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December 7, 2010

Kopachuck Ridge Estates Water District
4809 – 100th Avenue Court NW
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(253) 370 -0475

Mr. Greg Baer

Geologic Reconnaissance Letter
Water Tank Site
xxx Artondale Drive NW
Pierce County, Washington
PN: 4991320350
Job: KREWD.ArtondaleDr.GR

INTRODUCTION

This geological reconnaissance letter presents the results of our assessment on the general stability of the exposed soils slope above the existing Kopachuck Ridge Estates Water District water tanks located along Artondale Drive. The site is located in the Kopachuck area of Pierce County as shown on the attached Site Vicinity Map, Figure 1.

Our understanding of the project and site conditions are based on our initial site visit and meeting with you on March 3, 2010; our subsequent site reconnaissance on August 20, 2010; a review of available Pierce County permit and site development documents; a review of published geologic literature; and our experience in the site area. We understand that you had a Geotechnical Investigation of the site in 1995 as part of the design and construction of the newer, largest water tank. In 2003, a portion of the slope above the parcel sloughed down and over an existing 2-tier ecology block retaining wall. We understand that the Water District and Homeowners Association are concerned about the overall stability of the slope.

The purpose of our services was to evaluate the surface and subsurface conditions at the site as a basis for assessing the overall stability of the exposed soil face slopes, along with potential adverse impacts to and from the slopes within the site area. Our scope of work was outlined in our March 8, 2010 Proposal for Services, and received your written notice to proceed on August 2, 2010.

SITE CONDITIONS

The subject parcel is located at xxx Artondale Drive NW, approximately 60 feet west of the intersection of Artondale Drive NW and 100th Avenue Court NW. The parcel is circular in shape, has approximately 200 feet of frontage along Artondale Drive NW, and encompasses about 0.83 acres. The site is currently developed with two existing water tanks and equipment buildings. A short two-tier ecology block wall is located along the toe of the slope behind (north) of the three water tanks. The site is bounded by residential properties on the north, Artondale Drive on the south, and by undeveloped slopes on the east and west.

The site is located on the western margin on the Kopachuck Ridge glacial upland area. From Artondale Drive, the site is generally flat to gently sloping up. North of the existing water tanks is a short two-tier ecology block wall. The site slopes up from the block walls at inclinations between 50 and 100 percent, with up to 45 feet of vertical relief. From the top of the slope, grades flatten out to about 25 to 30 percent, and extend up to the existing residences to the north. Total topographic relief across the water tank parcel is on the order

of 50 feet, while total relief from Artondale Road up to the neighboring residences is on the order of 60 to 75 feet. An aerial photograph with topography was contour was obtained from the Pierce County CountyView GIS and is attached as Figure 2.

Vegetation on the lower, developed portion of the site consists of grass and weeds. Vegetation on the upper sloping portion of the site consists of native vegetation, including Madrona trees, young fir trees, sword ferns, salal, and other shrubs and groundcover.

No surface water or seepage was observed at the time of our site visit. The Kopachuck Ridge Estates neighborhood appears to have a stormwater conveyance system for the roads which prevents runoff from the roadways above the water tank site from impacting the slopes. Furthermore, the two closest residences likely have single family infiltration systems (no as built information was available at Pierce County). No evidence of deep-seated slope instability or historic landslides was observed on the slopes at the time of our site visit. Evidence of erosion and surficial sloughing was observed above the western water tank, and we understand that the slope has been prone to such sloughing in the past.

Site Soils

The USDA Natural Resource Conservation Service (NRCS) Web Soil Survey for Pierce County maps the soils in the area of the site as Indianola loamy sand (18C). The Indianola soils are derived from sandy outwash deposits that form on 6 to 15 percent slopes and are listed as having a "moderate" erosion hazard. Because of the steepness of the slopes, and given the observed near surface soil conditions, we would interpret the site soils to be more representative of the 18E soils, which form on slopes of 15 to 45 percent, and have a "moderate to severe" erosion hazard. A copy of the SCS map for the site vicinity is attached as Figure 3.

Site Geology

The *Geologic Map of the Fox Island 7.5 minute Quadrangle, Pierce County, Washington* by Logan, Walsh, and Troost (2006), indicates the site underlain by glacial till (Qgt). These glacial soils were deposited during the most recent Vashon Stade of the Fraser Glaciation, approximately 12,000 to 15,000 years ago. The glacial till consists of a heterogeneous mixture of clay, silt, sand, and gravel that was deposited at the base of the prehistoric continental glacial ice mass and was subsequently over-ridden. As such, the glacial till is considered overconsolidated and exhibits high strength and low compressibility characteristics. The glacial till is typically is overlain by a thin, intermittent veneer of recessional outwash and underlain by advance outwash. Outwash consists of poorly sorted mixtures of sand and gravel that were deposited by the receding and advancing ice mass, respectively. Like the till, the advance outwash was overridden by the prehistoric ice sheet and is considered over-consolidated, while the recessional outwash was not overridden and is considered normally consolidated. No areas of erosion, mass wasting, or landslides are indicated on the geologic map in the general site area. An excerpt of the above referenced map is included as Figure 4.

