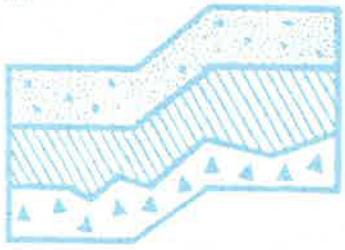
GEOTECHNICAL REPORT

Proposed Detention Pond W2
Gleneagle Development
Arlington, Washington

Project No. T-1775-8-3



Terra Associates, Inc.

Prepared for:

Woodland Ridge Joint Venture
Arlington, Washington

September 12, 1995

TERRA ASSOCIATES, Inc.
Consultants in Geotechnical Engineering, Geology
and
Environmental Earth Sciences

September 12, 1995
Project No. T-1775-8-3

Mr. Randy Wood
Woodland Ridge Joint Venture
7619 Country Club Drive, Suite A
Arlington, Washington 98223

Subject: Geotechnical Report
Proposed Detention Pond W2
Gleneagle Development
Arlington, Washington

Dear Mr. Wood:

As requested, we have conducted a geotechnical engineering study for the subject project. The attached report presents our findings and recommendations for the geotechnical aspects of project design and construction.

Our field exploration indicates the site is generally underlain by glacially-derived soils consisting of silty sand, sand, and silt. These materials are generally stable with respect to cutslopes constructed for detention facilities. In addition, our field exploration and laboratory test results indicate some of these glacial soils will generally be suitable for use as fill material to construct the pond's northern and western containment berms.

The test pits revealed a zone of groundwater occurring primarily at the northeastern portion of the site within sand and silty sand. The proposed pond excavation will likely expose cutfaces of this saturated soil. We recommend that you construct an interceptor drain that extends into the impermeable soil beneath the groundwater zone. This will reduce the potential for progressive failure of the cutslope due to uncontrolled seepage.

In summary, the soil conditions at the site are suitable for construction of the detention pond as proposed, provided the recommendations presented in this report are incorporated into project design and construction.

12525 Willows Road, Suite 101, Kirkland, Washington 98034 • **Phone (206) 821-7777**

We appreciate the opportunity to be of service to you during the design phase of this project and look forward to working with you during the construction phase. We trust the information presented in this report is sufficient for your current needs. If you have any questions or need additional information, please call.

Sincerely yours,

TERRA ASSOCIATES, INC.

Kevin P. Roberts, P.E.
Project Engineer

9-12-95

Theodore J. Schepper, P.E.
Principal Engineer

KPR/TS:tm

cc: Ms. Jennifer Steig, P.E., Higa Engineering, Inc.

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Gleneagle Development
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1.0 PROJECT DESCRIPTION

The project will consist of the construction of a new stormwater detention pond at the Gleneagle development in Arlington, Washington. The approximate location of the project site is shown on the Vicinity Map, Figure 1.

Higa Engineering, Inc. provided us with preliminary project plans consisting of Sheets 1 and 2 dated August 3, 1995 and Sheet 3 dated August 8, 1995. The plans indicate the project will include the construction of an approximately 480-foot long, 70-foot wide (measured at the two year MWS Elev. 148.5) detention pond at an area adjacent to and southeast of the site's existing gravel road. A new gravel road will be constructed on the top of the pond's northwestern containment berm at a maximum elevation of 155.5. This road will extend north of the proposed pond and turn eastward to bound the northern edge of a wetland area.

The pond bottom and invert of the 15-inch diameter outlet pipe will be at Elev. 147.0. The 100 year mean water surface elevation, and rim elevation of the southwest overflow structure are each at Elev. 154.5. Impounded water elevations higher than the ten year mean water surface elevation of 150.4 will flow northward out of the pond into a wetland area.

The lower portion of the pond's southeastern cutslopes will be excavated to a grade of 3:1 (Horizontal:Vertical). Slopes at this grade will extend from the pond's bottom to Elev. 156.0. At this elevation, the cutface will steepen to a grade of 2:1 to a maximum elevation of 190.0. An 8.5-foot high (maximum) cut and fill embankment will be constructed as the pond's western and northwestern containment structures. The inboard and outboard cut and fill embankment slopes will each be graded to a 3:1 angle.

2.0 SCOPE OF WORK

We conducted a surface reconnaissance and excavated eight backhoe test pits in the vicinity of the proposed detention pond on August 21, 1995. We developed geotechnical recommendations for project design and construction using the information obtained from the field exploration and laboratory testing program. Specifically, this report addresses the following:

- Evaluation of the soil types encountered within the proposed cutslope areas
- Criteria for site preparation, grading, and fill placement
- Infiltration potential of native soils
- Sidewall stability of proposed cuts
- Control of groundwater seepage from the cutslopes

3.0 SITE CONDITIONS

3.1 Surface

The project area is located east of and near the intersection of Woodlands Way and 67th Avenue NE in Arlington, Washington. The project site is bounded on the southeast and east by undeveloped property. An existing gravel road and Woodlands Way bound the site on the northwest and west, respectively.

During our visit to the site on August 21, 1995, we observed several inches of water within a 10 to 15-foot wide shallow ditch running parallel to the site's existing gravel road. The water was draining from north of the site southwestward toward an existing 15 inch drain pipe near Woodlands Way. Curbs and gutters along Woodlands Way direct stormwater from the road to catch basins.

We noted a spring within a shallow swale near the northern perimeter of the proposed pond. A small amount of water flowed from the spring northward to the shallow ditch adjacent to the gravel road. No other springs, seeps, or obvious surface water drainage features were observed in the hillside area.

Most of the site consists of ground sloping to the northwest at grades ranging from nearly flat near Woodlands Way to a maximum of about 1:1 in the vicinity of Test Pit TP-6. These steep slopes are generally no higher than about ten feet. A series of previously graded roads (likely logging roads) criss-cross the site forming localized breaks in the topography. The area northwest of the existing gravel road is relatively flat. We also observed small piles of fill and concrete debris north of the existing gravel road.

At the time of our visit, vegetation within the hillside area consisted of mature alder and conifers, with sparse fern and berry brambles comprising the understory. Grasses and isolated young trees were growing in the area north of the gravel road.

3.2 Soils

The soils at the site as noted in the test pits generally consist of glacially-derived silty sands and sands overlying very dense glacial till or hard silt. Clean, poorly-graded sand and gravelly sand are present at the flat area north of the existing gravel road.

The southern portion of the pond area (vicinity of Test Pits TP-1 and TP-2) showed a thin layer of topsoil or duff overlying tan to brown-gray, medium dense to dense silty sand or very stiff sandy silt to depths of approximately seven to nine feet. These soils were underlain by glacial till consisting of very dense silty sand.

In the northern pond area, we observed brown, medium dense to dense silty sand with gravel and cobbles overlying dense, blue-gray silty sand and sand at the higher elevations. We observed hard, gray to light brown, sandy silt underlying the brown silty sand and blue-gray sand at depths ranging between 8 and 14 feet.

Test Pits TP-7 and TP-8, located north of the gravel road, showed medium-grained sand that was brown and dense. This soil graded to brown-gray gravelly sand that was coarse-grained and dense.

The *Geologic Map of the Arlington West 7.5 Minute Quadrangle, Snohomish County, Washington* by James P. Minard dated 1985 shows the site as being located near the geologic contact between the Vashon Till and Marysville Sand Member. The dense to very dense silty sand with gravel encountered at the site correlates with the published description of the glacial till. The sand observed in Test Pits TP-7 and TP-8 correlates with the description given for the Marysville Sand Member.

Figures A-2 through A-5 present more detailed descriptions of the subsurface conditions encountered in the test pits. The approximate locations of the test pits are shown on Figure 2.

3.3 Groundwater

Groundwater was observed in Test Pits TP-3 through TP-6, and Test Pit TP-8 at depths ranging between 7 and 14 feet. Test Pit TP-8, located in the flat area north of the existing gravel road, showed groundwater within gravelly sand at a depth of 9.5 feet.

