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STORMWATER SITE PLAN

OFFICE COPY

for

RUNSTAD BEACH HOUSE

TPN 151024002000

Blakely Island, Washington

SAN JUAN COUNTY
COMMUNITY DEVELOPMENT & PLANNING
APPROVED PERMANENT SWPPP
Subject to terms and conditions of
Permit No. BUILD-10-0268
Approved by: CS Date: 8/30/10

August 2010

SAN JUAN COUNTY
COMMUNITY DEVELOPMENT & PLANNING
APPROVED CONSTRUCTION SWPPP
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S.J.C. COMMUNITY
AUG 26 2010
DEVELOPMENT & PLANNING

STORMWATER SITE PLAN
for
RUNSTAD BEACH HOUSE
TPN 151024002000
Blakely Island, Washington

This plan has been developed to conform to the content requirements of Volume I, Section 3.1.7 of the DOE Stormwater Management Manual, which provides a plan format and stipulates that the plan include information related to all other applicable requirements of the manual. Also included is the required Construction Stormwater Pollution Prevention (SWPP) plan required and described in Volume I, Section 3.1.6.

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Construction Stormwater Pollution Prevention Plan Page 15

Appendix A – Supplemental Site Information
NRCS supplemental Soil Mapping data
Hydrologic & Hydraulic Evaluation of Diversion Needs
Geotest Site Soils Investigation

Appendix B – Permanent Controls from DOE Stormwater Management Manual
BMP T5.10 – Downspout Dispersion
BMP T5.12 – Sheet Flow Dispersion
DOE Vol.III, Sect. 3.3.11.Infiltration Trenches
DOE Vol.V, Sect. 4.5.3 Outfall Systems

Appendix C – Construction Controls from DOE Stormwater Management Manual
BMP C105 – Stabilized Construction Entrance
BMP C121 – Mulching
BMP C123 – Plastic Covering (for erosion)
BMP C140 – Dust Control
BMP C151 – Concrete Handling
BMP C120 – Temporary and Permanent Seeding
BMP C201 – Grass-Lined Channel
BMP C232 – Gravel Filter Berm
BMP C233 – Silt Fence
BMP C234 – Vegetated Strip
BMP C240 – Sediment Trap

NOT INCLUDE IN THIS COPY

Project Overview

The proposed new Beach House is the second (along with the Cliff House) of two single-family homes to be developed on individual tax parcels within the 51.6 acre Runstad Estate at the south end of Blakely Island, as indicated in Figures 1 and 2. The locations are tax parcels recently modified by boundary line adjustments and (in the case of the Beach House) a simple land division for an unplatted parcel. Current estate development includes a main house, cabin, caretaker's home, boat house, several sheds and recreational facilities (tennis court and pool), as well as existing driveways and utilities serving the facilities. Existing development on the 10.9 acre lot where the Beach House is proposed includes the main common access road for properties at this end of the island and some unimproved access driveways to the shore from this roadway and from adjacent property to the east. Existing utilities are in the common roadway. The home site is mostly grass cover with forest upland and to either side and some tree cover along the south shoreline boundary. Slopes at the homesite are generally less than 20% toward the south shoreline, but steepen uphill to the north from the home site to as much as 40%. A new septic drainfield will be northeast of the new home. The project involves construction of a new home and garage, a new septic drainfield, extension of utilities to the house and a new driveway from the common access road above. All existing features have been in place for much longer than 2 years. Impervious areas present and proposed on the home site parcel are as follows:

Improvement (location ref.: Fig. 4 & 5)	Exist. Imperv. Area (sq.ft.)	New Imperv. Area (sq.ft.)	Total (sq.ft.)
ROOF/DECK:			
Proposed home roof		4,818	
Terrace and Path (beyond roof)		620	
TOTAL IMPERV. ROOF/DECK or PATH:		5,438	5,438
DRIVEWAY/PARKING (PGIS):			
Existing Road/Driveway	6,000		
New Driveway & Turn-around		6,300	
TOTAL PGIS:	6,000	6,300	12,300
TOTAL IMPERV. SURFACE:	**6,000**	**11,738**	**17,738**

Disturbed area for the construction of the proposed new home, garage, driveway, and utility improvements is estimated to be 25,000 sq. ft. (0.574 ac.), well below the DOE 3/4 acre threshold for native land conversion. Cut and fill work for the home siting (including grading to stabilize the uphill slope) is estimated to involve approx. 400 cu. yds. of cut and 80 cu. yds. of granular fill beneath slabs and at foundation drains. Appurtenant structure grading is estimated to be 70 cu. yds of cut and fill for utility trenching and septic drainfield as well as another 170 cu. yds. of driveway cut with approximately 90 cu. yds of granular road base surfacing within the 200 ft. shoreline setback and another 40 cu. yds. of cut and 25 cu. yds. of granular road base surfacing of driveway area uphill beyond the 200 ft. shoreline setback.