The Coastal Zone Atlas for Pierce County indicates the area around the site as "S" for stable. A copy of the Coastal Zone Atlas is included as Figure 5. No areas of landslides ("Uos" or "Urs") are located within 300 feet of the parcel as mapped by the Coastal Zone Atlas.

Subsurface Conditions

During our August 20, 2010 site visit, we explored subsurface conditions by excavating three shallow hand borings. The hand borings were excavated by using a 3-inch diameter hand auger and posthole digger. The hand borings were excavated to depths ranging from 3½ to 5½ feet below existing ground surface. No groundwater seepage was observed in our hand borings at the time of digging. The approximate locations of the hand augers are shown on the attached Site Plan, Figure 2.

Subsurface Conditions

The subsurface conditions encountered in our three hand borings appeared fairly uniform, and generally confirmed the mapped stratigraphy for the area. Our hand augers encountered ¼ to ½-foot of topsoil overlying loose, fine to medium sand. At depths of 2½ to 4 feet, the sand became denser and had minor amounts of gravel. Based on the blowcounts of the native soils in the provided geotechnical engineering report for the water tank foundations, we interpret these soils to be representative of advance outwash. The advance outwash was encountered to the full depth explored in our three hand augers. The soils encountered in our hand augers were visually classified in the field in general accordance with the Unified Soil Classification System (USCS), as described on Figure 6. Logs of the hand borings are included as Figure 7.

CONCLUSIONS

Based on our site evaluation and literature review, it is our opinion that if left uncovered or unprotected, that the near surface soils on the site are prone to erosion and sloughing, but are generally stable with regards to deep seated failure or land sliding. Because of the height and steepness of the existing unprotected slopes, ongoing maintenance and clean-up for erosion and sloughing should be expected. We anticipate that the amount of sloughing will be minimal, but as observed, vegetation at the top of the slope can become excessive, and undermined by the sloughing, resulting in episodes of larger debris slides. We have provided recommendations for mitigating the amount of erosion and stabilizing the bare slopes on the site. We have also assessed the slopes at the site relative to the current Pierce County Critical Areas Ordinance, as an indication of relative stability.

Landslide Hazard Indicators – per Pierce County Section 18E.80.020

The Pierce County Municipal Code, Chapter 18E defines a landslide hazard area as an area potentially subject to mass movement because of a combination of geologic, seismic, topographic, hydrologic, or manmade factors. These areas may be identified by the presence of any of the following indicators:

1. Areas of historic failures including areas of unstable, old and recent landslides or landslide debris within a head scarp.
2. Areas with active bluff retreat that exhibit continuing sloughing or calving of bluff sediments, resulting in a vertical or steep bluff face with little or no vegetation.
3. Areas with both of the following characteristics:
    a) Slopes steeper than 20 percent with a vertical relief of 20 feet or more; and
    b) Hillsides that intersect geologic contacts with relatively permeable sediment overlying a relatively impermeable sediment or bedrock.
4. Slopes that are parallel or sub-parallel to planes of weakness, such as bedding planes, joint systems and fault planes, in subsurface materials;
5. Areas exhibiting geomorphologic features indicative of past slope failures, such as hummocky ground, back-rotated benches on slopes, etc.
6. Areas with tension cracks/ground fractures along or near the edge of the top of a bluff or ravine.
7. Areas with structures that exhibit structural damages such as settling and cracking of the building foundation or separation of steps or porch from a main structure that is located near the edge of a bluff or ravine.
8. The occurrence of toppling, leaning, bowed, or jackstrawed trees that are caused by disruption of ground surface by active movement.
9. Areas with slopes containing soft or liquefiable soils.
10. Areas where gullying and surface erosion have caused dissection of the bluff edge or slope face as a result of drainage or discharge from pipes, culverts, ditches, and natural

drainage courses.

11. Areas where seeps or springs or indicators of a shallow groundwater table are observed on or adjacent to the face of the slopes.
12. Areas of greater than 40 percent slopes with 15 feet or more of vertical relief.
13. Areas that are at risk of mass movement due to seismic events.
14. Areas that include alluvial or colluvial fans located at the base of steep slopes and drainage.

No evidence of seepage, landslide activity, or significant erosion was observed at the site at the time of our site visit. Some slopes steeper than 20 percent were observed on site, but the site is not mapped as having intersecting contacts, nor were intersecting contacts observed during our reconnaissance. The slope between the water tanks and residences above the parcel is steeper than 40 percent with more than 15 feet of vertical relief. No planes of weakness or rockfall hazards were observed at the site. No areas of stream erosion or snow avalanche were observed at the time of our site visit. No other potential areas of debris flows or catastrophic flooding were observed at the site during our site visits. No evidence of active or historical deep seated rotational failures was observed at the site or within 300 feet of the site; however, evidence of surficial sloughing on the cut slope above the water tanks was noted.

