	1.76	1.38	1.39	1.16	.59	.74	1.24	1.66	2.19	2.68	18.64
3.	I	0.62	1.00	1.58	2.62	3.65	4.86	5.88	5.91	4.55	3.08	1.58	1.08	
4.	UPET	0.02	0.03	0.04	0.06	0.07	0.09	0.11	0.11	0.09	0.07	0.04	0.03	
5.	PET	0.45	0.71	1.22	2.05	2.75	3.59	4.42	4.06	2.83	1.95	0.92	0.65	
6.	$C_{R/O}$	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
7.	R/O	0.22	0.16	0.17	0.14	0.14	0.12	0.06	0.07	0.12	0.16	0.22	0.27	1.85
8.	i	1.96	1.51	1.59	1.24	1.25	1.04	0.53	0.67	1.12	1.50	1.97	2.41	
9.	i-PET	1.51	0.80	0.37	-0.81	-1.50	-2.55	-3.89	-3.39	-1.71	-0.45	1.05	1.76	
10.	APWL	0	0	0	-0.81	-2.31	-4.86	-8.75	-12.14	-13.85	-14.30	0	0	
11.	ST	2.00	2.00	2.00	1.30	0.59	0.15	0.03	0.03	0.03	0.03	2.00	2.00	
12.	²ST	0	0	0	-0.70	-0.71	-0.44	-0.12	0	0	0	1.97	0	
13.	AET	0.45	0.71	1.22	1.94	1.96	1.48	0.65	0.67	1.12	1.50	0.92	0.65	12.62
14.	PERC	1.51	0.80	0.37	0	0	0	0	0	0	0	0	1.76	4.44

SYMBOLS: T = mean air temperature; P = precipitation; I = heat index; UPET = unadjusted potential evapotranspiration; PET = potential evapotranspiration; $C_{R/O}$ = runoff coefficient; R/O = surface runoff; i = infiltration; i-PET = infiltration minus the potential evapotranspiration; APWL = accumulated potential water loss; ST = storage; ²ST = change in soil moisture storage; AET = actual evapotranspiration; PERC = percolation.



Base Map: U.S.G.S. 7½′ quad. Freland

EXPLANATION

13● Well With Number

SW NW Cross Section Location

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

Freeland Landfill
Site Location Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJM	1-28-85
CHECKED BY	JEE	3/19/85
REVISED		

Figure 34

remains wooded, (refer to Figure 35, Site Map). The waste mound fills a part of the excavated area and is covered with till and sand. On its north side, the mound slopes steeply to a large grassy area where some demolition debris has been dumped. West of this grassland, the county maintains a gravel stockpile. A pond is located in the woodlands on its east side. The landfill is presently used as a salvage/recycling facility and for disposal of wood waste burned at the site. However, during the course of this investigation, the disposal of municipal waste was observed. Access is from State Highway 525 which is the western boundary of the property. A green belt of trees has been preserved along the highway (see Figure 35, Site Map).

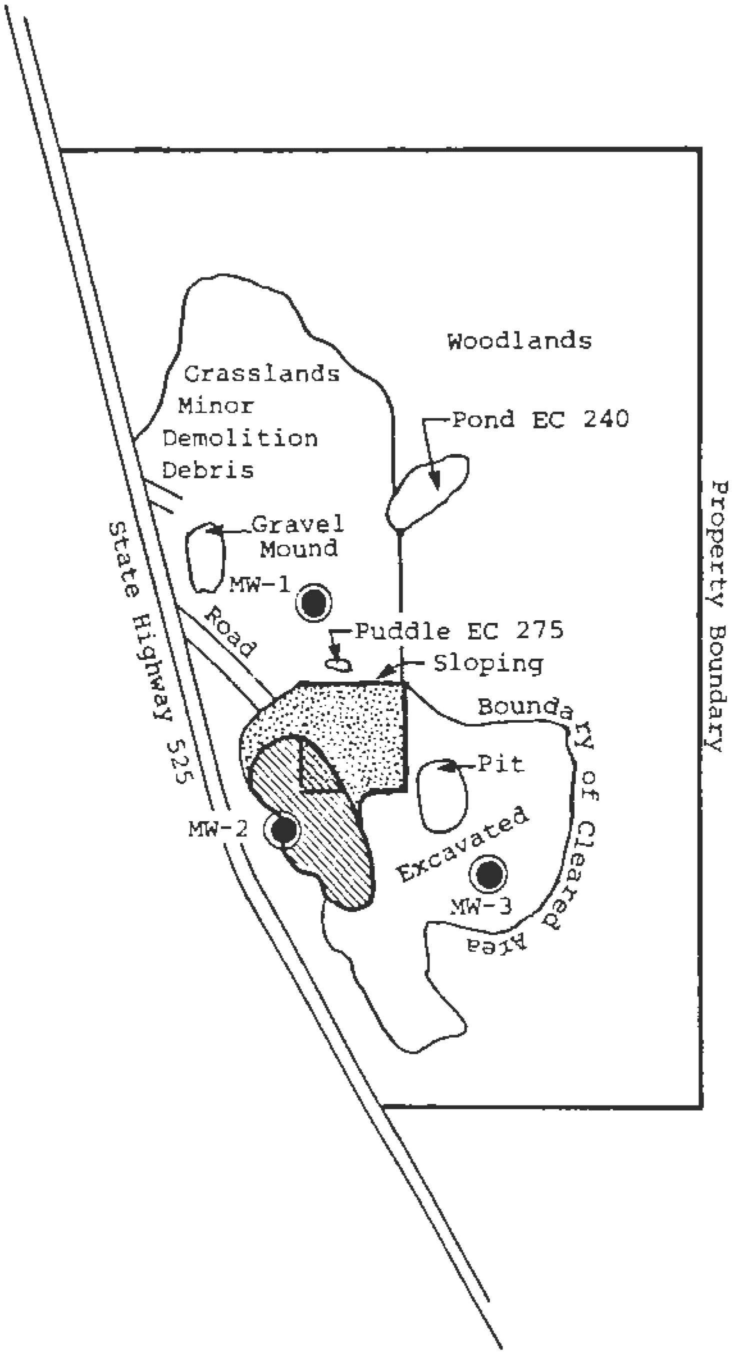
Freeland is one of two sites selected for initial ground water monitoring. Three monitoring wells were constructed during Phase II. Refer to Appendix 5 for site drilling and sampling description.

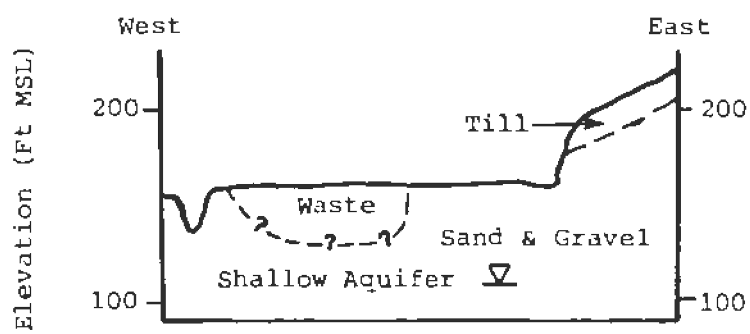
Climate. The landfill is on the margin of the Olympic rain shadow with annual precipitation about 28 inches at Greenbank, 5 miles north of the site. Temperature is assumed to be similar to that measured at Coupeville, with an annual mean of 50°F, a winter average of 40°F, and a summer average of 60°F.

Geology. The Vashon Till is the surficial unit in the site vicinity. The till has been removed at the landfill exposing Vashon Advance Outwash sand (refer to Figures 36, Surficial Geology, and 37, Geologic Cross Section). Nearby water well logs describe the upper part of the outwash as sand and clay (actually silt?) with the lower part being sand and gravel.

The Advance Outwash varies beneath the site. The northernmost boring (Freeland MW-1) penetrated a typical section of Advance Outwash where gravels grade into sand with depth. The western and eastern borings (MW-2 and MW-3, respectively), encountered silty gravels in the lower part of the Advance Outwash. The transition beds (approximately 40 feet of clay and sand) underlie the Advance Outwash. Outcrops in the bluffs east of the site and at Holmes Harbor indicate that gravels of the Olympia interglaciation may underlie the transition beds with till and sand of the Double Bluff Drift below this. It is difficult with the available information to define the deeper sequence accurately.

Hydrogeology. Water wells of the area appear to tap two aquifers, refer to Figure 38, Hydrostratigraphic Cross Section. The shallow or perched aquifer is in the sand and gravel (advance outwash) above the Transition Beds. Regional historical data indicate the potentiometric surface in this aquifer forms a mound east of the site inducing flow to the west under the site toward the valley, refer to Figure 39. However, the shallow ground water system was observed in only two of the three borings drilled during this investigation. Water was measured in MW-2 at





Schematic Cross Section

Approximate Scale in Feet

EXPLANATION

Approximate area underlain by waste

Area presently used for salvage and underlain by waste.

MW-1 Monitoring well drilled during this study

ISLAND COUNTY

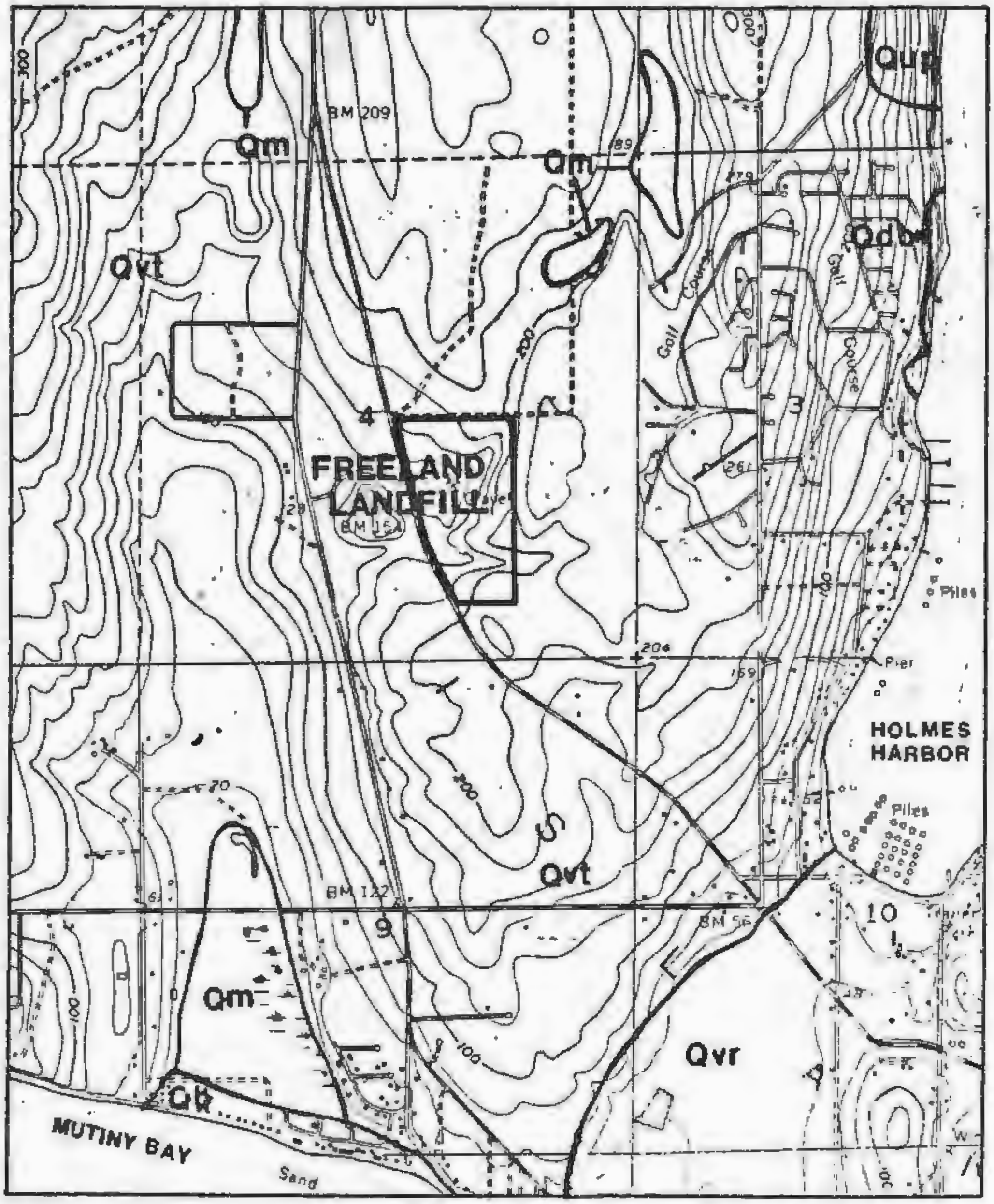
Freeland Landfill

Site Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-28-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 35



Base Map: U.S.G.S. 7½' quad. Freeland

EXPLANATION

Qb .. Beach Deposits, sand and gravel along shorelines.

Qm .. Marsh, Bog, Swamp Deposits, silt, clay, sand with organics including peat.

Qvr .. Vashon Recessional Deposits, glacial silt, sand, and clay, continential and marine deposits, interbedded.

Qvt .. Vashon Till, glacial silt, sand, clay, gravel, boulders, poorly sorted(well graded), massive, compact, typically resembles concrete in exposures.

Qup .. Pleistocene Deposit (undifferentiated), may include any glacial or non-glacial sediment deposited durring the pleistocene epoch.

Qdb .. Double Bluff Drift, glacial sand, gravel, lodgement till, silt and clay.