The occurrence of groundwater appears to generally be within the northern half of the site. In this area, we noted an approximately two to four-foot thick zone of waterbearing sand perched on the underlying hard silt. Please note that the subsurface observations were made during the dry season. The areal extent, as well as elevations of groundwater at the site, are expected to increase during the rainy season. Evidence of fluctuating groundwater elevations is given by mottling of some of the on-site soils.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 General

Based on our study, in our opinion, there are no geotechnical constraints that would preclude construction of the proposed detention facility. The site is primarily underlain by competent glacially-derived soils. Significant geotechnical features at the site are as follows:

- Excavation of the southwestern portion of the pond will likely expose dense to very dense, relatively impermeable glacial till soils. These soils are inherently stable and are characterized by low permeability and infiltration potential.
- The proposed pond cutslopes in the vicinity of Test Pits TP-3 through TP-6 will mostly expose medium dense to dense, brown and blue-gray silty sand. Some portions of the excavation may be close to or within the hard impermeable silt. It appears the proposed pond sides will expose saturated horizons of the blue-gray sand. As with the till soils, these soils should not present a stability problem with the pond construction, provided drainage is installed to reroute groundwater to a suitable outlet.
- The dense poorly-graded sand encountered in Test Pits TP-7 and TP-8 will provide suitable bearing support for the proposed berm and new gravel road construction.

- We anticipate much of the brown silty sand at the site will contain enough fines to be suitable for berm construction. The tan or gray sandy silt will prove difficult to compact properly due to a high percentage of fines and sensitivity to moisture conditions. The fines content of the berm fill will make construction of the berm during wet weather difficult. Recommendations for construction of the berm are given below.

4.2 Site Preparation and Grading

Before starting grading operations in the area of the proposed berm, vegetation and/or organic soil should be stripped to expose suitable medium dense to dense native soils. Based on our subsurface investigation, stripping depths in the area of the berm will be about eight inches at its west end, and between 8 and 18 inches along the north edge of the pond. These organic soils and soils that contain vegetation and root debris should not be used in construction of the proposed berm. Stripped vegetation should be removed from the site or used on-site in non-structural areas.

Following stripping, we recommend that the exposed subgrade be proofrolled prior to placement of the berm fill. Excessively soft and yielding areas, if of a large extent, should be removed and replaced with compacted embankment fill as discussed below.

4.3 Berm Construction

We recommend that the embankment material consist of soil that contains at least 20 percent (by weight) fines. The soil should not contain material that is cobble or boulder size (greater than six inches). Much of the native silty sand encountered at the site is expected to conform to this recommendation.

Our laboratory results indicate that some of the on-site light brown and blue-gray sand, or blue-gray silty sand, may not contain enough fines to be used by themselves as berm fill. If a shortage of suitable silty sand occurs, it may be possible to mix some of the light brown or gray sandy silt with the sand to increase the fines content and decrease permeability.

The berm fill should be placed in uniform loose layers not exceeding 12 inches in thickness. We recommend that the layers be mechanically compacted to a minimum of 95 percent of the soil's maximum dry density as determined by ASTM Test Designation D-698 (Standard Proctor). The moisture content of the soil at the time of compaction should be in the range of ±2 percent of its optimum as determined by this same standard.

4.4 Native Soil Infiltration Potential

Review of the proposed cutslope grades and the results of our field investigation show that the pond's bottom as well as its southern uphill slopes will be near or within relatively impermeable glacial till or hard silt. The coefficient of permeability value, k, of these soils is typically less than 1×10^{-6} cm/sec. Based on these results, we do not expect significant infiltration loss of impounded stormwater.

4.5 Cutslope Stability

The results of our subsurface study and data review indicate the southern cutslopes of the pond will likely extend into layers of saturated, cohesionless sands. Without proper drainage, a progressive sloughing failure of the weakened, saturated sands could be expected. This type of progressive failure could eventually compromise the stability of larger sections of the slope. Recommendations for drainage construction are presented in the Cutslope Drainage section of this report.

In our opinion, the proposed pond cutslope grades of 2:1 and 3:1 shown on the plans will be stable with respect to deep-seated failure and shallow surficial sloughing. This conclusion is based on the implementation of drainage in accordance with our geotechnical recommendations. We recommend that all finished slope faces be thoroughly compacted and vegetated to guard against erosion.

4.6 Cutslope Drainage

Groundwater presently flows from the site's higher elevations along the impermeable silt layer identified during our field investigation. In order to reduce the potential for instability of the pond's cutslope face due to uncontrolled seepage, an interceptor drain should be installed that collects groundwater and takes it to a suitable discharge point.

We recommend that the interceptor drain extend along the southeastern cutslope face in line with the planned finished contour Elev. 170. This recommended alignment is shown on Figure 2, Exploration Location Plan. The interceptor drain should extend into the impermeable silt stratum as identified at Test Pits TP-4 and TP-5. Based on soil information obtained the drain pipe invert should be planned at a maximum elevation of 165. We recommend using four-inch diameter slotted or perforated ABS drain pipe. The pipe should be bedded in washed one inch minus gravel and wrapped with filter fabric such as Mirafi 140N or equal. A typical detail for the interceptor drain is shown on Figure 3. Groundwater collected by the drain can be taken by tightline to discharge at the pond bottom.

5.0 ADDITIONAL SERVICES

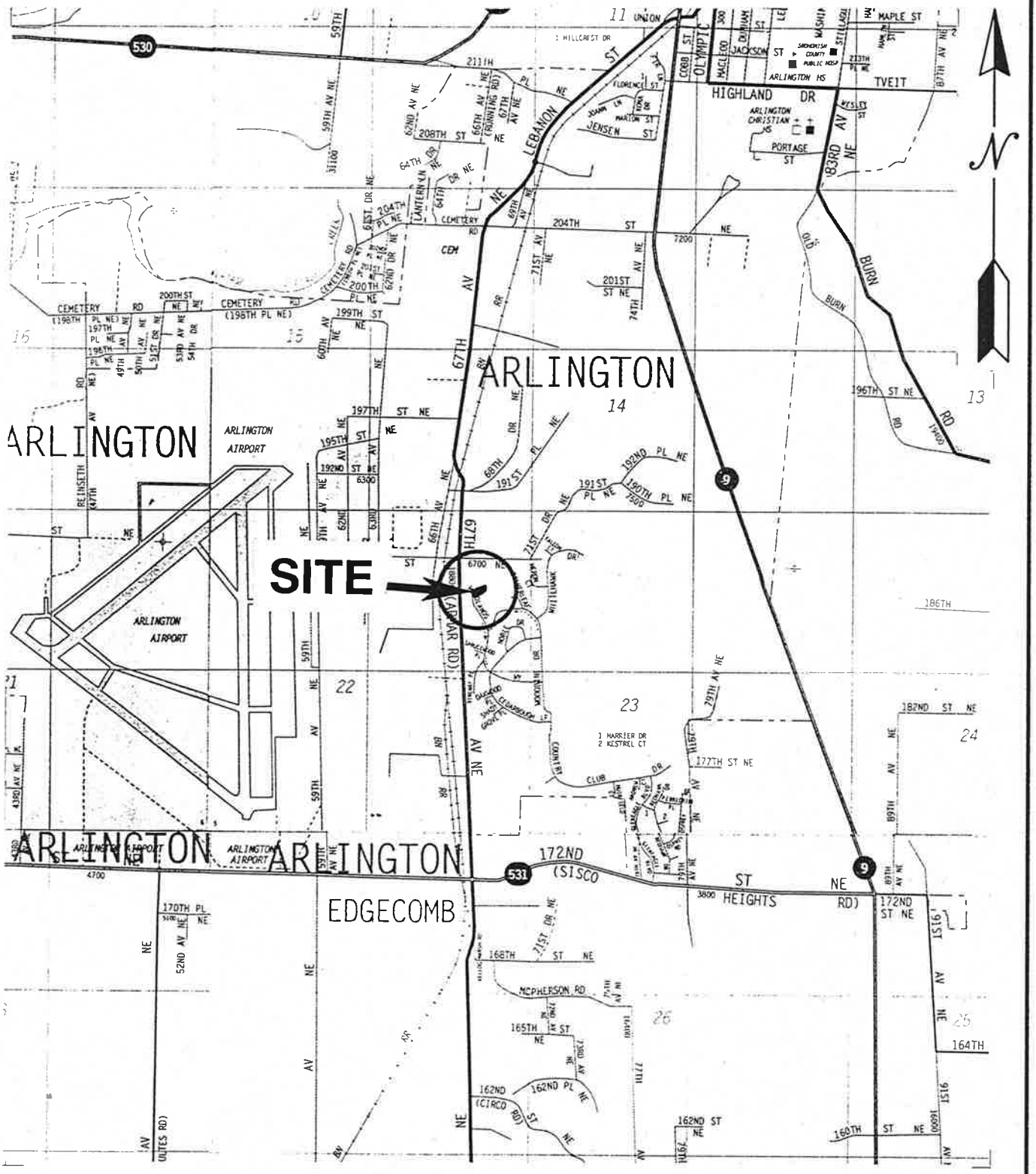
Terra Associates, Inc. should review the final design and specifications in order to verify that earthwork and drainage recommendations have been properly interpreted and implemented into project design.