Based on the above, it appears that one of the above 14 landslide hazard indicators occurs on the site (slopes over 40 percent with more than 15 feet of relief). However, no evidence of landslide activity or active landslides was observed at the site. Therefore, it is our opinion that it does <u>not</u> appear that an active landslide hazard area exists within 300 feet of the site. Since no active landslide is present on or within 300 feet of the site, no prescriptive buffer would be imposed by the Pierce County Critical Areas Ordinance Title 18E.

Slope Maintenance

As stated, the major issue appears to the steepness of the unprotected sand slopes. There are several options for improving stability of the slopes, including maintaining and improving vegetation, using geosynthetic, and using retaining walls to effectively lower or flatten he slope. These options are described below:

Vegetation Management

The exposed sandy soils are prone to ongoing erosion during periods of wet weather. Improving vegetation on the slope will minimize the impact of wind and rain on the slope, reducing the potential for future sloughing.

We recommend reviewing Washington Department of Ecology (WDOE) *Vegetation Management: A Guide for Puget Sound Bluff Property Owners* (Publication #93-31), *Slope Stabilization and Erosion Control Using Vegetation: A Manual of Practice for Coastal Property Owners* (Publication #93-30), and *Surface Water and Groundwater on Coastal Bluffs: A Guide for Puget Sound Property Owners* (Publication #95-107). These documents provide recommendations for using native species that are drought tolerate as vegetation cover on slopes. The vegetation prevents the rain from hitting the exposed soils, reducing the potential for erosion. The plans also extend roots down and into the near soils, improving the overall stability of the site.

Because it can take a year or two the for the plants to establish themselves, using a spray-on mulch (with a tacifier) or erosion blanket, such as Bonded Fiber Matrix, helps hold the soils around the plants in place until they mature.

We would recommend prior to planting or hydroseeding, that any undermined trees or shrubs at the top of the slope be removed to prevent toppling. Toppled trees can cause significant damage to the slopes.

The planting or landscaping plan can be created by a erosion specialist, arborist, or landscape architect that uses native plants. The plants could likely be installed by hand, minimizing the impact to the slope. The mulch or erosion blank can be sprayed on, also

reducing the impact to the slope. Furthermore, no permits would be required. This, in our opinion, would be the least costly alternative.

Geosynthetic Cover

Another option would be to cover the slope with a geosynthetic erosion blanket, such as jute netting, coconut blanket, or even a cellular confinement system such as GeoWeb.

These erosion control devices require a generally smooth, uniformly sloping surface, similar to the slope above the ecology block wall. As with the vegetation option, we would recommend that any undermining or overhanging tree, shrub, or vegetation at the top of the slope be removed to provide a uniform transition from the flatter, upper slope to the exposed soil slope.

Prior to installing the erosion blanket, surface water runoff should has been controlled by a shallow berm or swale installed along the top of the slope. The exposed native soils on the face of the slope can be covered with a spray-on mulch or bonded fiber matrix, with a native grass seed mixture. Locally, a seed mixture referred to as "Highway Mix" has good results. This mix has both grass and clover seeds that establish quickly and are drought tolerant. Once applied, the hydroseed should be covered with a roll-on mat erosion blanket. Blankets consist of open-grid jute netting to solid straw or coconut blanket to combination natural fiber/HDPE blankets. The blanket is usually anchored in a shallow trench at the top of the slope, and rolled down the face of the slope. Adjacent rolls are ship-lapped 6-12 inches to prevent exposure during wind. Soil staples are then used to hold the rolls in place. For slopes longer than 25 feet, the use of coir logs or wattles perpendicular to the slope can be used to slow down runoff, reducing the potential for rilling or erosion.

A more engineered method of permanent erosion control would be to install a geosynthetic erosion control device such as GeoWeb©. GeoWeb© is a cellular confinement system that can be filled with a topsoil mixture to promote revegetation. The web is tied to deadman anchors (lengths of 8-inch ductile iron pipe) installed at the top of the slope and is also anchored to the face of the slope with GeoWeb's proprietary Atra Anchors©. Once installed, the voids within the web are filled with topsoil and reseeded. The cells reduce the length of the slope to a series of 6-inch to 8-inch cells, that holds the surface in place while the vegetation establishes itself.

This is more of an engineered system that requires some additional effort during installation. However, the blankets can be installed by hand, minimizing the impact to the slope. This system will provided additional erosion protection than simply vegetation, as well as require less annual maintenance. An option of vegetation and erosion blanket would be our recommended option.

Gravity Walls

Finally, the lower wall can be improved (raised and strengthened) to provide additional catchment at the toe of the slope.

Suitable types of gravity walls include Kelly Block, Lock-Block, Redi-Rock and gabion walls. The proprietary large block concrete walls consist of various concrete blocks that have some sort of interlocking feature that "locks" the wall in place. The ecology blocks currently used only have the half-round channel and keyway that is not considered a strong interlocking feature.