Geologic Contact

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

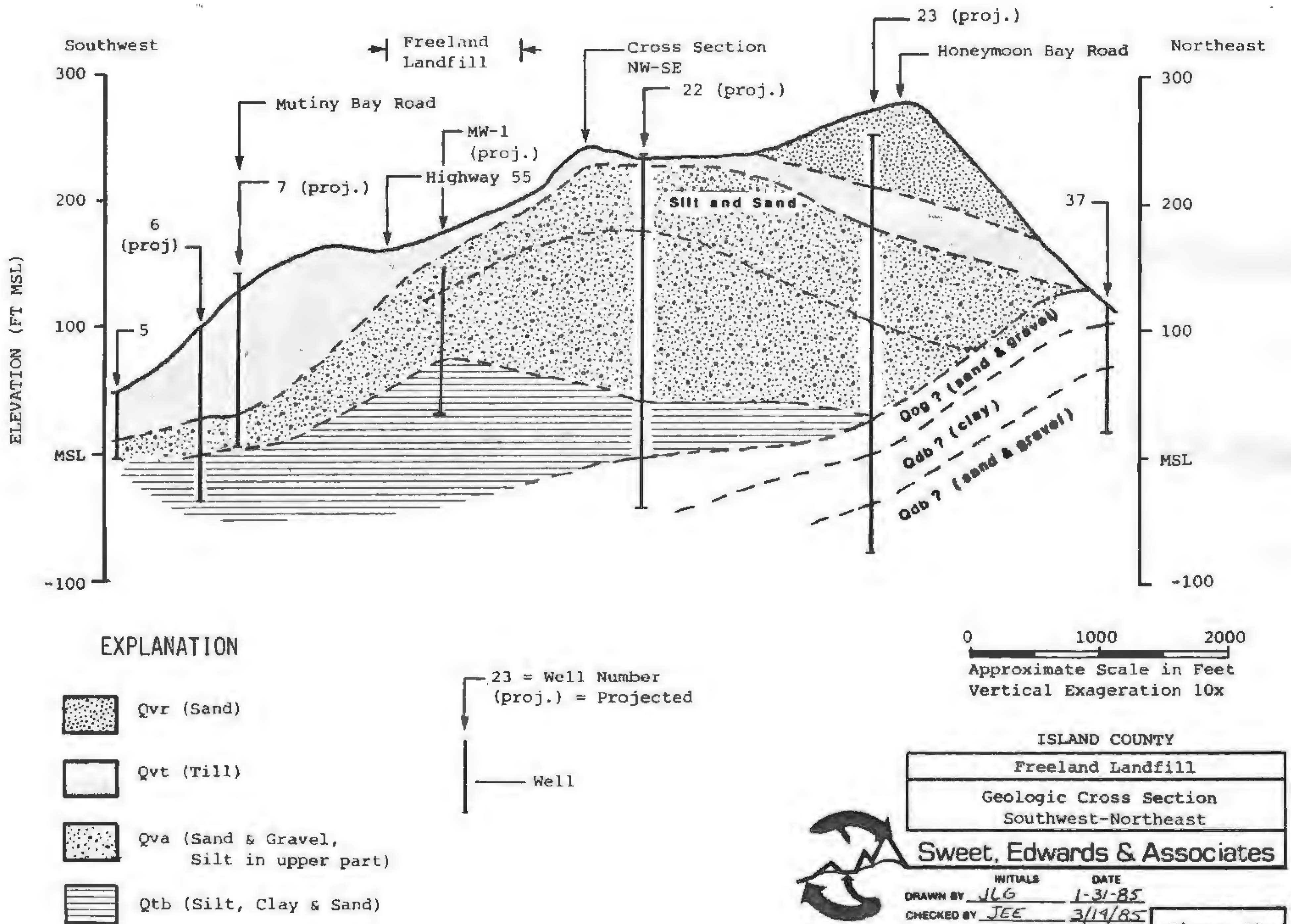
Freeland Landfill

Surficial Geology

Sweet, Edwards & Associates

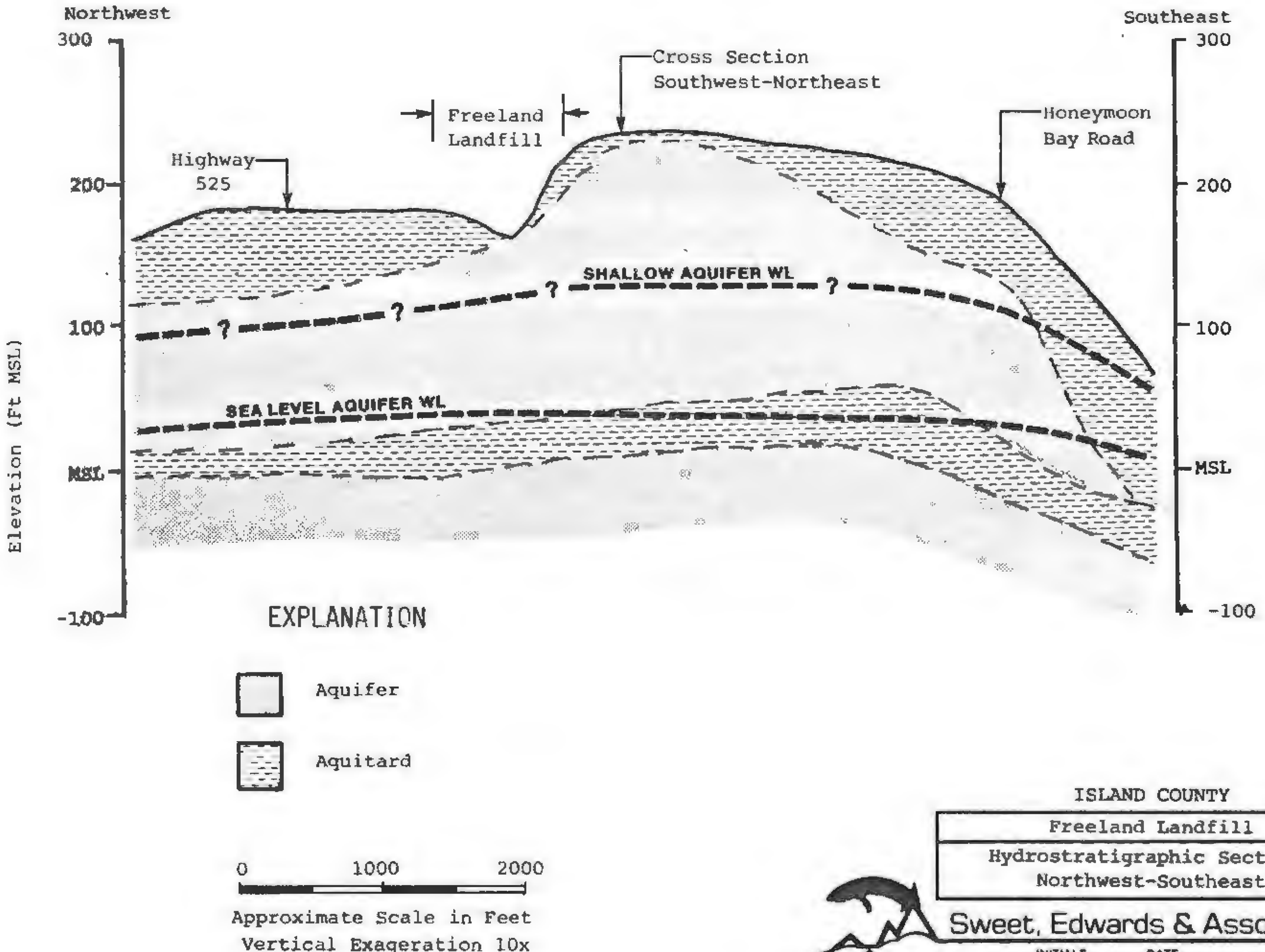
	INITIALS	DATE
DRAWN BY	JLG/SJM	2-1-85
CHECKED BY	TEE	3/14/86
REVISED		

Figure 36



Southwest
Freeland Landfill
Cross Section NW-SE
23 (proj.)
Honeymoon Bay Road
Northeast
Mutiny Bay Road
22 (proj.)
MW-1 (proj.)
Highway 55
7 (proj.)
6 (proj)
5
37
Silt and Sand
Qog ? (sand & gravel)
Qdb ? (clay)
Qdb ? (sand & gravel)
ELEVATION (FT MSL)
300
200
100
MSL
-100
EXPLANATION
Qvr (Sand)
Qvt (Till)
Qva (Sand & Gravel, Silt in upper part)
Qtb (Silt, Clay & Sand)
23 = Well Number
(proj.) = Projected
Well
0
1000
2000
Approximate Scale in Feet
Vertical Exageration 10x
ISLAND COUNTY
Freeland Landfill
Geologic Cross Section Southwest-Northeast
Sweet, Edwards & Associates
INITIALS DATE
DRAWN BY JLG 1-31-85
CHECKED BY JEE 3/14/85
REVISED mmm 12.13.85

Figure 37



ISLAND COUNTY

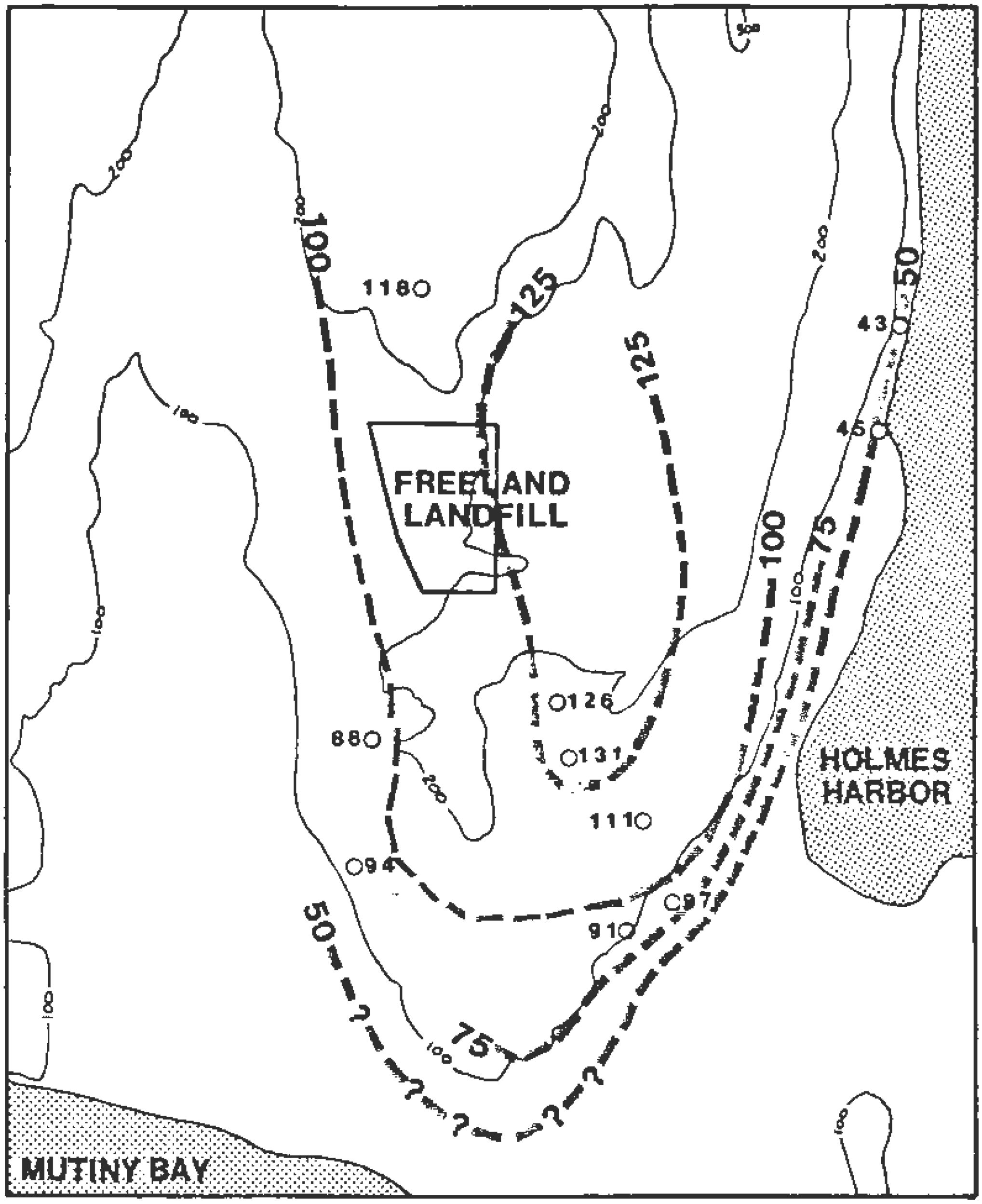
Freeland Landfill

Hydrostratigraphic Section
Northwest-Southeast

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-30-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/5/85

Figure 38



Base Map: U.S.G.S. 7.5' quad. Freeland

EXPLANATION

—100— Elevation Contour (Ft MSL)

O 33 Well with old or reported water level measurement

50 — Water level elevation

Note: Historic data only, does not reflect site water level data collected during this investigation.

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

Freeland Landfill

Water Level Elevation Map
Shallow Aquifer

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	ILG	1-29-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 39

109.9 feet. Water was measured at elevation 94.5 feet in MW-3 to the east but was 15 feet lower in elevation indicating a ground water flow gradient to the east which is the opposite direction indicated by the historical regional data. The shallow ground water system was not observed in MW-1.

The extraordinarily dry year may account for the anomalous ground water flow directions. Sweet-Edwards has observed ground water flow direction reversals at other locations in western Washington during 1985. However, rather than a flow direction reversal it may be likely that 1985 water levels in the shallow aquifer have declined to such low levels, only pockets or depressions in the undulating or irregular top of the perching layer are saturated.