Terra Associates, Inc. should provide geotechnical services during construction in order to observe compliance with the design concepts, specifications, and recommendations. Our engagement during construction will also allow for design changes if subsurface conditions differ from those anticipated prior to the start of construction.

6.0 LIMITATIONS

This report is the property of Terra Associates, Inc. and was prepared in accordance with generally accepted geotechnical engineering practices. This report is intended for specific application to the proposed Detention Pond W2 at the Gleneagle development and for the exclusive use of Woodland Ridge Joint Venture and their authorized representatives. No other warranty, expressed or implied, is made.

The analyses and recommendations presented in this report are based upon data obtained from the test pits performed on-site. Variations in soil conditions can occur, the nature and extent of which may not become evident until construction. If variations appear evident, Terra Associates, Inc. should reevaluate the recommendations in this report prior to proceeding with construction.

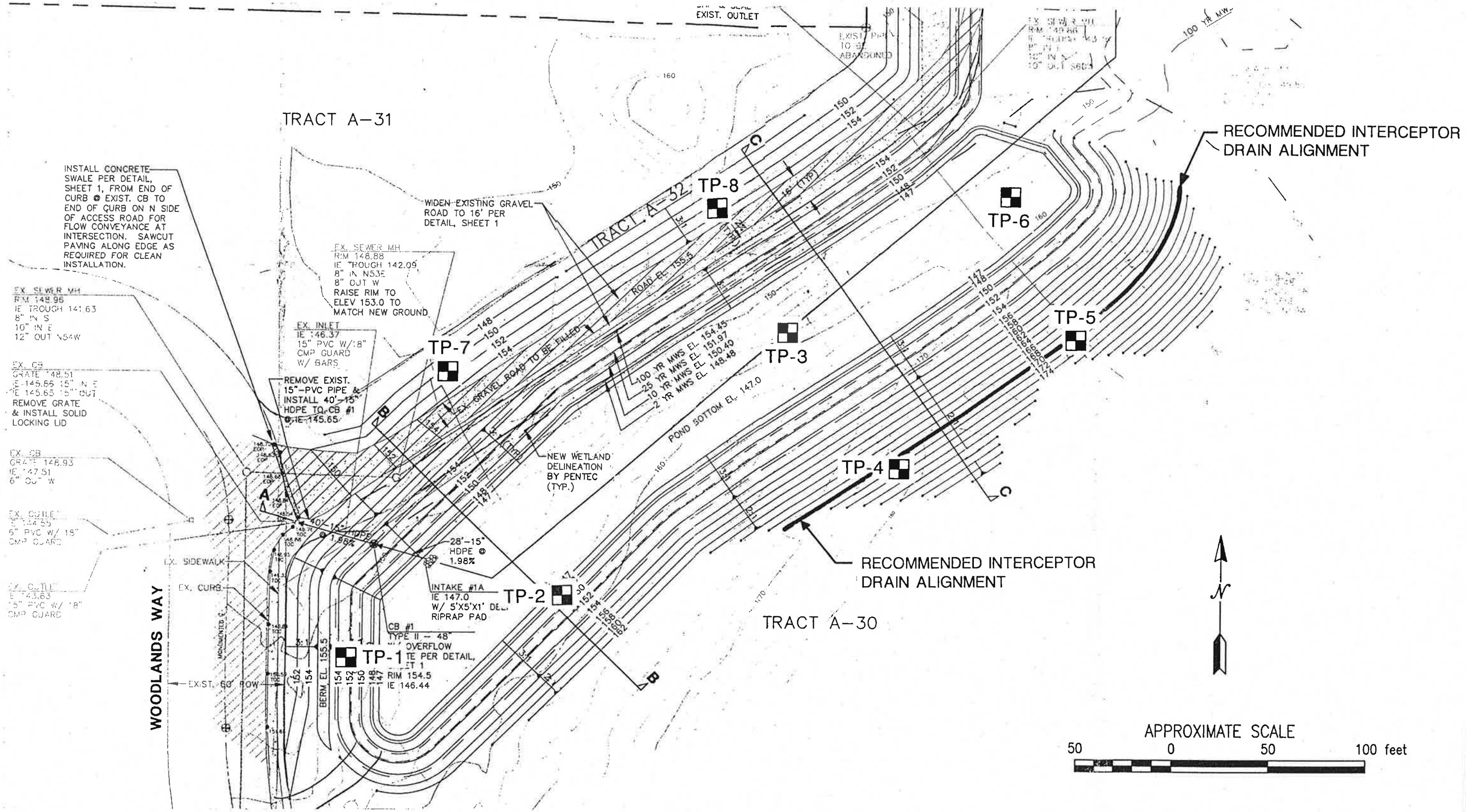


REFERENCE:
THE THOMAS GUIDE, SNOHOMISH COUNTY, WASHINGTON, PAGES 316, 317, 336 AND 337, 1995 EDITION.

TERRA ASSOCIATES
Geotechnical Consultants

VICINITY MAP
DETENTION POND W2, GLENEAGLE
ARLINGTON, WASHINGTON

Proj. No.1775-8-3	Date 9/95	Figure 1



LEGEND:

■ APPROXIMATE TEST PIT LOCATION

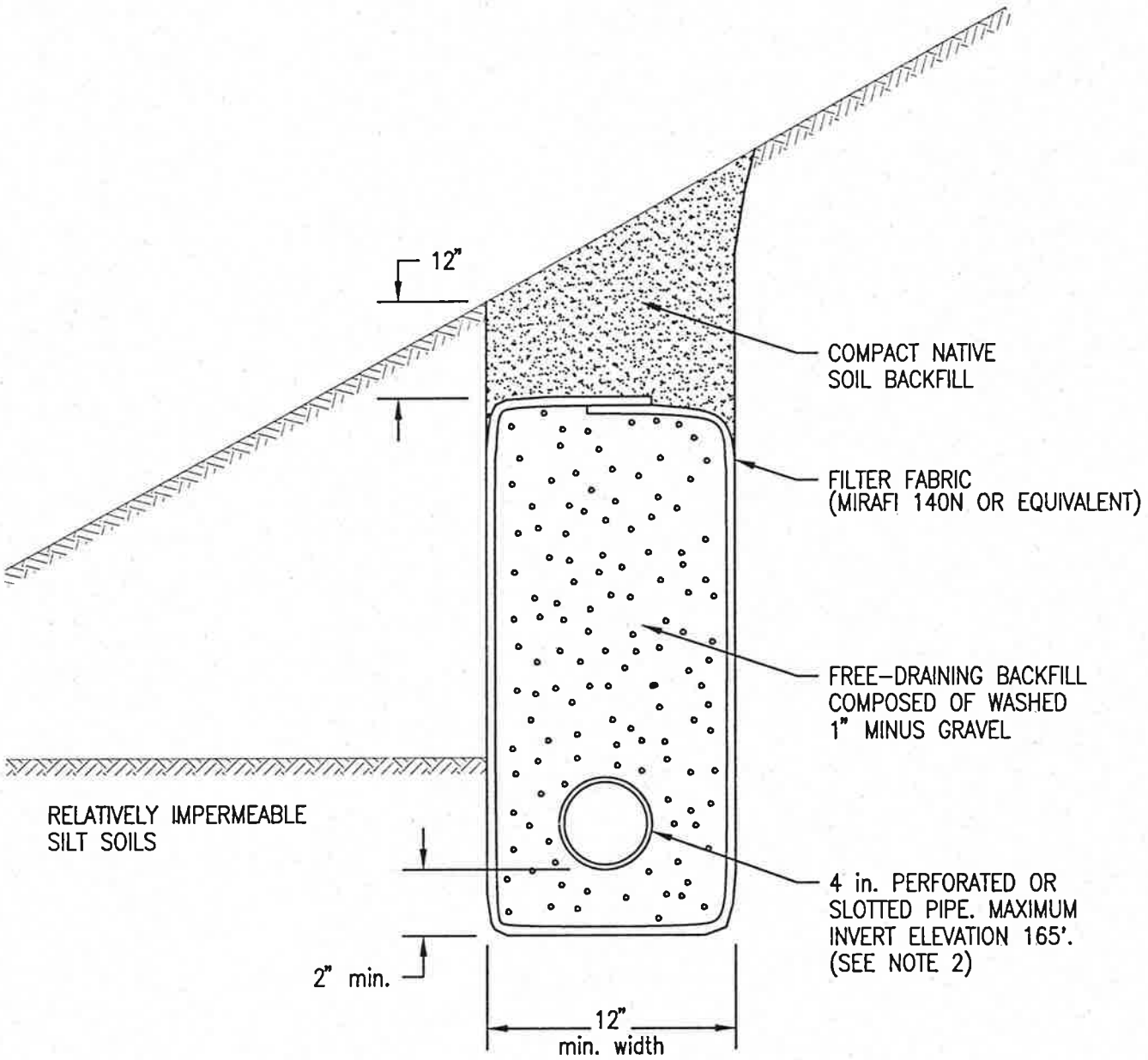
REFERENCE:

SITE PLAN PROVIDED BY HIGA ENGINEERING, INC., JOB No. 1151, SHEET 2 OF 3, DATED 8/3/95.

TERRA ASSOCIATES
Geotechnical Consultants

EXPLORATION LOCATION PLAN
DETENTION POND W2, GLENEAGLE
ARLINGTON, WASHINGTON

Proj. No. 1775-8-3	Date 9/95	Figure 2



NOT TO SCALE

NOTES:

1. METHOD OF DRAIN INSTALLATION AND TRENCH SIDEWALL STABILITY SHOULD BE ASSESSED BY THE CONTRACTOR.
2. DRAIN INVERT ELEVATION REQUIRED TO BE FIELD VERIFIED. ELEVATION GIVEN IS FOR PLANNING PURPOSES ONLY.

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TYPICAL INTERCEPTOR DRAIN DETAIL
DETENTION POND W2, GLENEAGLE
ARLINGTON, WASHINGTON

Proj. No.1775-8-3	Date 9/95	Figure 3

APPENDIX A
FIELD EXPLORATION AND LABORATORY TESTING

Detention Pond W2
Gleneagle Development
Arlington, Washington

On August 21, 1995, we performed our field exploration using a rubber-tired backhoe. We explored subsurface soil conditions at the site by excavating eight test pits to a maximum depth of 16 feet below existing grade. The test pit locations are shown on Figure 2. The test pit locations were approximately determined by measurements from existing site features and survey stakes. The test pit logs are presented on Figures A-2 through A-5.

A geotechnical engineer from our office conducted the field exploration and classified the soil conditions encountered, maintained a log of each test pit, obtained representative soil samples, and observed pertinent site features. All soil samples were visually classified in accordance with the Unified Soil Classification System (USCS) described on Figure A-1.

Representative soil samples obtained from the test pits were placed in closed containers and taken to our laboratory for further examination and testing. The moisture content of each sample was measured and is reported on the Test Pit Logs. Grain size analyses were performed on seven of the samples. The results are shown on Figures A-6 through A-9.

MAJOR DIVISIONS			LETTER SYMBOL	GRAPH SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS More than 50% material larger than No. 200 sieve size.	GRAVELS More than 50% of coarse fraction is larger than No. 4 sieve.	Clean Gravels (less than 5% fines)	GW		Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP		Poorly-graded gravels, gravel-sand mixtures, little or no fines.
		Gravels with fines	GM		Silty gravels, gravel-sand-silt mixtures, non-plastic fines.
			GC		Clayey gravels, gravel-sand-clay mixtures, plastic fines.
	SANDS More than 50% of coarse fraction is smaller than No. 4 sieve.	Clean Sands (less than 5% fines)	SW		Well-graded sands, gravelly sands, little or no fines.
			SP		Poorly-graded sands or gravelly sands, little or no fines.
		Sands with fines	SM		Silty sands, sand-silt mixtures, non-plastic fines.
			SC		Clayey sands, sand-clay mixtures, plastic fines.
FINE GRAINED SOILS More than 50% material smaller than No. 200 sieve size.	SILTS AND CLAYS Liquid limit is less than 50%		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL		Organic silts and organic clays of low plasticity.
	SILTS AND CLAYS Liquid limit is greater than 50%		MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic.
			CH		Inorganic clays of high plasticity, fat clays.
			OH		Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS			PT		Peat and other highly organic soils.

DEFINITION OF TERMS AND SYMBOLS

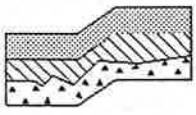
SAND or GRAVEL

Density	Standard Penetration Resistance in Blows/Foot
Very loose	0-4
Loose	4-10
Medium dense	10-30
Dense	30-50
Very dense	>50

SILT or CLAY

Consistency	Standard Penetration Resistance in Blows/Foot
Very soft	0-2
Soft	2-4
Medium stiff	4-8
Stiff	8-16
Very stiff	16-32
Hard	>32

I	2" OUTSIDE DIAMETER SPLIT SPOON SAMPLER
I	2.4" INSIDE DIAMETER RING SAMPLER OR SHELBY TUBE SAMPLER
P	SAMPLER PUSHED
*	SAMPLE NOT RECOVERED
▽	WATER LEVEL (DATE)
⏢	WATER OBSERVATION STANDPIPE
C	TORVANE READINGS, tsf
q_u	PENETROMETER READING, tsf
W	MOISTURE, percent of dry weight
pcf	DRY DENSITY, pounds per cubic foot
LL	LIQUID LIMIT, percent
PI	PLASTIC INDEX
N	STANDARD PENETRATION, blows per foot



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SOIL CLASSIFICATION SYSTEM
DETENTION POND W2
GLENEAGLE DEVELOPMENT
ARLINGTON, WASHINGTON

Proj. No. T-1775-8-3	Date 8/95	Figure A-1

Test Pit No. TP-1

Logged by: KPR

Approximate Elev. 152

Date: 8/21/95

Depth (ft.)	USCS/ Graph	Soil Description	W (%)
0		8 inches TOPSOIL/DUFF.	
	SM	Brown silty SAND, fine grained, with gravel and few cobbles, with roots, medium dense, moist.	25.4
5	SM	Brown-gray silty SAND, fine to medium grained, with some gravel and few 6 inch cobbles, with mottles, medium dense to dense, moist.	15.4
	SM	Gray silty SAND, fine-grained, with minor gravel, very dense, moist. (Glacial Till)	12.3
10		Test pit terminated at 10.5 feet. No groundwater or caving of test pit walls observed.	
15			

Test Pit No. TP-2

Logged by: KPR

Approximate Elev. 159

Date: 8/21/95

Depth (ft.)	USCS/ Graph	Soil Description	W (%)
0	SM	(2 inches FOREST DUFF) Brown silty SAND, with roots and trace gravel, fine to medium grained, loose to 8 inches becoming medium dense, moist to wet.	25.2
	SP	Light brown SAND, fine to medium grained, dense, moist.	9.1
5	ML	Tan sandy SILT, very fine grained sand, with mottles, very stiff, moist, non-plastic.	22.8
10	SM	Dark gray-brown silty SAND, very fine to medium grained, very dense, moist. (Glacial Till)	18.2
15		Test pit terminated at 15 feet. No groundwater or caving of test pit walls observed.	