Gravity walls should always bear on firm, unyielding, non-organic, native soils or on structural fill soils placed over such native soils. For frost and erosion protection, all gravity walls should be embedded at least 18 inches below the adjacent ground surface. However, greater depths might be required in certain locations to develop adequate sliding resistance or passive pressure.

Not-with-standing the various dimensions of the proprietary systems, a single row of blocks would typically provide an exposed wall height of 1 to 1½ feet. Each succeeding row of blocks would increase the exposed wall height by about 2½ feet.

Typically, for any exposed wall height up to 13½ feet (six rows) and a backslope angle ranging from level to 3H:1V, the upper three rows of modules can be oriented parallel to the cut bank, whereas all of the lower rows of modules should be oriented perpendicular to the cut bank. For backslope angles ranging from 3H:1V to 2 H:1V, typically only the upper two rows can be oriented parallel to the cut bank. Using these configurations, our calculations indicate that walls ranging up to six rows high will be stable if properly drained. This requires twice the number of blocks per wall (although the Redi-Rock system and Kelly Block system now have double width blocks). Regardless of height, the wall face should be battered into the slope at an angle no steeper than 1H:6V. Given the height and batter of the existing walls, and steepness of the slope, adding a third block to the existing wall would not be considered a "stable solution".

Effective drainage behind gravity walls is critical to prevent a buildup of hydrostatic pressure. Consequently, we recommend that a curtain drain be placed behind the entire wall, with a 4-inch-diameter perforated pipe at the base. The drainpipe should be bedded in pea gravel or washed rock, and be wrapped with filter fabric.

While a new or taller wall would provide a structural solution to the ongoing maintenance, the cost would be significantly higher than the previous options. Furthermore, a permit and actual wall design would be required. Installation would require considerable amounts of additional excavation and removal of soils from the site.

LIMITATIONS

We have prepared this report for Kopachuck Ridge Estates Water District, and other members of the design team for use in evaluating a portion of this project. Subsurface conditions described herein are based on our observations of exposed soils on the parcel. This report may be made available to regulatory agencies or others, but this report and conclusions should not be construed as a warranty of subsurface conditions. Subsurface conditions can vary over short distances and can change with time.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time this report was prepared. No warranty, express or implied, should be understood.

◆ ◆ ◆

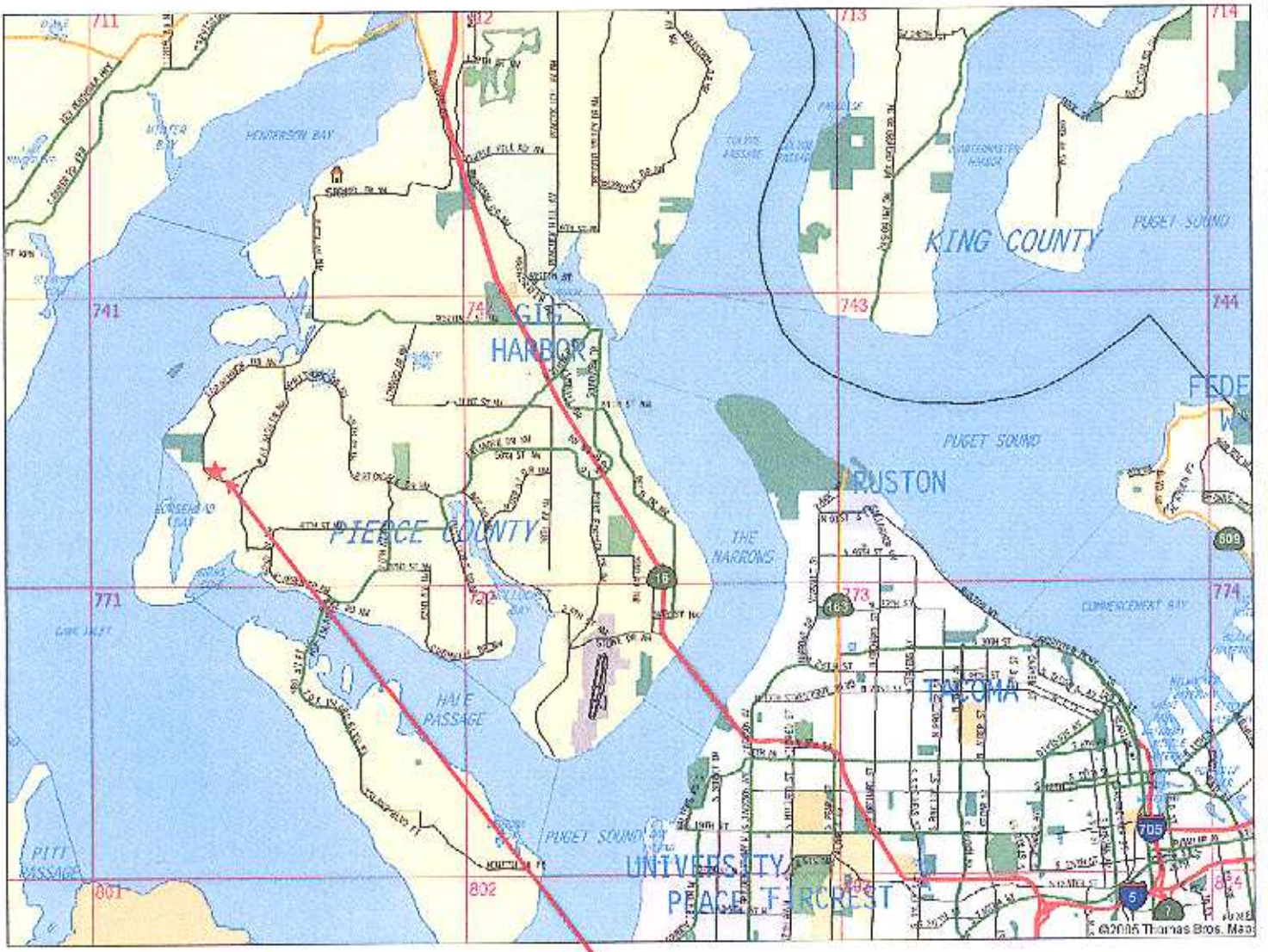
We have appreciated working for you on this project. Please do not hesitate to call at your earliest convenience if you have any questions or comments.