Recharge to the shallow aquifer is from precipitation on the upland. Thin or absent till on the upland promotes ready recharge. Discharge is to the underlying sea level aquifer and (under high ground water conditions) to the valley west of the site.

The deep sea level aquifer is more complicated and poorly defined in the immediate vicinity of the landfill. The uppermost clay layer of the transition beds confines the water in the units below. Wells have been completed in the gravel and sand found near or below sea level including those within the transition beds. Water level elevations indicate that all units have similar piezometric levels and are probably hydraulically connected. Water levels in MW-1 on site support this conclusion.

Recharge to the sea level aquifer is probably both through the older sand and gravel units found at relatively higher elevations to the north and east and the clays and sands of the transition beds. Available water level elevations indicate that a ground water ridge is present under the landfill in this aquifer with consequent radial, but predominantly southerly flow (refer to Figure 40).

Beneficial Use. A total of 43 wells have been identified as within one mile of the site, refer to Table 17, Well Inventory. Field well data recently collected by the Health Department indicate 36 wells are in use. Shallow ground water flow is considered to be influenced by the valley to the west. Therefore, six wells referenced in Water Supply Bulletin 25 (WSB25) were added to aid definition of the ground water system for this area.

The primary use of ground water is for small domestic needs. Based on existing well log data, approximately three-fourths of the active wells are developed in the sea level aquifer. The remaining active wells are probably drawing water from the shallow aquifer, except for well 20 which might be in a perched zone above the till. Well data analyzed from WSB25 show that

TABLE 17
FREELAND LANDFILL - WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
1	Frantz	29/2/4B	220	118	147	---	---	---	high Fe content
2	Mutiny Bay Park	29/2/4F	158	28*	177	-20 - -9	yes	---	
3	Crosley	29/2/4L	110	12*	143	---	yes	---	
4	Meadowwood Protective Assn.	29/2/4L	110	25*	115	---	---	---	high Fe content
5	Andrews	29/2/4N	50	34*	51	0 - 10	yes	---	
6	Haworth	29/2/4P	100	-21*	143	-48 - -43	yes	---	
7	Curtiss	29/2/4P	145	44*	140	5 - 11	yes	---	
8	Wilson	29/2/9B	180	88*	118	62 - 67	yes	---	
9	Baggerly	29/2/9B	200	--	114	---	---	---	
10	Sawyer	29/2/9E	15	21	60	---	yes	---	flowing artesian
11	Novarra	29/2/9F	110	94*	24	---	---	---	
12	Sawyer	29/2/9G	120	5	209	---	yes	---	petroleum taste & smell
13	Sumner	29/2/9L	100	--	205	-88 - -93	yes	---	
14	Breithaupt	29/2/9K	140	14	322	-169 - -178	yes	---	
15	Wyvel	29/2/10M	112	91*	32	---	yes	---	
16	Pasbrig	29/2/10E	120	25	200	---	yes	---	
17	Petro	29/2/10E	109	97	67	---	partial	---	
18	Whidbey Is. Sand & Gravel	29/2/10E	145	111*	80	65 - 73	yes	---	
19	Richards	29/2/9A	170	131	89	81 - 86	yes	---	high Fe content
20	Smith	29/2/9A	175	126*	55	---	yes	---	
21	Vasil	29/2/9B	210	29*	198	---	---	---	
22	Ware	29/2/4J	240	35	280	-40 - -30	yes	---	pump test
23	Harbor Hills Water Co.	29/2/3L	255	17	327	-72 - -62	yes	yes	
24	Harbor Hills Water Co.	29/2/3K	40	-193*	275	-235 - -215	yes	yes	
25	Lewis	29/2/3N	230	128*	228	-3 - -2	yes	---	
26	Wente	29/2/3N	199	33	212	-13 - -9	yes	---	
27	St. Augustine's in the Wood	29/2/10C	115	27*	124	---	yes	---	

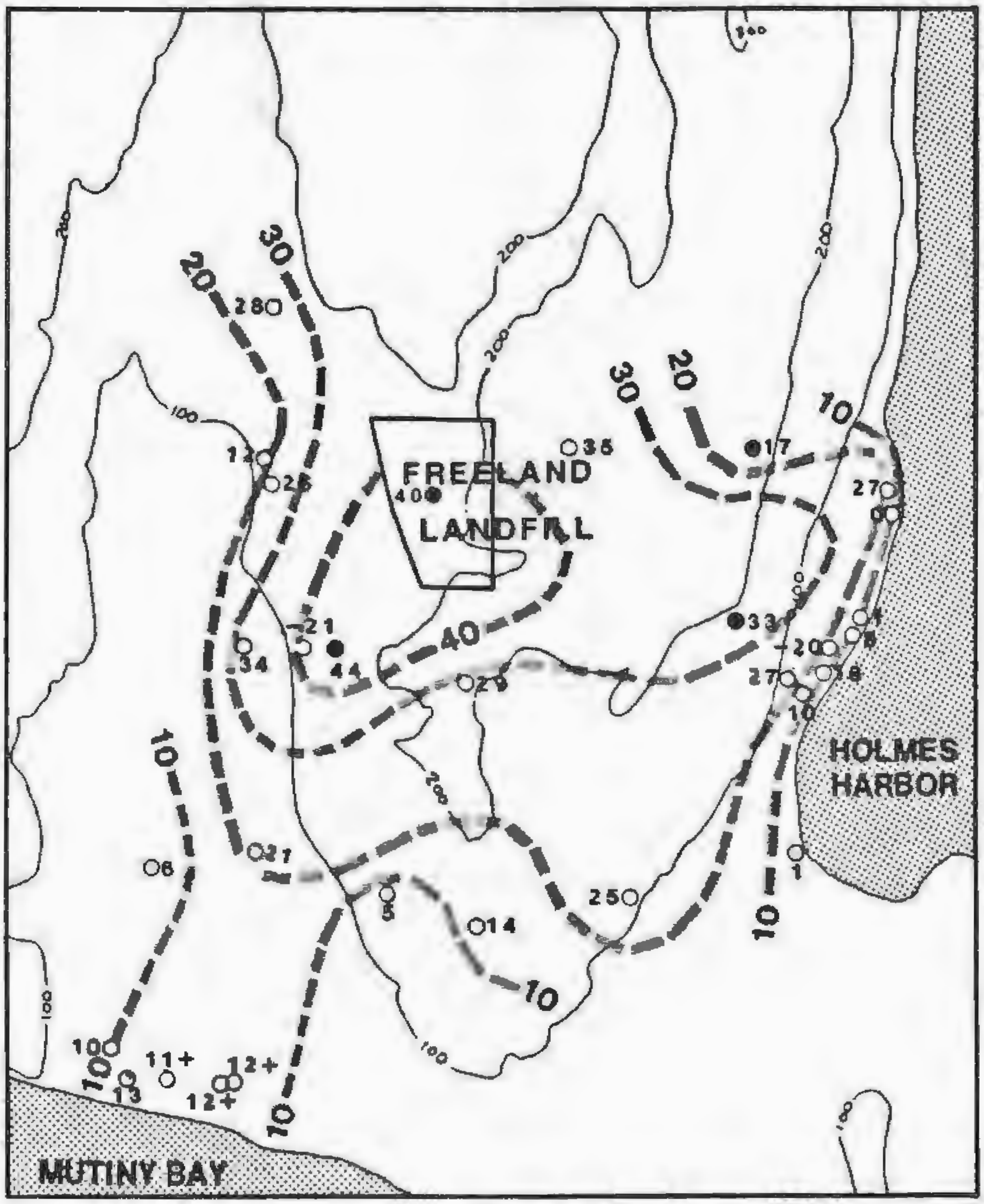
See last page of this table for footnotes

TABLE 17

FREELAND LANDFILL - WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
26	Wente	29/2/3N	199	33	212	-13 - -9	yes	---	
27	St. Augustine's in the Wood	29/2/10C	115	27*	124	---	yes	---	
28	McIntosh	29/2/10C	75	10*	135	---	---	---	
29	Harbor Shores	29/2/10F	25	1*	95	---	yes	---	
30	Ward	29/2/10C	70	18*	130	---	yes	---	
31	Yenter	29/2/3P	60	-20*	131	-71 - -66	yes	---	
32	Prael	29/2/3P	20	8	115	-95 - -90	yes	---	
33	Whitehead	29/2/3P	20	1*	110	-90 - -85	yes	---	
34	Monty	29/2/3K	20	0*	90	-66 - -56	yes	---	
35	Ambrose	29/2/3K	55	27	77	-22 - -11	yes	---	
36	Bradshaw's Addn. W.S.	29/2/3K	60	45*	32	---	---	---	
37	Robinson	29/2/3G	120	42*	95	25 - 30	yes	---	
38	Pratt	29/2/9E	25	6*	23	---	yes	---	
40	Hill	29/2/9N	40	13*	114	-74 - -69	yes	---	
41	Rose	29/2/9N	10	11+*	58	-48 - -40	yes	---	flowing artesian
42	Proby, Ayres, Monette	29/2/9N	10	12+*	86	---	yes	---	flowing artesian
43	Simmons	29/2/9N	10	12+*	90	---	yes	---	flowing artesian

Note: Site Well Number is used to designate wells on Site Location Map
All elevations are in feet above mean sea level.
All measurements are in feet.



Base Map: U.S.G.S. 7.5' quad. Freeland

EXPLANATION

100 — Elevation Contour (Ft MSL)

21○ Well with old or reported water level measurement

91● Well with recent water level measurement

20 — Water level elevation

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

Freeland Landfill
Water Level Elevation Map Sea Level Aquifer

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-29-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 40

the average yield of wells in this area increases with increasing depth, while the specific capacity decreases.

Water Quality. Very limited existing water quality data were available for wells near the Freeland Landfill. Except for a tendency toward elevated iron concentrations throughout the area, existing data suggested essentially good ground water quality regionally. Saltwater intrusion does not appear to be a problem in this area. Flowing artesian wells occur near the shores of Mutiny Bay indicating considerable hydraulic head. Electrical conductivities for ponds near the site range from 240 to 275 micromhos.

As part of this investigation two of the three single completion monitor wells constructed were sampled and tested. Refer to Appendix 6, Ground Water Quality Testing Data.

The data are limited to one well accessing the deep sea level aquifer (MW-1) and one well accessing the shallow perched aquifer. The data are in part anomalous, however, preliminary evaluation indicates significant impacts to the ground water regime from the landfill.

Initial testing for total organic carbon (TOC) and total halogenated organics (TOX) yielded extraordinarily high concentrations in both MW-1 and MW-2 (MW-1: TOC was 2.50 mg/l; TOX was 1.08 mg/l, and MW-2: TOC was 18.3 mg/l; TOX was 0.3 mg/l). Concern for the potential of significant organic contamination resulted in immediate resampling by the Health Department and testing for volatile organic parameters. None of these volatile organic constituents were detected and subsequent indicator parameter sampling and testing in January 1986 yielded TOC and TOX values substantially lower than the initial testing (MW-1: TOC 1.4 mg/l; TOX <.007 mg/l and MW-2: TOC 4.3 mg/l; TOX .018 mg/l). April 1986 samples exhibited slightly lower concentrations than January samples for both TOX and TOC, except in MW-2 where TOX was approximately .025 mg/l.

The inconsistency in the data suggests contamination during the initial sampling. This may have occurred as a result of improper handling or possibly the introduction of organic contaminants to the well during bailing. Deterioration of the bailing rope was observed and is noted in Appendix 5.

However, ground water contamination by organic constituents should not be ruled out until a more substantial database has been established because:

1. Indicator parameter (see Table 4) testing was performed on quadreplicate samples for each well. Concentration values for all of the parameters tested are relatively close (within 3% of the mean) for each of the four samples.

Sampling contamination typically exhibits a greater variation.

2. Ground water contamination associated with landfills tends to move through aquifers in slugs or as a pulse. This is particularly valid for organic contamination which may have a limited source area/quantity.

3. Indicator parameters other than TOC and TOX for both the October 1985 and January 1986 samplings indicate ground water contamination of the shallow aquifer.

Secondary drinking water standards for manganese (MCL = .05 mg/L) are exceeded in both the shallow and deep aquifers (.14 mg/L and .21 mg/L, respectively). Conductivities for the deep aquifer ranged from 290-400 micromhos per centimeter. Although moderately high, these levels for manganese and conductivity are characteristic for this part of western Washington and may represent background levels for these parameters. Conductivities for the shallow aquifer are about 1100 micromhos/cm and more indicative of water quality impacts from landfill operations. Sulfate and chloride concentrations in the shallow aquifer are also indicative of contamination due to landfill operations (224-328 and 34-94 mg/L, respectively).

Waste Characterization. Beginning in 1950, the Freeland site was operated in an old gravel pit for disposal of domestic waste. In 1978, disposal was restricted to demolition waste/white goods (see Figure 35). Sporadic dumping of septic sludge and pumpings has been reported. A portion of the site is set aside as a salvage/recycling center and the site is currently receiving waste.

Leachate Generation. An estimated 3.70×10^5 gallons (1.12 acre-feet) of leachate are generated annually at the site (refer to Table 18, Water Balance). Water percolates through about 30 feet of refuse. About 22 percent of the yearly rainfall (Greenbank rain gauge) falling on the 2.14-acre site percolates through the sparsely vegetated sandy till cover.

Pollution Potential. The Freeland Landfill was rated fourth in terms of pollution potential. This was due to the high beneficial use nearby and the shallow depth to ground water. The water quality data collected during Phase II confirms that ground water quality in the shallow aquifer has been impacted by landfill operations.