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TEST PIT LOGS
DETENTION POND W2
GLENEAGLE DEVELOPMENT
ARLINGTON, WASHINGTON

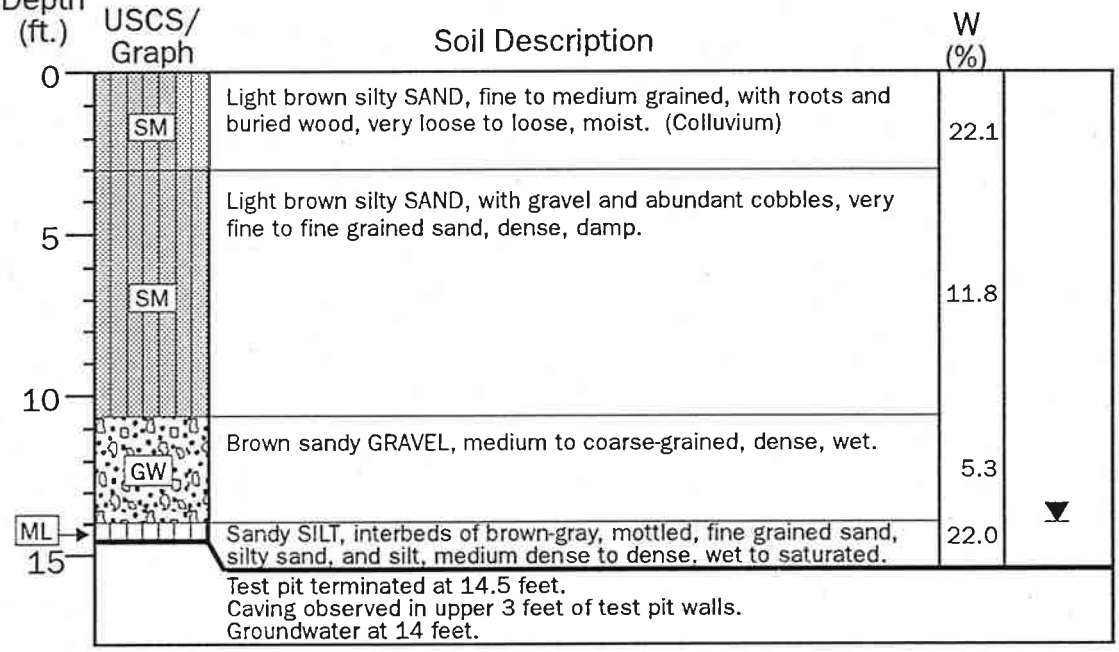
Proj. No. T-1775-8-3 | Date 8/95 | Figure A-2

Test Pit No. TP-3

Logged by: KPR

Approximate Elev. 158

Date: 8/21/95

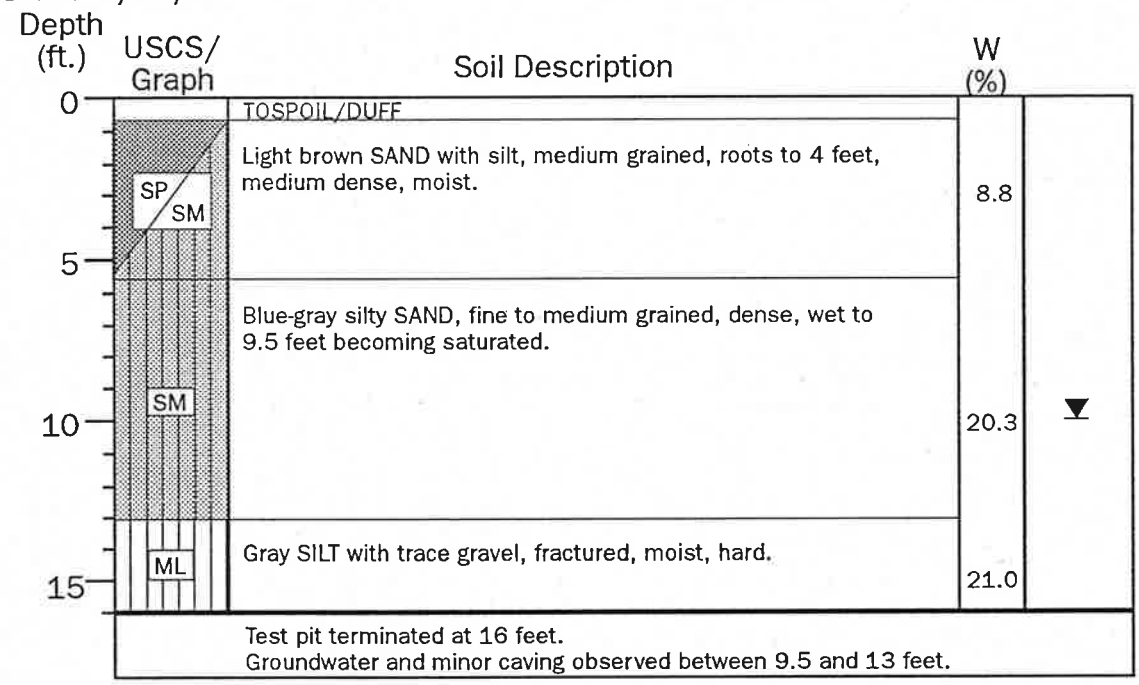


Test Pit No. TP-4

Logged by: KPR

Approximate Elev. 178

Date: 8/21/95



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TEST PIT LOGS
DETENTION POND W2
GLENEAGLE DEVELOPMENT
ARLINGTON, WASHINGTON

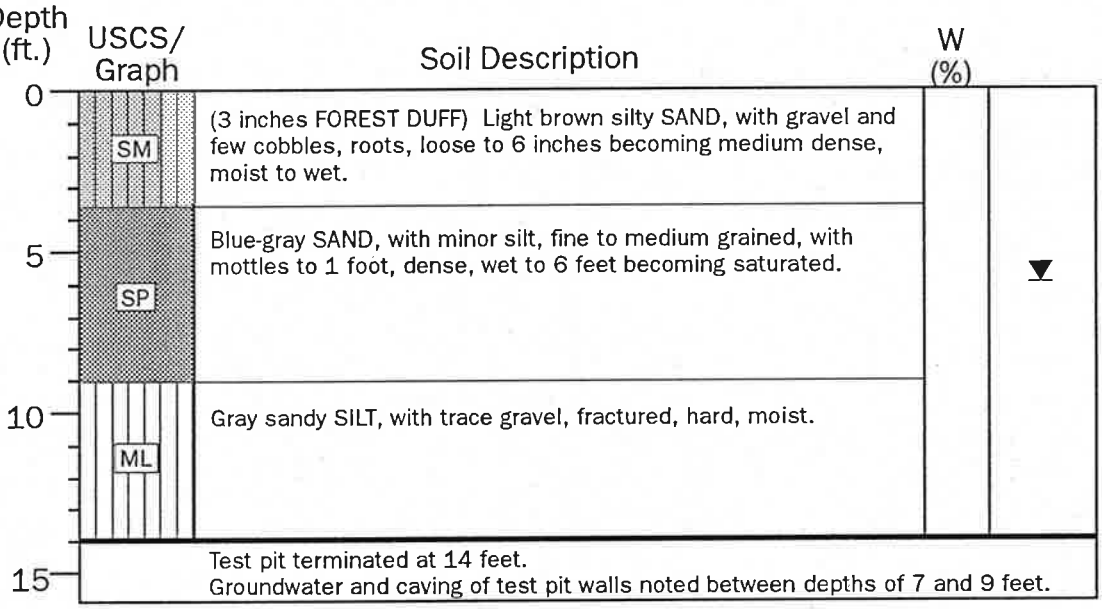
Proj. No. T-1775-8-3	Date 8/95	Figure A-3