Respectfully submitted,
GeoResources, LLC

Keith S. Schembs, LEG
Principal

Brad Biggerstaff, LEG
Principal

KSS:BB:kss
Doc ID: KREWD.ArtondaleDr.GR
Attachments:
Figure 1: Vicinity Map
Figure 2: Site Plan
Figure 3: NRCS Soil Survey
Figure 4: USGS Geology Map
Figure 5: Coastal Zone Atlas
Figure 6: Soil Classification System
Figure 7: Hand Auger Logs



Approximate Site Location

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Site Vicinity Map

XXX Artondale Drive NW
Pierce County, Washington

DocID: KREWD.Artondale.SVM	August 2010	Figure 1

XXX Artondale Drive NW

Map Legend

- Drainage - Vaults
- Drainage - Sediment Traps
- Drainage - Manholes
- Drainage - Filters
- Drainage - Dry Wells
- Drainage - Control Structures
- Drainage - Catch Basins
- Drainage - Break Points
- Highlighted Tax Parcels
- Tax Parcels
- Contours - 10 ft
- Drainage - Pipes
- Drainage - Channels
- Hydro - Centerlines
- Roads
- Interstate
- Limited Access State Routes
- Other State Routes
- Ramps
- Major Arterial
- Collector
- Local Access
- Channel Migration Zone
- Floodway
- County Floodways
- County Floodplains
- 1% Annual Chance Flood
- VE - Coastal High Hazard Areas
- X - 0.2% Annual Chance Flood
- Hydro - Surface Boundaries
- Water body
- Island
- Swamp
- County - 2008 - Ortho

Figure 2

10/7/10 10:46 AM

Scale 1:720

0 30 60 ft.