Monitoring Strategy. The three wells installed during the Phase II investigation provided a substantial amount of information regarding subsurface conditions. Ground water flow appears to be to the west; however, due to the site's apparent location near a ground water ridge (refer to Figure 39, Water Elevation Map) and the unusually dry climatic conditions, the

TABLE 18

MOISTURE BALANCE FOR FREELAND LANDFILL

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1. T	38.6	41.0	44.2	49.0	53.2	57.6	61.0	61.1	56.5	50.9	44.2	41.5	49.9
2. P	3.70	2.80	2.40	2.20	2.10	1.30	0.70	1.20	1.30	2.20	4.0	3.80	27.7
3. I	0.62	1.00	1.58	2.62	3.65	4.86	5.88	5.91	4.55	3.08	1.58	1.08	36.23
4. UPET	0.02	0.03	0.04	0.06	0.07	0.09	0.11	0.11	0.09	0.07	0.04	0.03	
5. PET	0.45	0.71	1.22	2.05	2.75	3.59	4.42	4.06	2.83	1.95	0.92	0.65	25.6
6. $C_{R/O}$	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	
7. R/O	0.74	0.56	0.48	0.44	0.42	0.26	0.14	0.24	0.26	0.44	0.80	0.76	5.54
8. i	2.96	2.24	1.92	1.76	1.68	1.04	0.56	0.96	1.04	1.76	3.2	3.04	
9. i-PET	2.51	1.53	0.70	-0.29	-1.07	-2.55	-3.86	-3.10	-1.79	-0.19	2.28	2.39	
10. APWL	0	0	0	-0.29	-1.36	-3.91	-7.77	-10.87	-12.66	-12.85	0	0	
11. ST	4.00	4.00	4.00	3.71	2.82	1.46	0.56	0.52	0.52	0.52	2.80	4.00	
12. ²ST	0	0	0	-0.29	-0.89	-1.36	-0.9	-0.04	0	0	2.28	1.20	
13. AET	0.45	0.71	1.22	2.05	2.57	2.40	1.46	1.0	1.04	1.76	0.92	0.65	16.23
14. PERC	2.51	1.53	0.70	0	0	0	0	0	0	0	0	1.19	5.93

SYMBOLS: T = mean air temperature; P = precipitation; I = heat index; UPET = unadjusted potential evapotranspiration; PET = potential evapotranspiration; $C_{R/O}$ = runoff coefficient; R/O = surface runoff; i = infiltration; i-PET = infiltration minus the potential evapotranspiration; APWL = accumulated potential water loss; ST = storage; ²ST = change in soil moisture storage; AET = actual evapotranspiration; PERC = percolation.

westerly flow direction is uncertain. Under Program A, additional wells ranging from about 100 to 150 feet deep should be constructed. Because ground water contamination has been identified, two wells should access the deep sea level aquifer and one well should access the shallow perched aquifer. The wells should be located near the three existing monitor wells shown on Figure 35, Site Map. Due to the inconsistency of water levels in the perched aquifer, the monitor wells should be constructed during the spring to facilitate saturated zone identification. Additional well installation will be about $18,600. Based on the data obtained from these borings, the monitoring program should be expanded to include a minimum of one well upgradient and three wells downgradient for both the perched aquifer and the sea level aquifer, or sufficient wells to meet DOE-MFS. Sampling and testing should meet the Minimum Functional Standards as previously described. First year monitoring costs will be about $12,400 and about $7,000 annually thereafter.

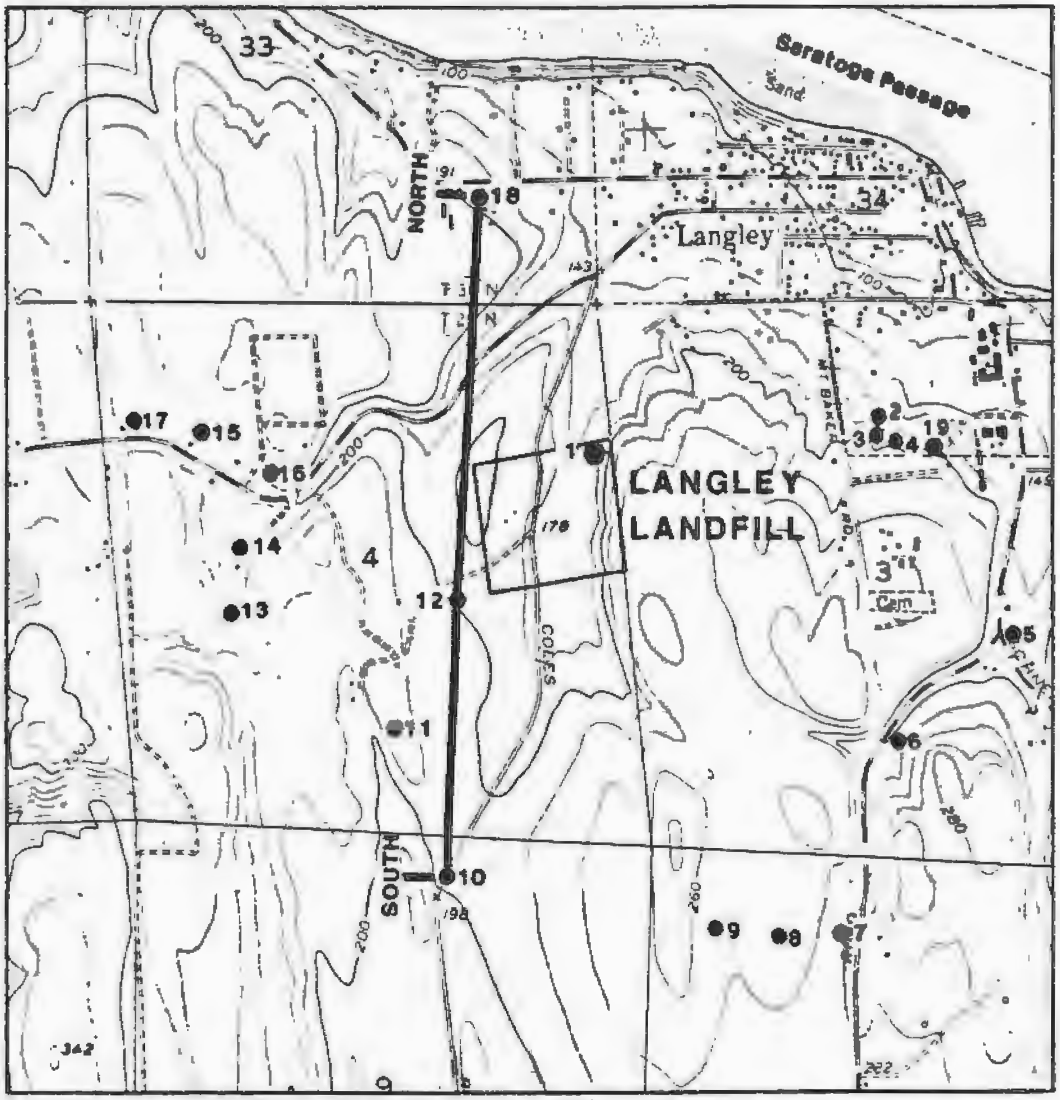
Because there is indication of a high potential for ground water contamination a Type B monitoring program is not recommended. However, in addition to Type A monitoring, existing water supply well Nos. 1 through 9 and 20 through 22 should be tested for indicator parameters. This additional offsite sampling and testing will cost approximately $1,800 for the indicator parameters (refer to Table 4) or $2,900 for DOE MFS parameters. Where TOC exceeds 5 mg/L or TOX exceeds .05 mg/L, volatile organics testing should be performed.

Langley Landfill

The Langley Landfill is owned and operated by the City of Langley. The property occupies a north-south trending valley through which Coles Road passes. The site is located less than a mile southwest of Langley in a wooded area of rolling uplands (Figure 41). The waste mound is located against the eastern slope of this valley at elevations between 180 and 230 feet above mean sea level. A dirt road enters the east part of the property but forks in three directions a short distance from Coles Road. Demolition debris has been placed on the flat part of the valley (see Figure 42, Site Map).

Evidence of sand or gravel mining operations is present below the road that leads to the top of the waste, but it is not clear if material was removed where the waste was placed. A pistol range has been built in the remaining pit. A drainage ditch is present on the upslope side of the waste mound. Dense woods surround the landfill.

Climate. Rainfall has been measured at Langley and averages 38 inches per year, indicating this part of the island is outside the Olympic rain shadow. Temperature is assumed to be



Base Map: U.S.G.S. 7½' quad. Langley

EXPLANATION

●4 Well With Number

NORTH SOUTH Cross Section Location

N

0 2000 4000

Approximate Scale in Feet

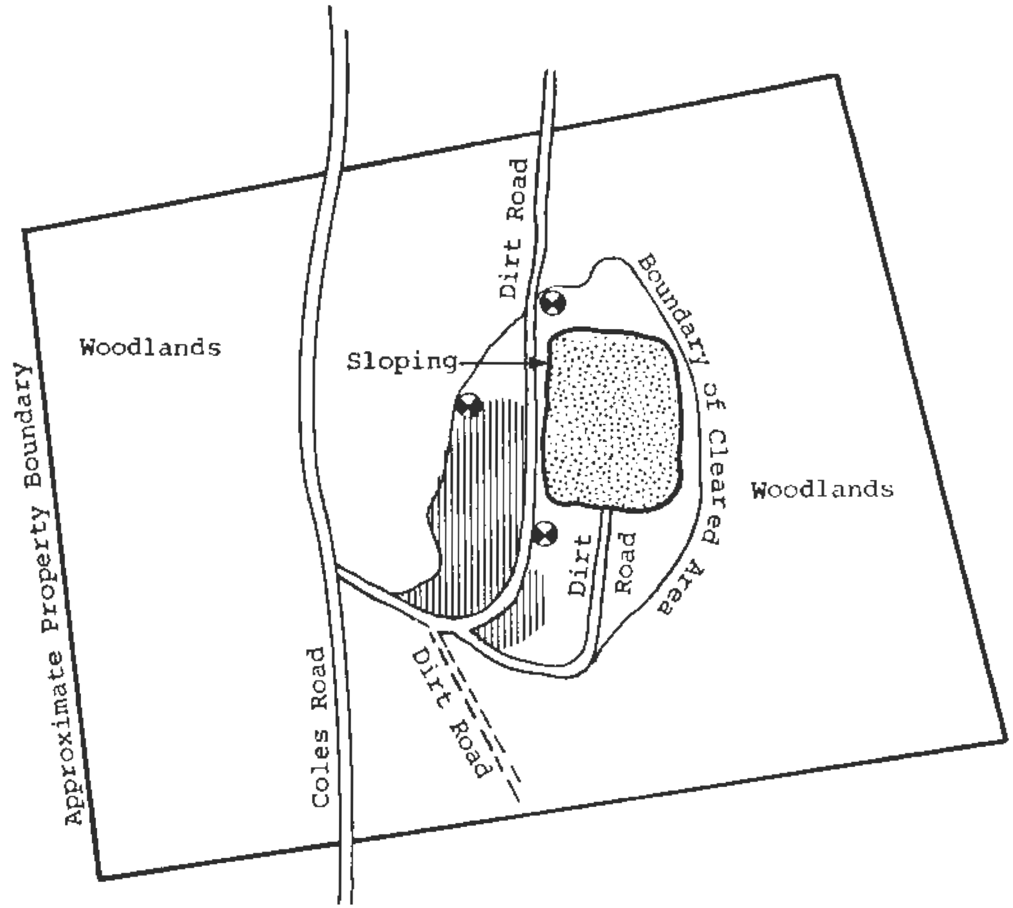
ISLAND COUNTY

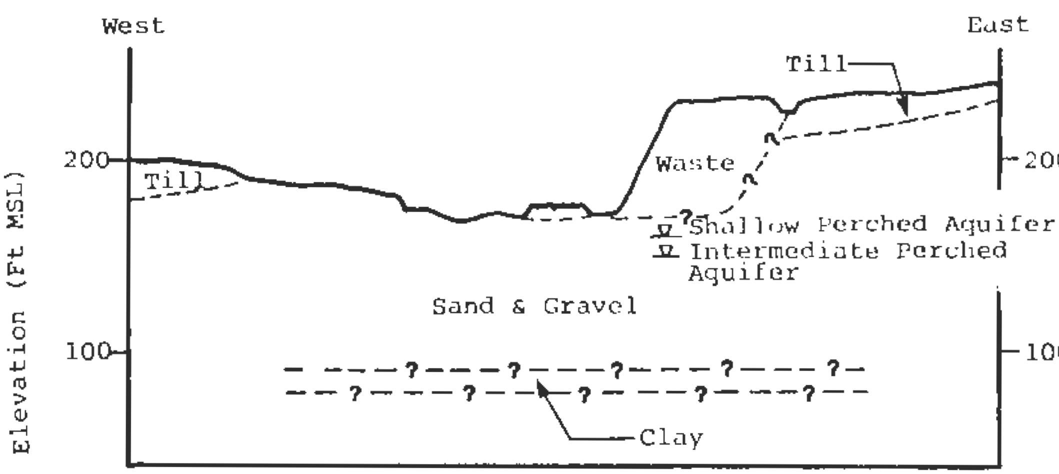
Langley Landfill
Site Location Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJM	1-28-85
CHECKED BY	JEE	3/19/85
REVISED	mmm	12 13 85

Figure 41





Schematic Cross Section

N

0 400 800
Approximate Scale in Feet

EXPLANATION

- Maximum area underlain by waste
- Demolition disposal area
- Proposed monitoring well location

ISLAND COUNTY

Langley Landfill

Site Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-28-85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 42

influenced by the surrounding seas and similar to that recorded at Coupeville.