Test Pit No. TP-5

Logged by: KPR

Approximate Elev. 176

Date: 8/21/95

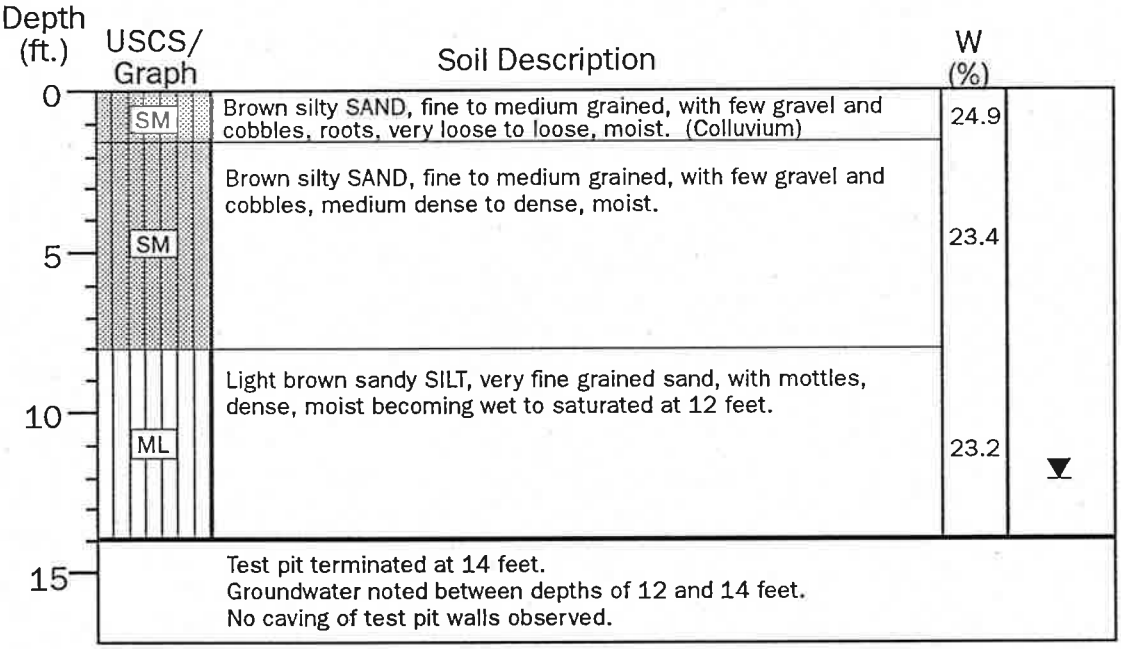


Test Pit No. TP-6

Logged by: KPR

Approximate Elev. 158

Date: 8/21/95



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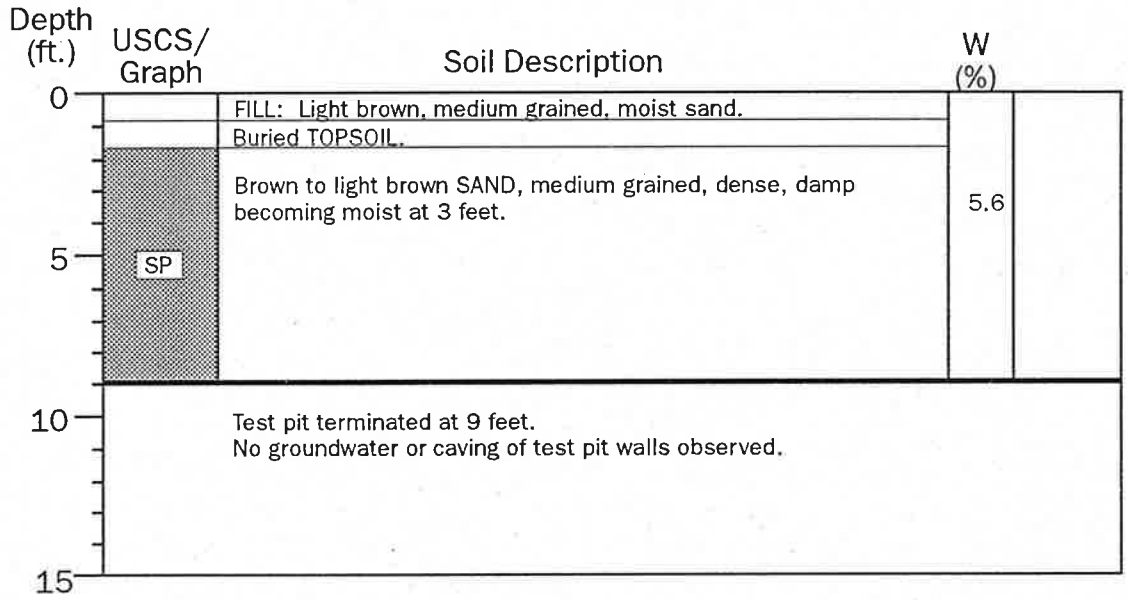
TEST PIT LOGS
DETENTION POND W2
GLENEAGLE DEVELOPMENT
ARLINGTON, WASHINGTON