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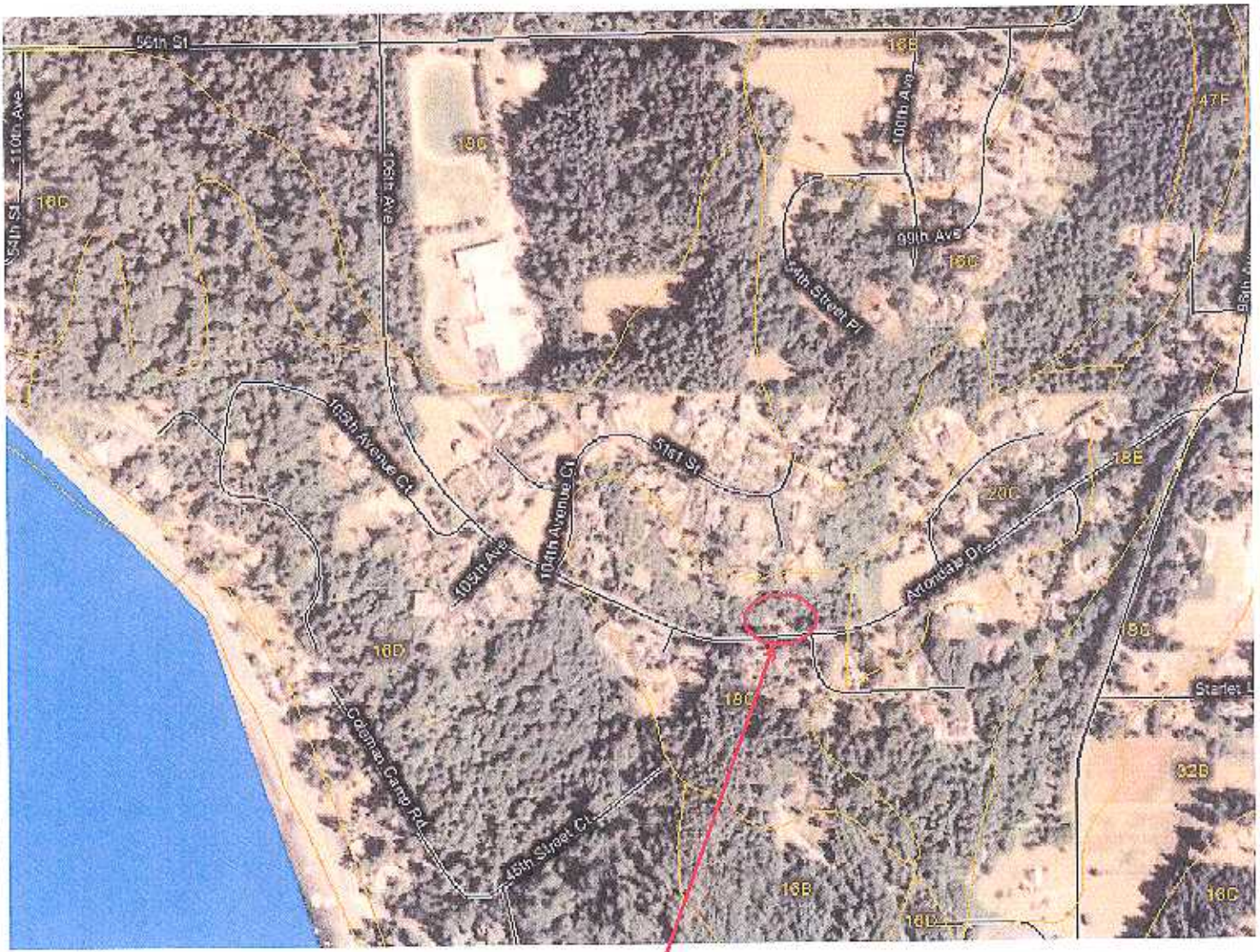

Not to Scale

Approximate Site Location

(map created from the USDA Natural Resource Conservation Service Web Soil Survey)

Soil Type	Soil Name	Parent Material	Slopes	Erosion Hazard	Hydrologic Soils Group
18C	Indianola loamy sand	Sandy Glacial Outwash	6 to 15	Moderate	A

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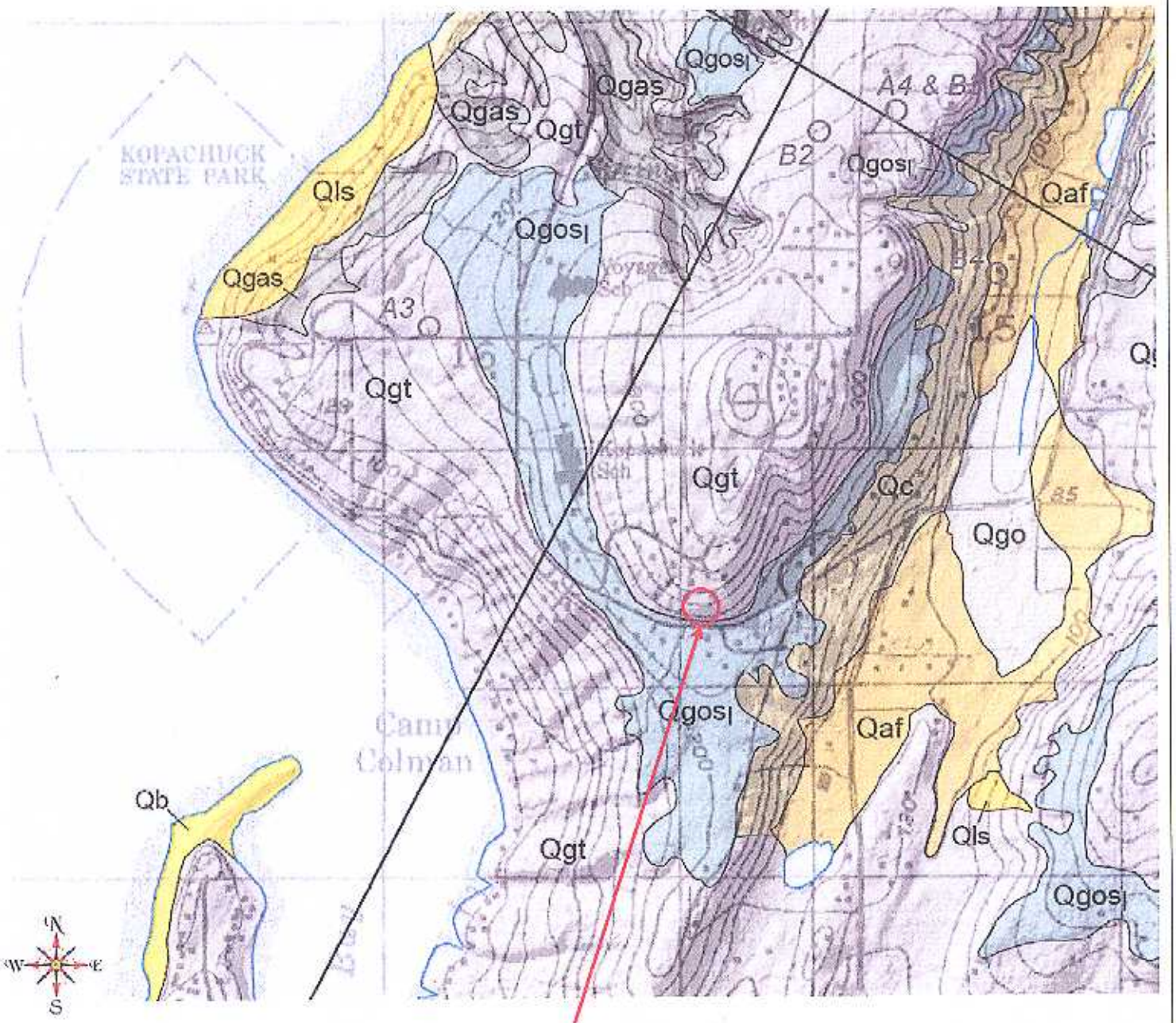
NRCS SCS Soils Map