Geology. This landfill is located on the west slope of a small valley that has been eroded through the till exposing advance outwash sand, refer to Figure 43, Surficial Geology. The relationship between the advance outwash and the underlying transition beds is somewhat complex and indicates one or more retreats and readvances of the ice sheet (see Figure 44, Geologic Cross Section). A clay layer located at approximately 100 feet above mean sea level may extend as far north as the site. Subsurface information is too sparse to determine with certainty if this layer is continuous and part of the transition beds. The Whidbey formation underlies the transition beds at approximately sea level.

Hydrogeology. Three potentiometric surfaces were identified from the available data. Insufficient data are available to define a potentiometric surface for any of the ground water flow regimes. The upper two levels are perched on or above the clay layer identified at 100 feet above mean sea level. The available water level data, topography, and apparent increase in elevation of the perching clay layer to the south, indicate a possible northward flow direction in the intermediate perched aquifer. Production zones of wells that have penetrated to the sea level aquifer are all developed in the Whidbey Formation. Flow direction in the sea level aquifer is not well defined, but may be to the south under the site.

An unused aquifer may be present in the advance outwash immediately above the transition beds. Seeps were observed at this level in the cliffs west of Langley.

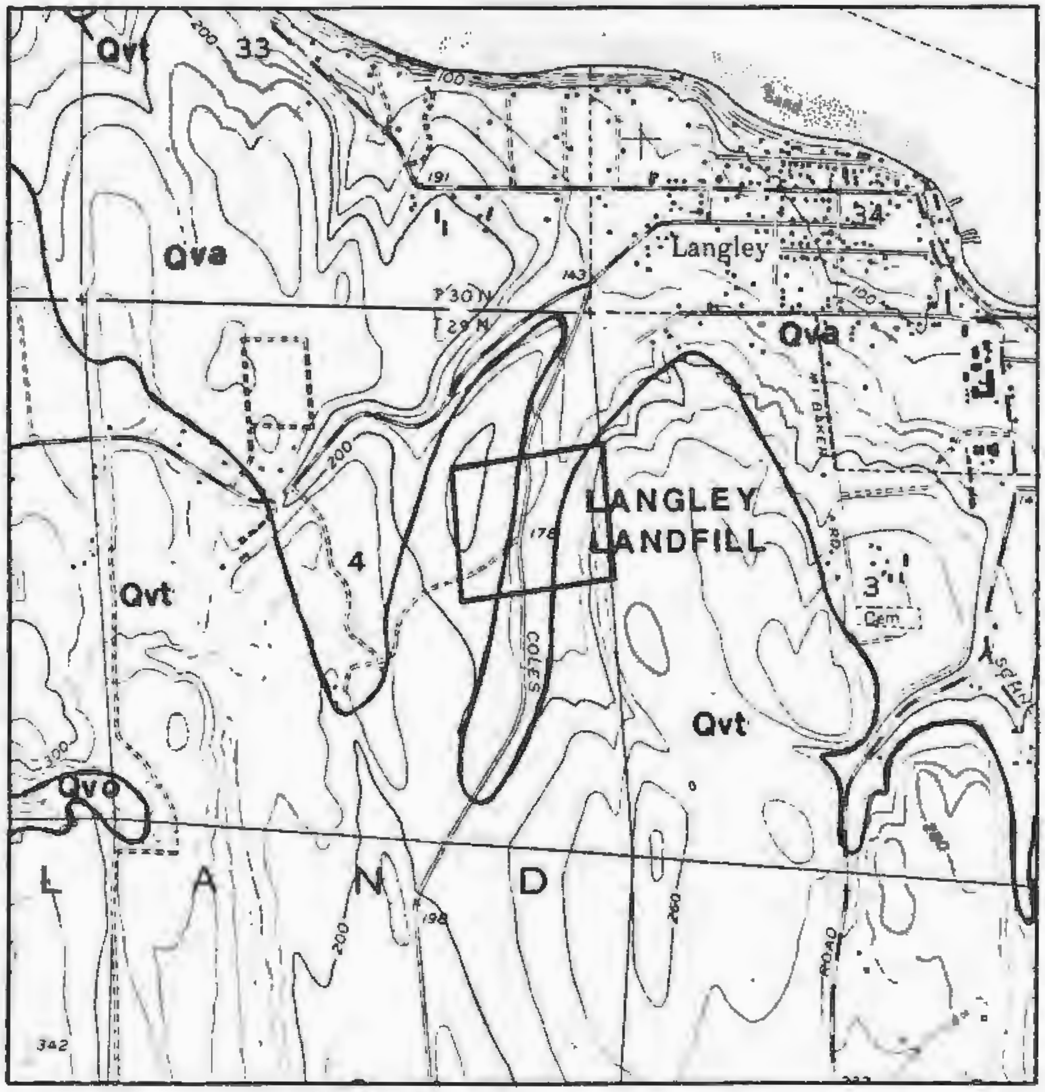
Beneficial Use. Twenty-nine wells have been identified within a mile of the Langley Landfill, refer to Table 19, Well Inventory. At least 16 wells are in current use for domestic purposes. No current data are available on the status of the other 13 wells except that one has been abandoned. Almost two-thirds of the active wells appear to be using ground water from a shallow perched aquifer. The specific capacity of wells in the Langley area increases with decrease in elevation of the producing zone, i.e., the sea level wells have higher specific capacity than the shallow wells.

Water Quality. Limited water quality data are available for wells near Langley Landfill. The only existing data are for the sea level aquifer suggesting generally good ground water quality. Ground water appears to be moderately hard and contains relatively low concentrations of dissolved solids. Elevated concentrations of manganese were also found in ground water at the landfill site and a deep U.S.G.S. test well east of the

TABLE 19
LANGLEY LANDFILL - WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
1	Town of Langley, Well #5	29/3/4H	164	7*	300	---	---	yes	
2	Town of Langley	29/3/3B2	175	10	244	-69 - -48	yes	---	
3	Town of Langley	29/3/B6	175	---	245	-68 - -56	yes	---	not in use
4	Town of Langley	29/3/3B3	155	127	42	113 - 134	yes	---	
5	D.O.E./U.S.G.S.	29/3/3J	180	---	1005	---	yes	yes	U.S.G.S. TH #6
6	Reams	29/3/3Q	215	170*	48	---	yes	---	
7	Pilkington	29/3/10C	230	125*	121	111 - 116	yes	---	
8	Bolgen	29/3/10D	250	183	105	149 - 154	yes	---	
9	Bower-Rivendall	29/3/10D	259	159	134	127 - 132	yes	---	
10	Richard	29/3/9B	200	-20*	260	-59 - -49	yes	---	
11	Baggerly	29/3/4Q	225	8	247	-22 - -11	yes	partial	
12	Inglewood Park	29/3/4K	205	5*	288	-83 - -73	yes	yes	pump test
13	Reeves	29/3/4L	220	---	85	130 - 135	yes	---	
14	Holmes Harbor Rod & Gun Club	29/3/4L	220	---	68	---	---	---	
15	Baker	29/3/4D	230	159*	89	141 - 151	yes	---	
16	Pinewood	29/3/4F	220	176	95	125 - 215	yes	---	
17	Wolff	29/3/4D	260	165*	130	130 - 135	yes	---	
18	Rorex	30/3/33R	200	10*	248	-48 - -38	yes	---	
19	Town of Langley	29/3/3B7	195	---	48	---	---	---	

Note: Site Well Number is used to designate wells on Site Location Map
All elevations are in feet above mean sea level. All measurements are in feet.



Base Map: U.S.G.S. 7½' quad. Langley

EXPLANATION

Qvt .. Vashon Till, glacial silt, clay, gravel, boulders, poorly sorted(well graded), massive, compact, typically resembles concrete in exposures.

Qva .. Vashon Advance Outwash, glacial sand, pebbely, clean, horizontal and cross bedded.

Qvo .. Vashon Meltwater Deposits (undifferentiated), shown where field criteria for differentating between Qva and Qvr are unclear, may include one or both of those units.

Geologic Contact

N

0 2000 4000

Approximate Scale in Feet

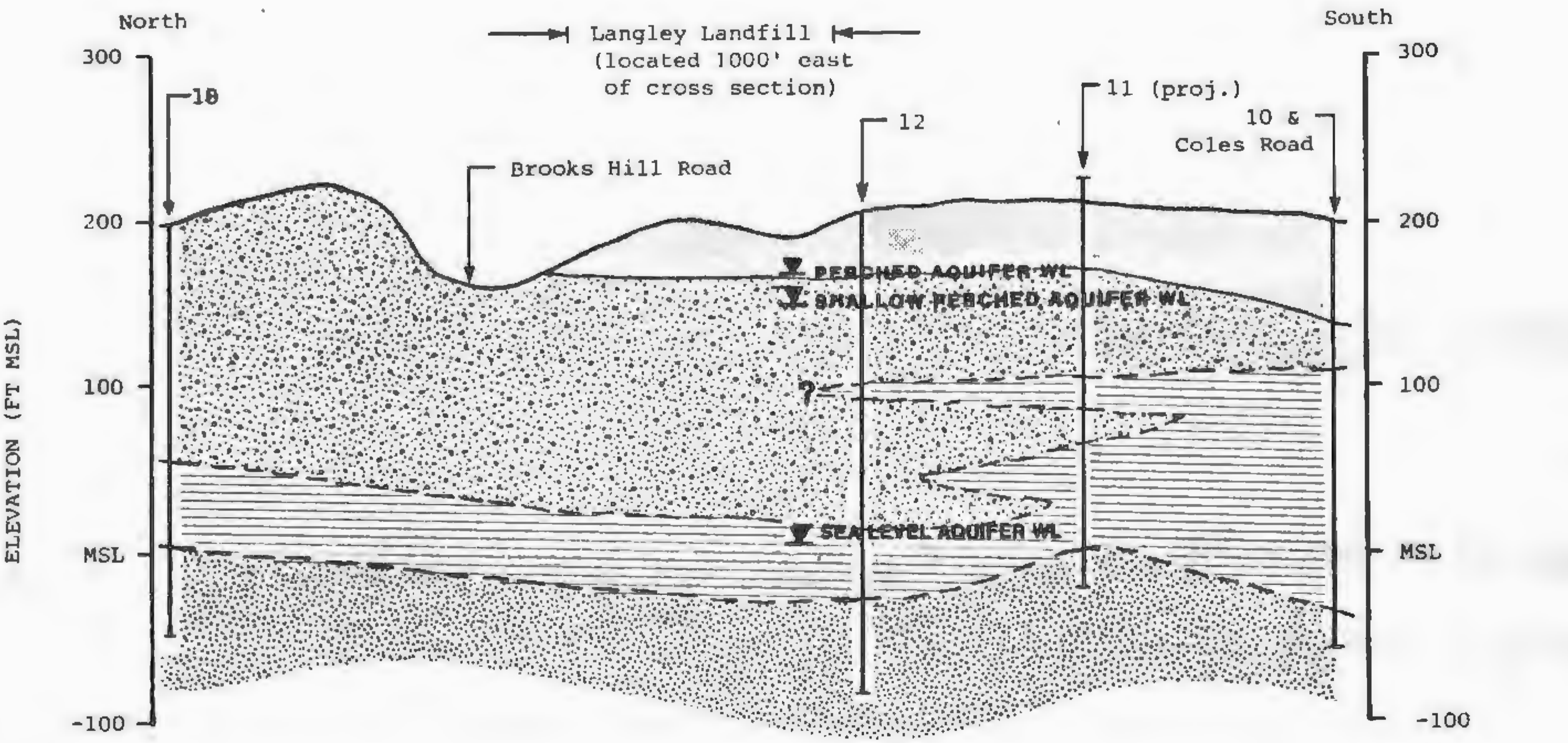
ISLAND COUNTY

Langley Landfill
Surficial Geology

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJM	2-1-85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 43



0 1000 2000
Approximate Scale in Feet
Vertical Exageration 10x

EXPLANATION

Qvt (Till)	
Qva (Sand & Gravel)	
Qtb (Clay & Sand)	
Qw (Sand)	

11 = Well Number
(proj.) = Projectied

Well

ISLAND COUNTY

Langley Landfill

Geologic Cross Section
North-South

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-31-85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 44

landfill. The U.S.G.S. test well (well 5, Figure 41) did not encounter brackish water until depths of 204 to 325 feet below sea level.

Waste Characterization. The Langley site began as a burning dump in a sand pit in 1947 and closed in 1970 (see Figure 42). During operation, the site primarily received domestic and demolition waste. Evidence of some recent illegal dumping was noted during this study including demolition and apparent paint waste.

Leachate Generation. The estimated volume of leachate entering the Langley ground water system annually is 9.89×10^5 gallons (3.03 acre-feet), refer to Table 20, Moisture Balance. About 44 percent of the annual rainfall on the 2.2-acre site infiltrates through the unvegetated sand cover to enter the estimated 60-foot thickness of waste.

Pollution Potential. The Langley Landfill was rated fifth in terms of pollution potential. The site ranked high with respect to depth of ground water (less than 10 feet), but medium to low in all other categories.

Monitoring Strategy. Insufficient data are available to determine the direction of ground water flow at the Langley site. Therefore, Program A includes drilling three 50-foot wells as shown on Figure 42, Site Plan , to determine ground water flow direction and a fourth 150-foot well based on the data from the first three wells. Additional wells may be required to meet DOE MFS. Access problems will require extensive road building. Initial cost for well installation will be about $22,000. In addition, the nearby City of Langley well should be monitored. Sampling and testing should initially cover the DOE-MFS parameters. First-year monitoring will cost about $8,300 and $4,700 annually thereafter.