Proj. No. T-1775-8-3	Date 8/95	Figure A-4

Test Pit No. TP-7

Logged by: KPR
Date: 8/21/95

Approximate Elev. 150

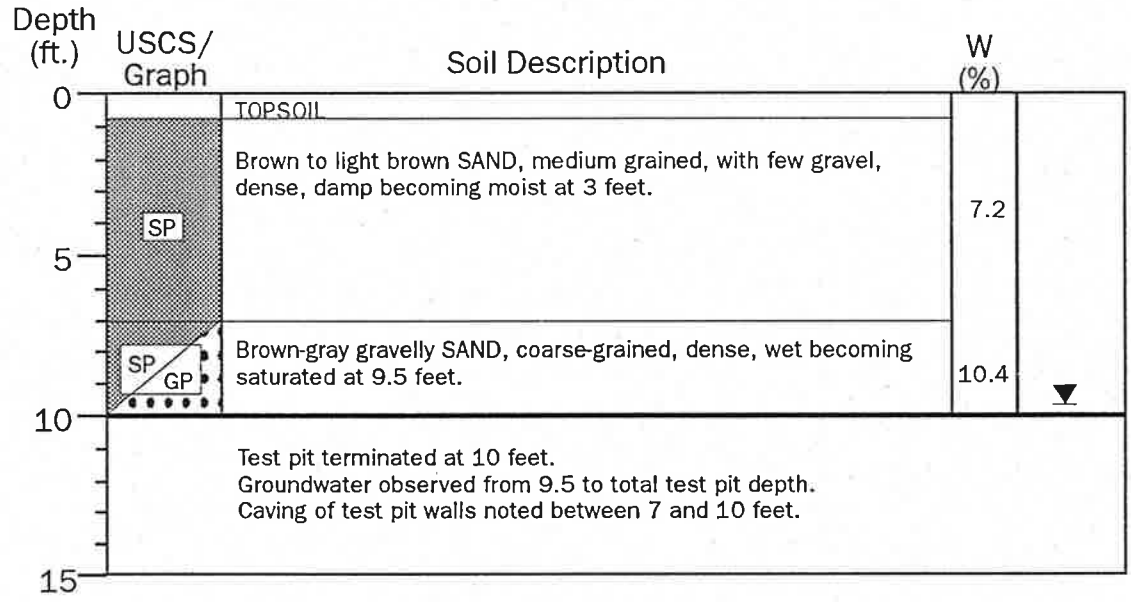


Test Pit No. TP-8

Logged by: KPR

Date: 8/21/95

Approximate Elev. 150



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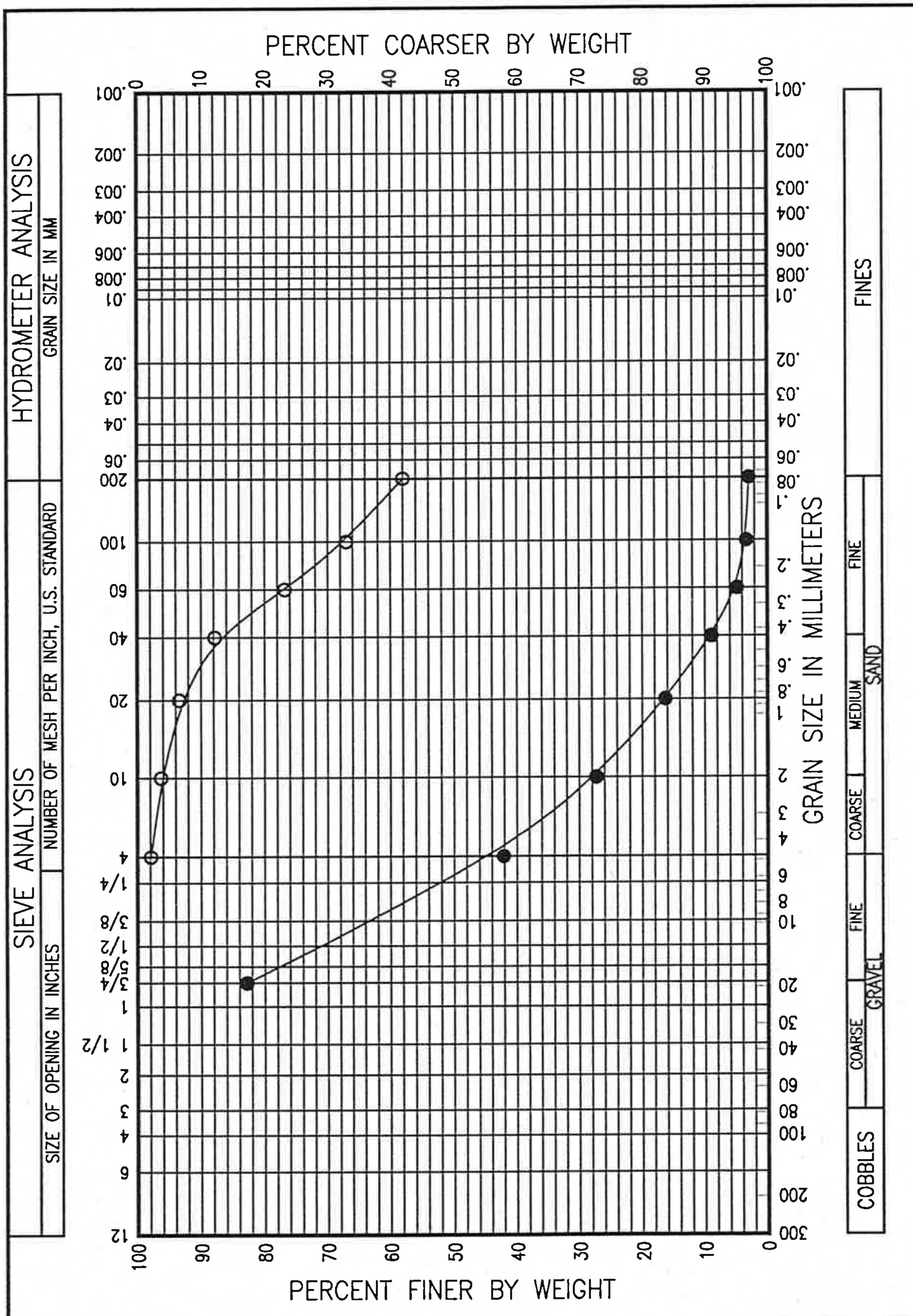
Geotechnical Consultants

TEST PIT LOGS
DETENTION POND W2
GLENEAGLE DEVELOPMENT
ARLINGTON, WASHINGTON

Proj. No. T-1775-8-3	Date 8/95	Figure A-5



Key	Boring or Test Pit	Depth (ft.)	USCS	Description	Moisture Content (%)	LL	PL
●	TP-3	10.5	GW	clean sandy GRAVEL	5.3		
○	TP-3	14.5	ML	sandy SILT	22.0		

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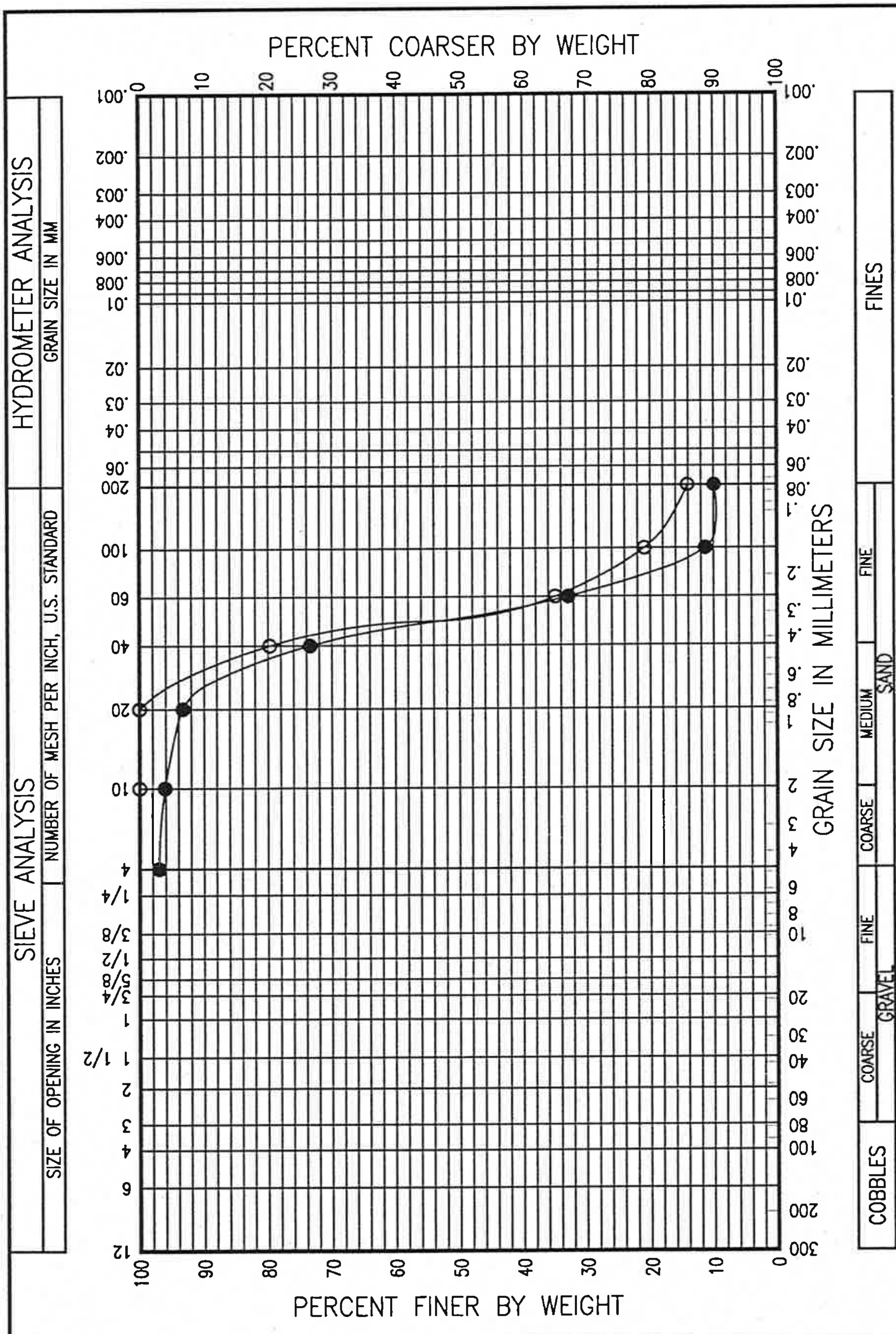
GRAIN SIZE ANALYSIS
DETENTION POND W2, GLENEAGLE
ARLINGTON, WASHINGTON

Proj. No.1775-8-3	Date 9/95	Figure A-6



Key	Boring or Test Pit	Depth (ft.)	USCS	Description	Moisture Content (%)	LL	PL
●	TP-4	2.0	SP-SM	SAND with silt	8.8		
○	TP-4	10.0	SM	silty SAND	22.8		