XXX Artondale Drive NW
Pierce County, Washington

DocID: KREWD.Artondale.SCS	August 2010	Figure 3



Approximate Site Location

An excerpt from the *Geologic Map of the Fox Island 7.5 minute Quadrangle, Pierce County, Washington* by Robert L. Logan, Timothy J. Walsh, and Kathy Goetz Troost (June 2006)

Not to Scale

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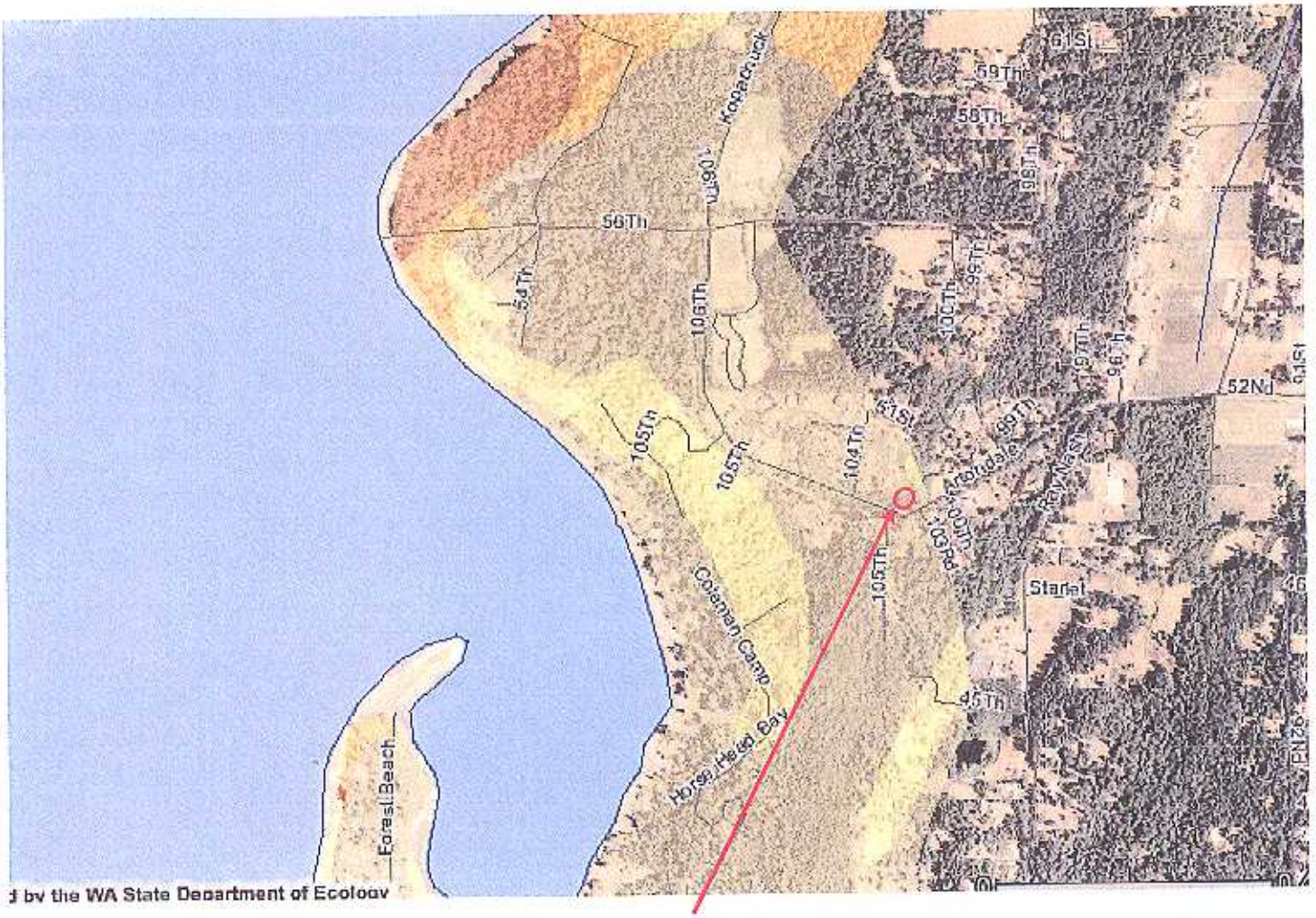
USGS Geologic Map