Program B includes monitoring existing well nos. 1 and 12 (refer to Figure 41, Site Location). Any new wells drilled within 2,000 feet of the site should also be monitored. Monitoring costs for the first year should be approximately $4,700 with $2,200 annually thereafter.

Cultus Bay Landfill

The Cultus Bay Landfill is located on the southern end of Whidbey Island on slopes of a valley draining into Cultus Bay (refer to Figure 45, Site Location Map). Waste has been dumped in a tributary gully between elevations 160 and 210 feet above mean sea level. Access is from Cultus Bay Road along the eastern property boundary.

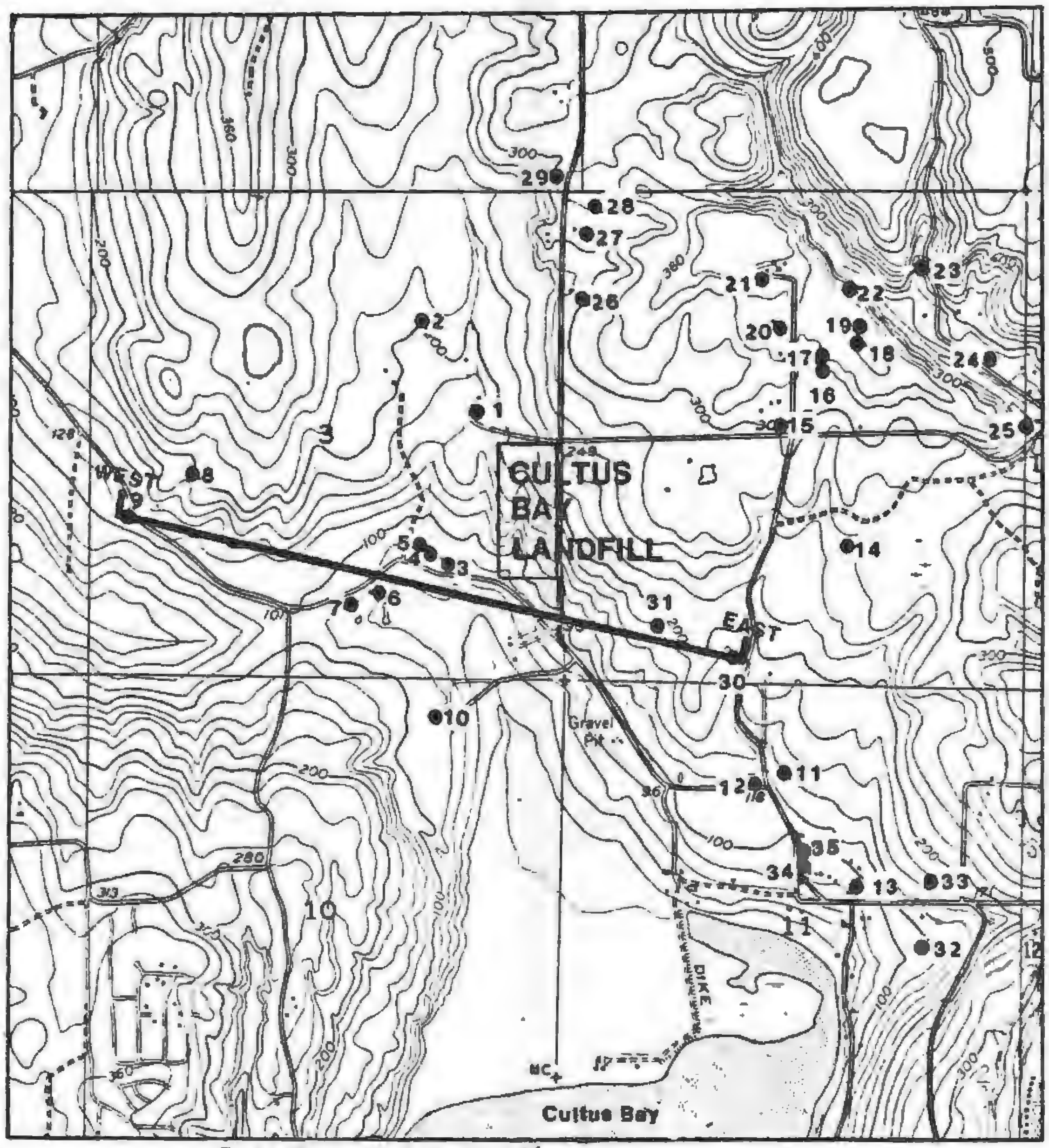
A perennial stream flows through the valley. During winter

TABLE 20

MOISTURE BALANCE FOR LANGLEY LANDFILL

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1.	T	38.6	41.0	44.2	49.0	53.2	57.6	61.0	61.1	56.5	50.9	44.2	41.5	49.9
2.	P	4.8	4.4	3.8	2.8	2.4	2.2	0.8	1.2	1.7	3.6	5.2	4.8	38.0
3.	I	0.62	1.00	1.58	2.62	3.65	4.86	5.88	5.91	4.55	3.08	1.58	1.08	36.23
4.	UPET	0.02	0.03	0.04	0.06	0.07	0.09	0.11	0.11	0.09	0.07	0.04	0.03	
5.	PET	0.45	0.71	1.22	2.05	2.75	3.59	4.42	4.06	2.83	1.95	0.92	0.65	25.6
6.	$C_{R/O}$	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
7.	R/O	0.48	0.44	0.38	0.28	0.24	0.22	0.08	0.12	0.17	0.36	0.52	0.48	3.77
8.	i	4.32	3.96	3.42	2.52	2.16	1.98	0.72	1.08	1.53	3.24	4.68	4.32	
9.	i-PET	3.87	3.25	2.20	0.47	-0.59	-1.61	-3.70	-2.98	-1.30	1.29	3.76	3.67	
10.	APWL	0	0	0	0	-0.59	-2.20	-5.90	-8.88	-10.18	0	0	0	
11.	ST	2.00	2.00	2.00	2.00	1.45	0.62	0.09	0.03	0.03	1.32	2.00	2.00	
12.	^{a}ST	0	0	0	0	-0.55	-0.83	-0.53	-0.06	0	1.29	0.68	0	
13.	AET	0.45	0.71	1.22	2.05	2.71	2.81	1.25	1.14	1.53	1.95	0.92	0.65	17.39
14.	PERC	3.87	3.25	2.20	0.47	0	0	0	0	0	0	3.08	3.67	16.54

SYMBOLS: T = mean air temperature; P = precipitation; I = heat index; UPET = unadjusted potential evapotranspiration; PET = potential evapotranspiration; $C_{R/O}$ = runoff coefficient; R/O = surface runoff; i = infiltration; i-PET = infiltration minus the potential evapotranspiration; APWL = accumulated potential water loss; ST = storage; ^{a}ST = change in soil moisture storage; AET = actual evapotranspiration; PERC = percolation.



Base Map: U.S.G.S. 7½' quad. Maxwelton

EXPLANATION

● 4 Well With Number

WEST EAST Cross Section Location

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

Cultus Bay Landfill

Site Location Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJm	1-28-85
CHECKED BY	JEE	3/14/85
REVISED		

Figure 45

a stream also flows down what remains of the gully partly filled by the waste. Another intermittent stream flows across the southeast part of the property. This is the only site in the county with nearby surface runoff. This runoff is the result of the greater rainfall in the area and the geology.

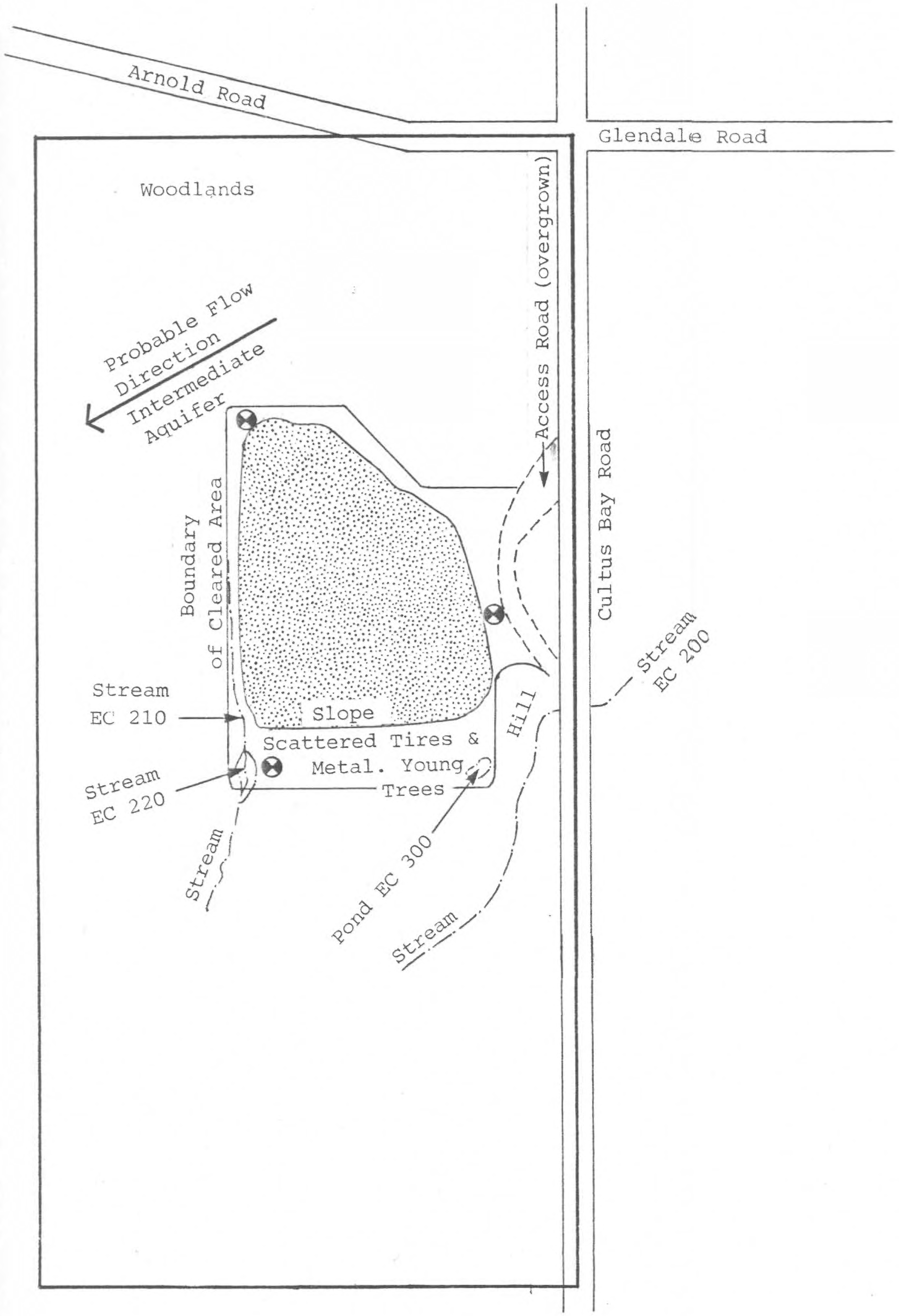
Less than a quarter of the rectangular shaped property is occupied by the now closed landfill (see Figure 46). Undercut banks on the northern and eastern sides of the waste mound indicate earth moving has taken place though it is unclear how much the natural land surface has been altered prior to placement of the wastes. The surface of the waste mound is flat lying and well covered with sandy till brought from a pit southeast of the site. Grasses, blackberries, and other shrubs and saplings are growing on this surface and on the steep southern slope. Below the waste mound, young trees are well established though old tires and metal objects are scattered amongst them.

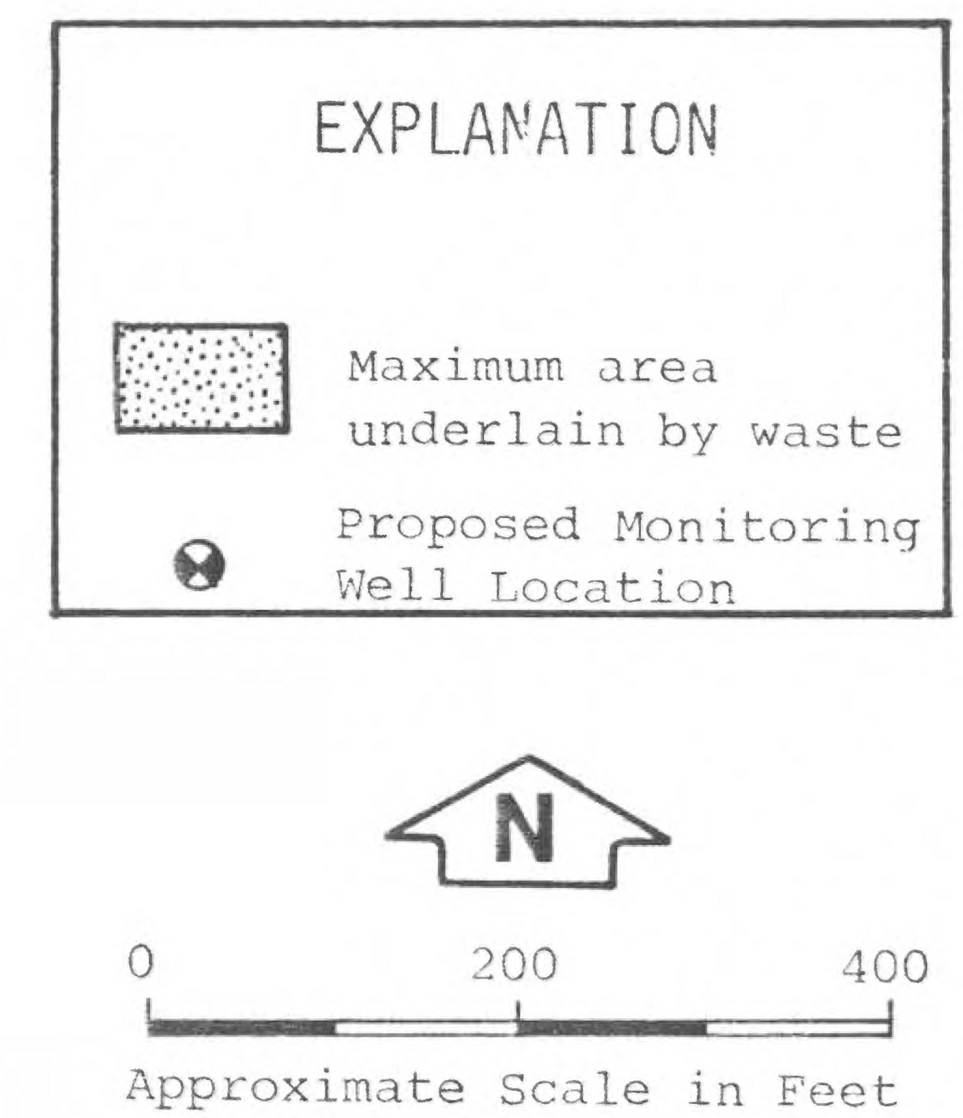
Climate. The nearest station reporting rainfall data is at Langley. Precipitation is about 38 inches per year. The nearest applicable temperature data are for Coupeville and average 40°F in the winter and 60°F in the summer with an annual mean of 50°F.