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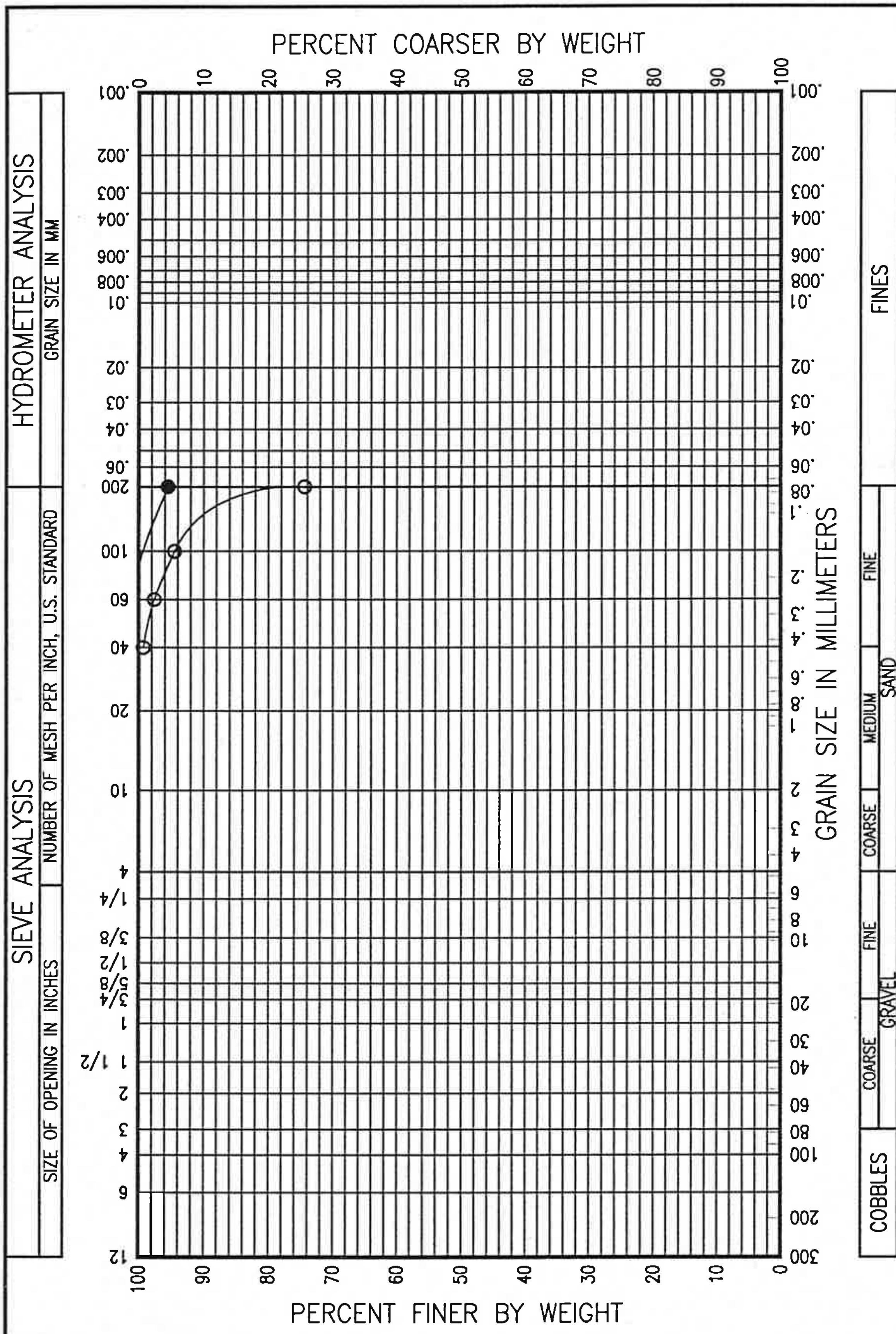
GRAIN SIZE ANALYSIS
DETENTION POND W2, GLENEAGLE
ARLINGTON, WASHINGTON

Proj. No.1775-8-3	Date 9/95	Figure A-7



Key	Boring or Test Pit	Depth (ft.)	USCS	Description	Moisture Content (%)	LL	PL
●	TP-4	13.0	ML	SILT	21.0		
○	TP-6	11.0	ML	sandy SILT	23.2		

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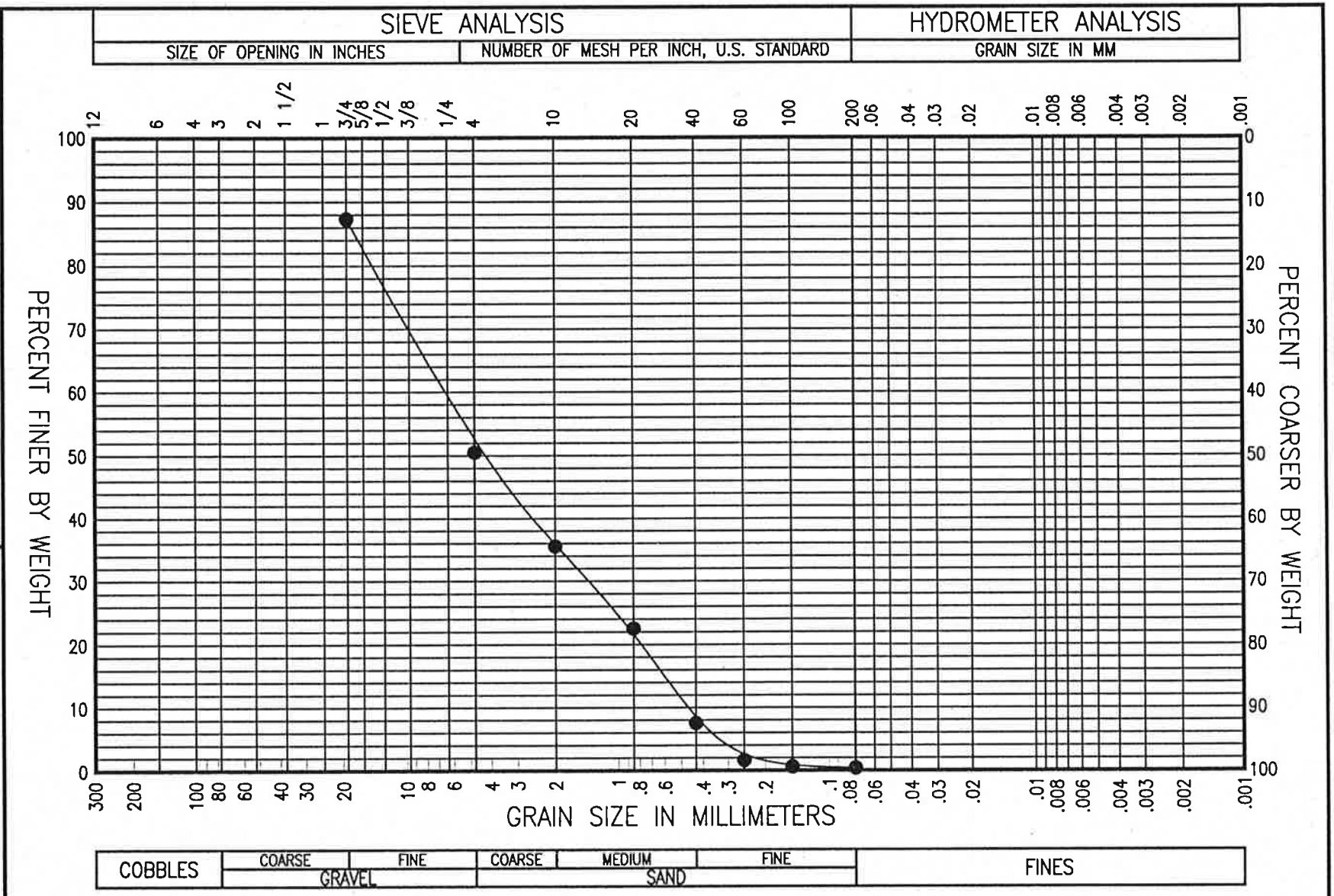
GRAIN SIZE ANALYSIS
DETENTION POND W2, GLENEAGLE
ARLINGTON, WASHINGTON

Proj. No.1775-8-3 | Date 9/95 | Figure A-9



Key	Boring or Test Pit	Depth (ft.)	USCS	Description	Moisture Content (%)	LL	PL
●	TP-8	9.0	SP-GP	gravelly SAND	10.4		