XXX Artondale Drive NW
Pierce County, Washington

DocID: KREWD.Artondale.USGS	August 2010	Figure 4



Approximate Site Location

Slope Stability

- Stable
- Intermediate
- Unstable
- Unstable Recent Landslide
- Unstable Old Landslide
- Modified

N W E S

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Coastal Zone Atlas

XXX Artondale Drive NW
Pierce County, Washington

DocID: KREWD.Artondale.CZA	August 2010	Figure 5

SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE GRAINED SOILS More than 50% Retained on No. 200 Sieve	GRAVEL More than 50% Of Coarse Fraction Retained on No. 4 Sieve	CLEAN GRAVEL	GW	WELL-GRADED GRAVEL, FINE TO COARSE GRAVEL
			GP	POORLY-GRADED GRAVEL
		GRAVEL WITH FINES	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	SAND More than 50% Of Coarse Fraction Passes No. 4 Sieve	CLEAN SAND	SW	WELL-GRADED SAND, FINE TO COARSE SAND
			SP	POORLY-GRADED SAND
		SAND WITH FINES	SM	SILTY SAND
			SC	CLAYEY SAND
FINE GRAINED SOILS More than 50% Passes No. 200 Sieve	SILT AND CLAY Liquid Limit Less than 50	INORGANIC	ML	SILT
			CL	CLAY
		ORGANIC	OL	ORGANIC SILT, ORGANIC CLAY
	SILT AND CLAY Liquid Limit 50 or more	INORGANIC	MH	SILT OF HIGH PLASTICITY, ELASTIC SILT
			CH	CLAY OF HIGH PLASTICITY, FAT CLAY
		ORGANIC	OH	ORGANIC CLAY, ORGANIC SILT
HIGHLY ORGANIC SOILS			PT	PEAT

NOTES:

1. Field classification is based on visual examination of soil in general accordance with ASTM D2488-90.
2. Soil classification using laboratory tests is based on ASTM D2487-90.
3. Description of soil density or consistency are based on interpretation of blow count data, visual appearance of soils, and or test data.

SOIL MOISTURE MODIFIERS:

Dry- Absence of moisture, dry to the touch

Moist- Damp, but no visible water

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

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Soil Classification System
XXX Artondale Drive NW
Pierce County, Washington

Hand Auger HA-1

Location: southeast of existing water towers, above ecology block wall, lower third of slope

Depth (inches)	Soil Type	Soil Description
0 - 6		Topsoil
6 - 28	SM	Light brown fine SAND with gravel (loose, moist)
28 - 66	SP	Brown fine to medium grained SAND with gravel (medium dense to dense at depth, moist) (Advance Outwash Sand)

Terminated at 5½ feet below ground surface at refusal.
Moderate caving observed within upper foot.
No groundwater seepage or significant mottling observed

Hand Auger HA -2

Location: upslope and west of existing water towers.

Depth (inches)	Soil Type	Soil Description
0 - 3		Topsoil
3 - 49	SP	Light brown fine SAND (loose, moist)
49 - 58	SP	Brown fine to medium grained SAND with gravel (medium dense to dense, moist) (Advance Outwash Sand)

Terminated at 4¾ feet below ground surface.
Moderate caving observed within upper foot.
No groundwater seepage or significant mottling observed

Hand Auger HA -3

Location: west of existing water towers.

Depth (inches)	Soil Type	Soil Description
0 - 30	SM	Light brown SAND with silt (loose, moist)
30 - 42	SP	Brown SAND with gravel (dense, moist) (Advance Outwash Sand)

Terminated at 3½ feet below ground surface.
Moderate caving observed within upper foot.
No groundwater seepage or significant mottling observed

Exposed Slope Soil Log

Location: north of existing water towers.

Depth (feet)	Soil Type	Soil Description
0 - ½		Topsoil & forest duff
½ - 4	SP	Light brown SAND (loose, moist)
4 - 6½	SP	Brown SAND with gravel with fine laminations (dense, moist) (Advance Outwash Sand)
6½ - 10	-	Covered by loose sand (colluvium)

Observed from height of exposed soils to ground surface of water tower pad area.
Moderate caving observed within upper foot.
No groundwater seepage or significant mottling observed

Logged by: R. M. Hadley **Excavated on: August 20, 2010**

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