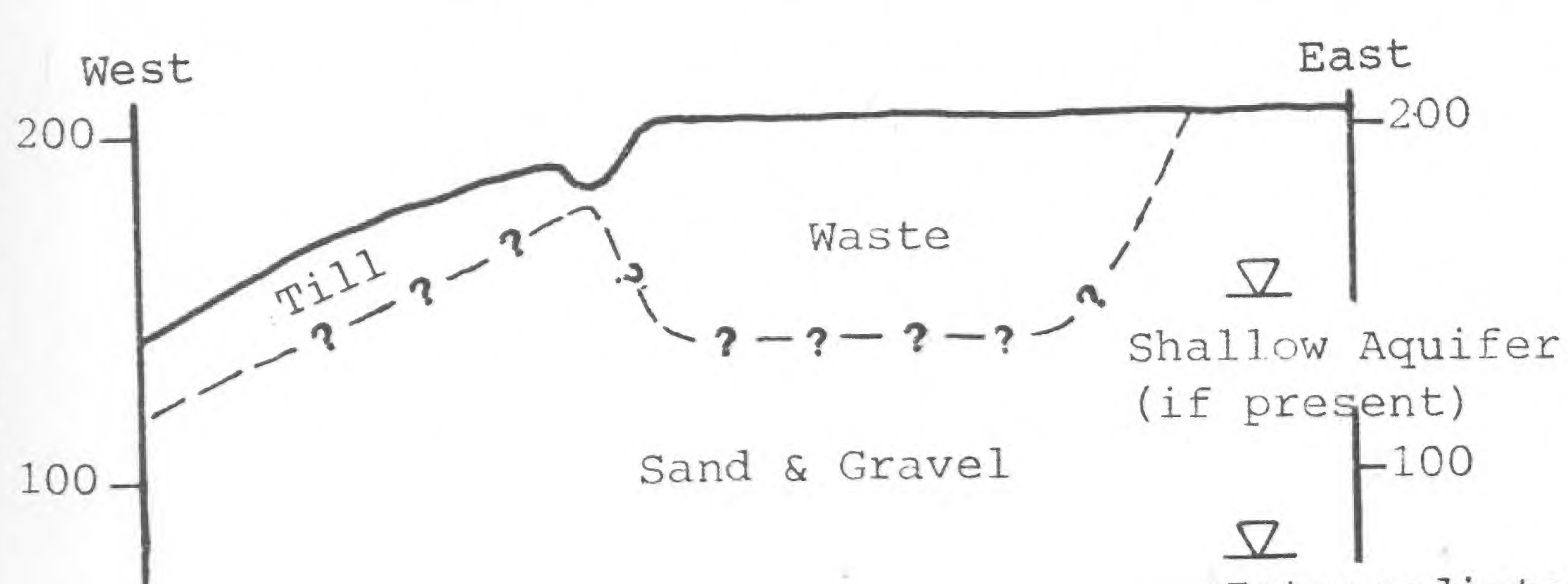
Geology. The Cultus Bay Landfill is located in an area of thin or absent till cover (see Figure 47, Surficial Geology Map). Till was identified in a bank immediately southwest of the waste area but the banks on the southeast and east side are advance outwash. The till is sandy and was used to cover the waste. Advance outwash appears to underlie the area surrounding the landfill.

The pre-Vashon geology is poorly understood in this area due to the lack of outcrop and inadequate subsurface information. Sandy clay or clay is described in the well logs below the advance outwash and may belong to the transition beds (refer to Figure 48, Geologic Cross Section). The deepest well log indicate a clay thickness in excess of 175 feet which is uncharacteristic of the transition beds.

Hydrogeology. Definition of the ground water system of the Cultus Bay Landfill area is complicated by the uncertain geology and variation of piezometric levels amongst the limited number of wells. Four different piezometric levels have been identified, two north of the site and two south of the site. This implies that four different aquifers may be present. The uppermost one (elevation 300 feet) is to the north and perched above or in the till. It is unclear whether the second aquifer in this north area is within or below the advance outwash. Flow in both northern aquifers appears to be to the southwest. Due to the lack of a well-defined till unit at the site, the uppermost perched aquifer is probably not present beneath the site.







Schematic Cross Section

ISLAND COUNTY

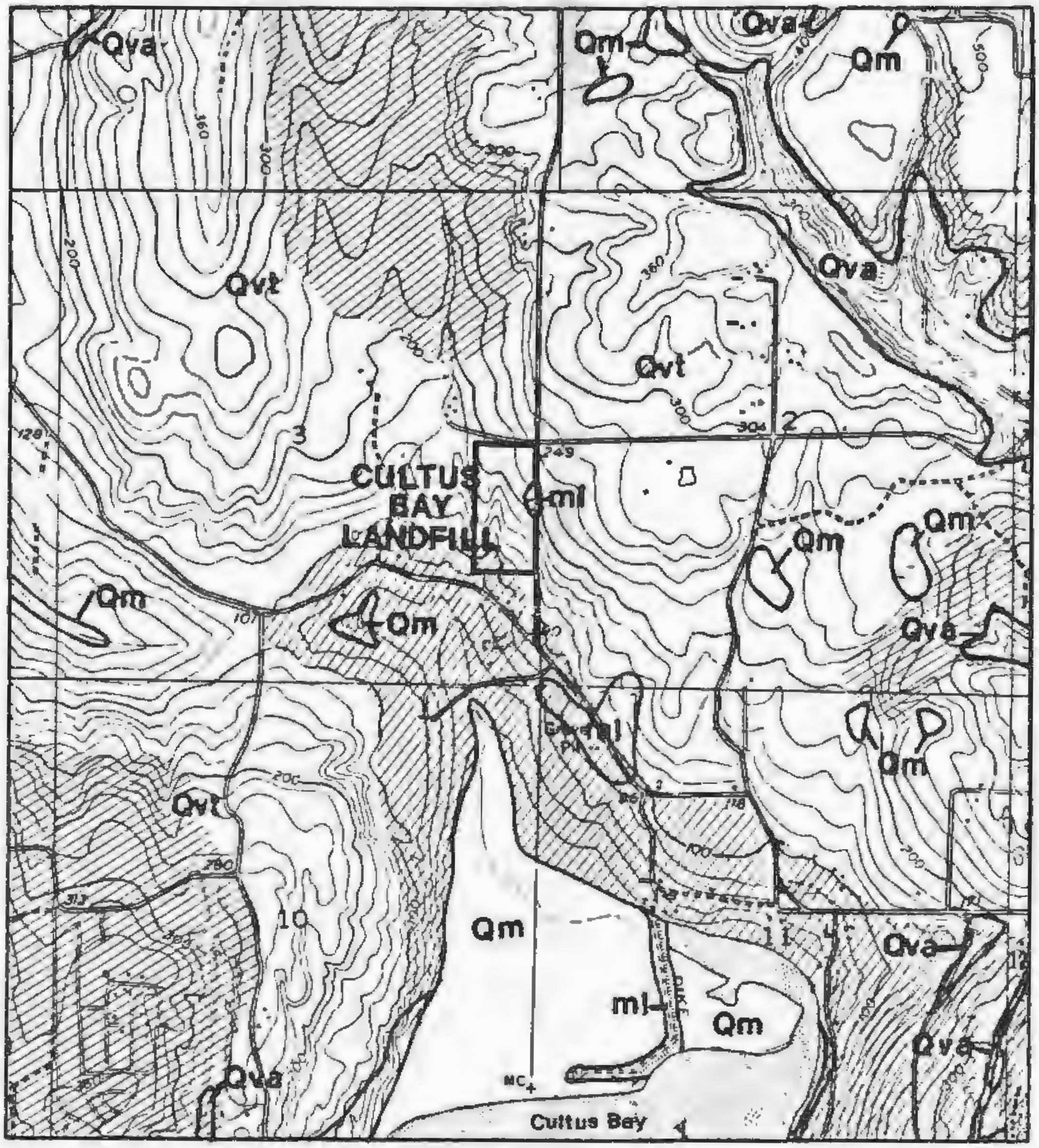
Cultus Bay Landfill

Site Map

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJM	1/28/85
CHECKED BY	JEE	3/14/85
REVISED	mmm	12/3/85

Figure 46



Base Map: U.S.G.S. 7½' quad. Maxwelton
Geology After: Preliminary Geologic Map of Maxwelton Quad.

EXPLANATION

Areas of thin or absent till

ml .. Modified Land, dredge spoils, fill, and other materials placed by man.

Qm .. Marsh, Bog, Swamp Deposits, silt, clay, sand with organics including peat.

Qvt .. Vashon Till, glacial silt, sand, clay, gravel, boulders, poorly sorted (well graded), massive, compact, typically resembles concrete in exposures.

Qva .. Vashon Advance Outwash, glacial sand, pebbley, clean, horizontal and cross bedded.

Geologic Contact

N

0 2000 4000
Approximate Scale in Feet

ISLAND COUNTY

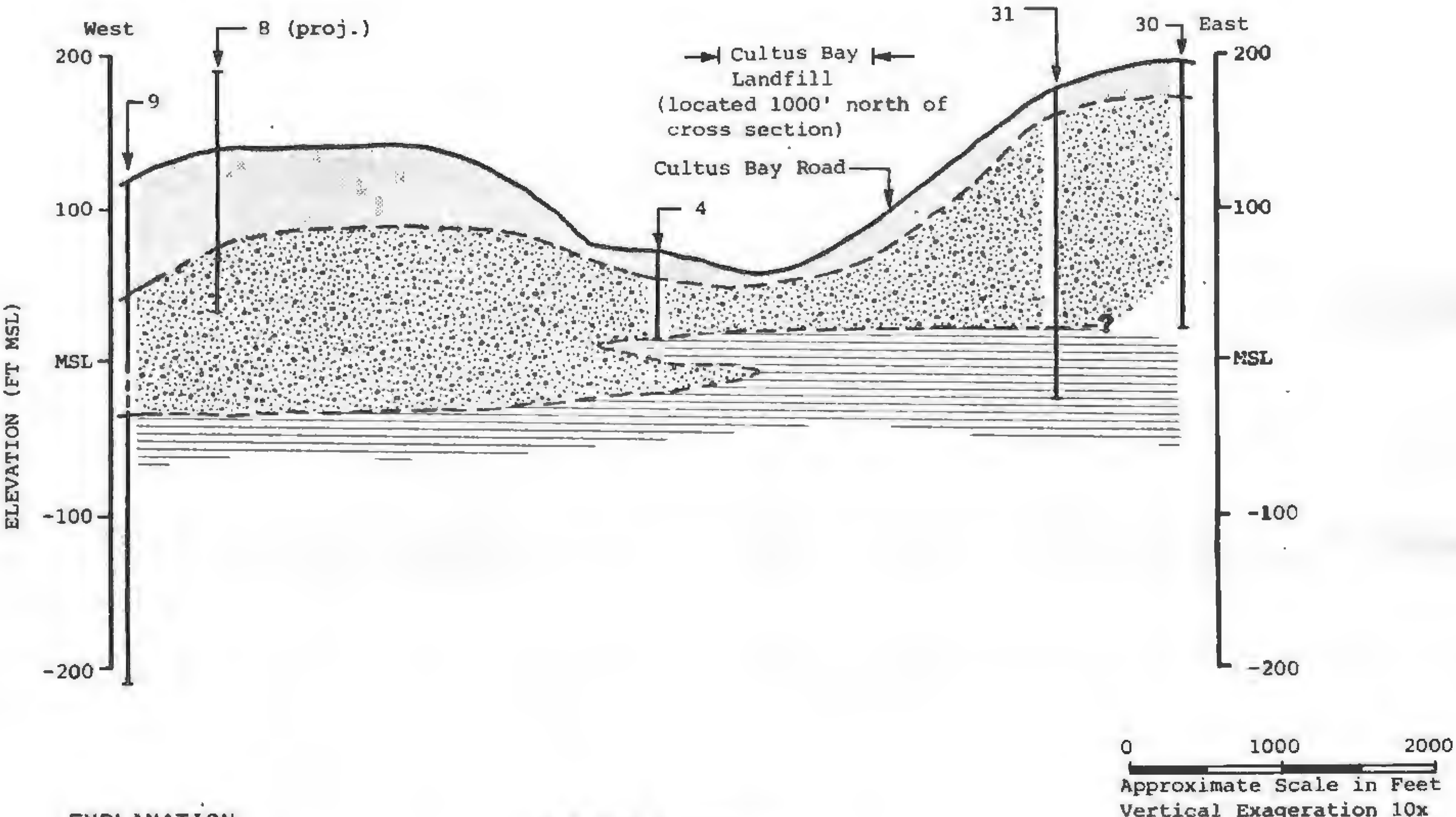
Cultus Bay Landfill

Surficial Geology

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG/SJM	2-1-85
CHECKED BY	JEE	3/19/85
REVISED		

Figure 47



EXPLANATION

Qvt (Till)

Qva (Sand & Gravel)

Qtb (Clay)

8 = Well Number
(proj.) = Projected

Well

ISLAND COUNTY

Cultus Bay Landfill

Geologic Cross Section
West-East

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-31-85
CHECKED BY	JEE	3/19/85
REVISED		

Figure 48

Piezometric levels of 25 to 50 feet above sea level and 50 to 75 feet above sea level define the two aquifers which have been identified south and east of the site. The upper (elevation 50 to 75 feet) aquifer appears to be in the base of the advance outwash. It is the most heavily used aquifer in the area. The lowest (elevation 25 to 50 feet) aquifer occurs in the sand layers found within the Whidbey Formation clay.

It is possible that the piezometric levels define different parts of the same aquifer, but it is not possible to determine this with the available subsurface information. Flow in the elevation 50 to 75 feet aquifer is to the southwest under the site. Data are sufficient to draw a water level map only for this aquifer (see Figure 49).

Beneficial Use. A total of 32 wells (mostly domestic) are located within a mile of the Cultus Bay Landfill, refer to Table 21, Well Inventory. Four wells outside the one-mile radius near Cultus Bay were added to the inventory from WSB25 to aid definition of the ground water system.

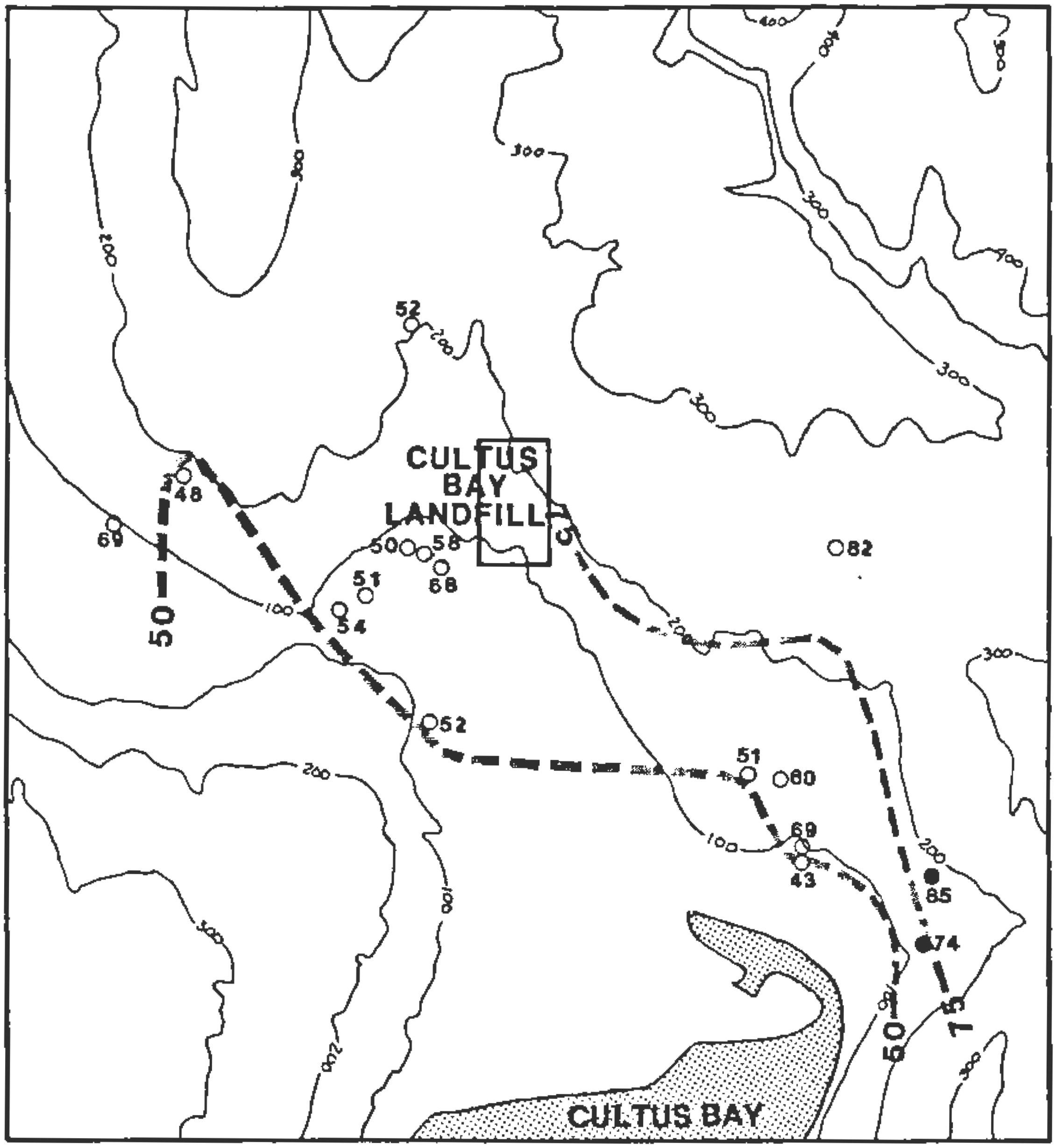
Existing well log data suggest that approximately three quarters of these wells are using ground water from the deep sea level aquifer. The remaining wells are probably obtaining water from the perched and shallow aquifers. Analysis of well data conducted for WSB25 shows that average yield and specific capacity of wells in this area increase with increasing depth.

Water Quality. No known water quality data exists for the 36 wells inventoried around the Cultus Bay Landfill.

Waste Characterization. The Cultus Bay site received waste from 1958 to 1978 (see Figure 46). The apparent small volume of waste indicates that the site was operated as a burning dump for much of this period. Both domestic and demolition wastes were disposed at the site.

Leachate Generation. The annual volume of leachate entering the ground water system at Cultus Bay is estimated to be 8.66×10^5 gallons (2.66 acre-feet), refer to Table 22, Moisture Balance. About 33 percent of the annual incident precipitation on the 2.5-acre site infiltrates through the vegetated sand-gravel cover and enters the refuse pile. An average 60-foot section of refuse was estimated for calculation at this site.

Pollution Potential. The Cultus Bay Landfill site was rated seventh out of the nine sites, only slightly higher than Hastie Lake. Although beneficial use and discharge ranked moderate, the age and type of facility (closed, burning dump, and the type of waste ranked low, along with the depth to ground water (greater than 50 feet). It is important to note, however, that the hydrogeology in the area is very complex and little data are available.



Base Map: U.S.G.S. 7.5' quad. Maxwelton

EXPLANATION

—100— Elevation Contour (Ft MSL)

60○ Well with old or reported water level measurement

74● Well with recent water level measurement

50— Water level elevation

N

0 2000 4000

Approximate Scale in Feet

ISLAND COUNTY

Cultus Bay Landfill

Water Level Elevation Map
Shallow Aquifer

Sweet, Edwards & Associates

	INITIALS	DATE
DRAWN BY	JLG	1-29-85
CHECKED BY	JEE	3/14/85

Figure 49

TABLE 21

CULTUS BAY LANDFILL - WELL INVENTORY

Site Well #	Owner/Name	Location T/R/S	Ground Elev.(ft)	Water Level Elevation (*old/reported)	Total Well Depth	Productive Zone Elevation	Litho. Log Avail.	Wtr Qualty Data Available	Comments
1	Arnold	28/3/3H	171	165*	13	---	---	---	
2	White	28/3/3G	200	52*	177	---	---	---	
3	Alder	28/3/3K	75	68*	10	---	---	---	
4	Simons	28/3/3K	80	58*	54	25 - 30	yes	---	
5	Dolman	28/3/3K	80	50*	52	28 - 33	yes	---	
6	Turner	28/3/3Q	60	51*	34	30 - 34	yes	---	
7	Silverman	28/3/3Q	80	54*	88	-8 - 2	yes	---	
8	Iverson	28/3/3M	180	48*	155	29 - 34	yes	---	
9	Davis	28/3/3M	110	69*	329	-44 - -24	yes	---	
10	Gould	28/3/10B	89	52*	42	---	---	---	
11	Bailey's Corner	28/3/11C	124	60*	96	---	yes	---	
12	Johnson	28/3/11C	118	51*	81	37 - 43	yes	---	
13	Douglass	28/3/11G	95	23*	94	4 - 9	yes	---	
14	Veit	28/3/21C	260	82	212	48 - 52	yes	---	
15	Lyle Dexter	28/3/2F	310	--	--	---	---	---	
16	Wickum	28/3/2G	320	280*	68	262 - 267	yes	---	
17	Wesley Dexter	28/3/2G	325	--	--	---	---	---	
18	Standley	28/3/2G	340	292	64	276 - 281	yes	---	
19	Doly	28/3/2G	340	284	65	273 - 278	yes	---	
20	Butcher	28/3/3F	350	310*	77	274 - 279	yes	---	
21	Gibson	28/3/2C	359	293*	79	---	---	---	
22	Braun	28/3/2B	320	159*	186	129 - 134	yes	---	
23	Partin	28/3/2A	300	140*	200	100 - 105	yes	---	
24	W.E. Johnson	28/3/2H	280	279*	9	---	---	---	
25	Byjnowski	28/3/2H	240	--	60	183 - 188	yes	---	
26	Surface	28/3/2D	285	282*	10	---	---	---	iron
27	Poolman	28/3/2D	305	297*	14	---	---	---	
28	Patterson	28/3/2D	320	192*	181	139 - 143	yes	---	
29	Darvo	29/3/34R	325	301*	30	---	yes	---	
30	Grey	28/3/2P	180	35	175	5 - 15	yes	---	
31	Westby	28/3/2N	191	59	206	---	yes	---	
32	Roberts	28/3/11J	110	74*	45	---	yes	---	
33	Brockman	28/3/11H	179	85*	112	67 - 77	yes	---	
34	Kamback	28/3/11G	85	43*	73	---	---	---	
35	Bryant	28/3/11G	100	69*	80	---	---	---	

Note: Site Well Number is used to designate wells on Site Location Map
All elevations are in feet above mean sea level. All measurements are in feet.

TABLE 22

MOISTURE BALANCE FOR CULTUS BAY LANDFILL

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1.	T	38.6	41.0	44.2	49.0	53.2	57.6	61.0	61.1	56.5	50.9	44.2	41.5	49.9
2.	P	4.8	4.4	3.8	2.8	2.4	2.2	0.8	1.2	1.7	3.6	5.2	4.8	38.0
3.	I	0.62	1.00	1.58	2.62	3.65	4.86	5.88	5.91	4.55	3.08	1.58	1.08	36.23
4.	UPET	0.02	0.03	0.04	0.06	0.07	0.09	0.11	0.11	0.09	0.07	0.04	0.03	
5.	PET	0.45	0.71	1.22	2.05	2.75	3.59	4.42	4.06	2.83	1.95	0.92	0.65	25.6
6.	$C_{R/O}$	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
7.	R/O	0.48	0.44	0.38	0.28	0.24	0.22	0.08	0.12	0.17	0.36	0.52	0.48	3.77
8.	i	4.32	3.96	3.42	2.52	2.16	1.98	0.72	1.08	1.53	3.24	4.68	4.32	
9.	i-PET	3.87	3.25	2.20	0.47	-0.59	-1.61	-3.70	-2.98	-1.30	1.29	3.76	3.67	
10.	APWL	0	0	0	0	-0.59	-2.20	-5.90	-8.88	-10.08	0	0	0	
11.	ST	8.00	8.00	8.00	8.00	7.43	6.21	3.82	2.65	2.24	3.53	7.29	8.00	
12.	³ST	0	0	0	0	-0.57	-1.22	-2.39	-1.17	-0.41	1.29	3.70	0.71	
13.	AET	0.45	0.71	1.22	2.05	2.73	3.2	3.11	2.25	1.94	1.95	0.92	0.65	21.18
14.	PERC	3.87	3.25	2.20	0.47	0	0	0	0	0	0	0	2.96	12.75

SYMBOLS: T = mean air temperature; P = precipitation; I = heat index; UPET = unadjusted potential evapotranspiration; PET = potential evapotranspiration; $C_{R/O}$ = runoff coefficient; R/O = surface runoff; i = infiltration; i-PET = infiltration minus the potential evapotranspiration; APWL = accumulated potential water loss; ST = storage; ³ST = change in soil moisture storage; AET = actual evapotranspiration; PERC = percolation.

Monitoring Strategy. The hydrogeology in the vicinity of the Cultus Bay Landfill is very complex and insufficient data are available to develop or recommend a comprehensive monitoring program. We recommend that a site characterization including three double completion wells, 150 feet deep, be performed prior to developing a monitoring program. Well installation would cost about $34,000. Sampling and testing of the three double completion wells should be performed for the DOE-MFS parameters as part of the site characterization. Based on the data obtained a comprehensive monitoring program can be developed.

A monitoring program employing existing wells would have to include at least ten wells and the results would probably be inconclusive.