RUNSTAD BEACH HOUSE

Vicinity Map with Site & Topography Delineated

(from USGS, WA Quadrangle Maps)

Scale: 1" = 1,000'

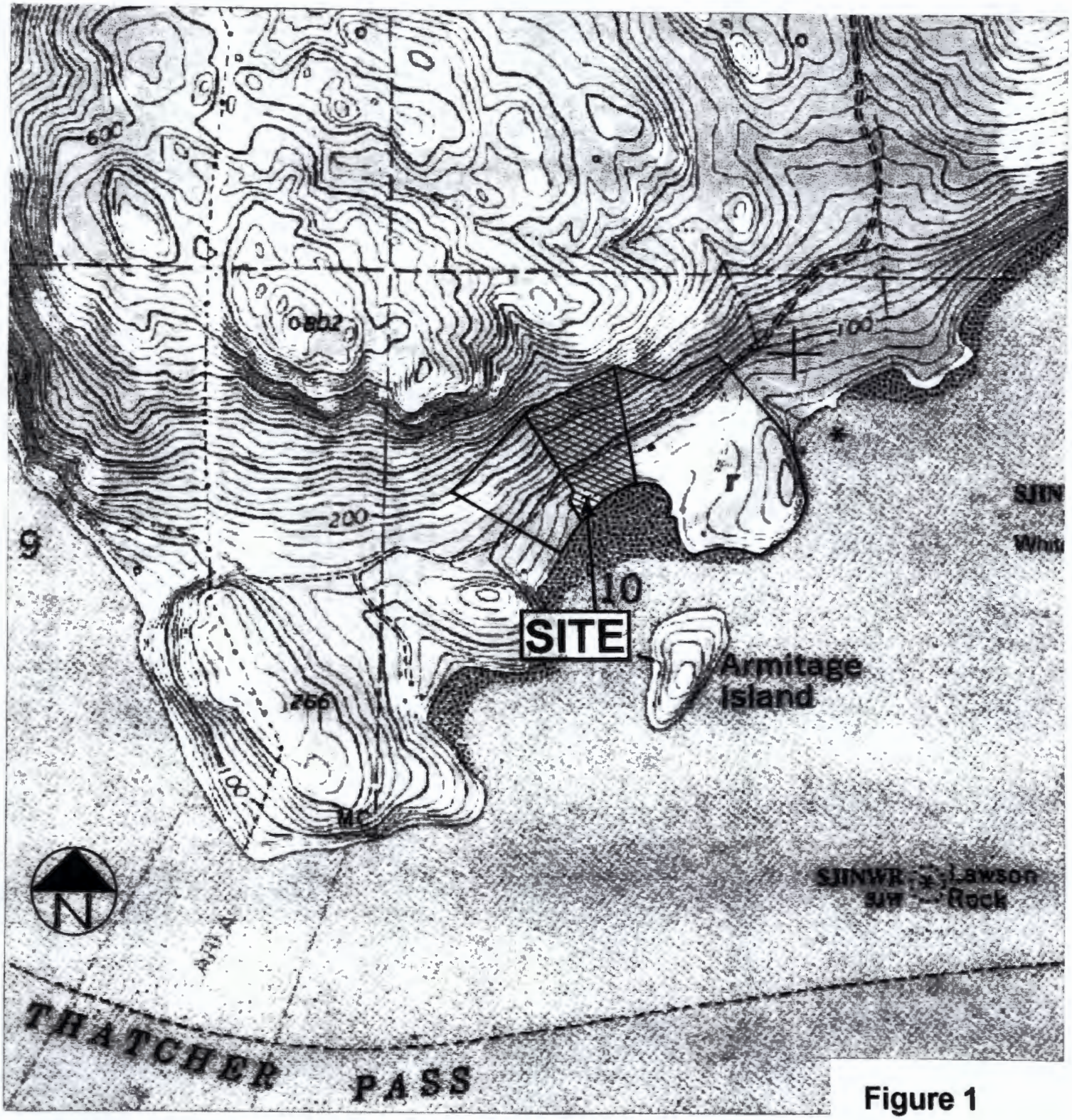


Figure 1

Existing Conditions Summary

The Runstad Estate is in a mostly forested area at the south end of Blakely Island. Existing development has resulted in large grassy areas and a pond surrounding improvements that include a main house (The Great House) along with a boat house, cabin, caretaker's house, pool, tennis court, and several service sheds and related driveways for access. Most of these improvements are in the flatter areas of the site where ground slope is approximately 10% or less. The estate fronts on the shoreline of Rosario Strait in northern Puget Sound. The proposed new Beach House is located on a relatively flat grassy area along the shoreline. The shoreline bank drops off onto a gravelly beach at the south boundary of the property. An existing common access road for the south end of the island crosses the property above the homesite and includes power and water utilities. The home site is currently undeveloped with unimproved driveways coming down from the common access road and from adjacent lot improvements along the shoreline to the east. Slopes at the new home site are 20% or less toward the southerly shoreline and steepen to as much as 40% above the home site. Tributary runoff toward the home site is from the steep hillside above and could be significant. An aerial photo is provided in Appendix A to further indicate site conditions.

The U.S. Natural Resources Conservation Service 2007 *Soil Survey for San Juan County* classifies the soil cover at the site. The proposed Beach House site is located in an area classified as Hoypus sandy loam, 10 to 40% slopes (Unit 3012 on mapping provided in Figure 3). This material is classified in Hydrologic Soil Group A (high infiltration rate, low runoff potential). It should be noted, however, that the soil cover for much of the upland tributary hillside area above the home has a high (Hydrologic Soil Group D) runoff potential. More specific NRCS data is presented in Appendix A. In addition, a site-specific investigation was conducted by GeoTest (copy of report in Appendix A) indicating a presence of clayey material at shallow depth that may inhibit surface infiltration in many locations.

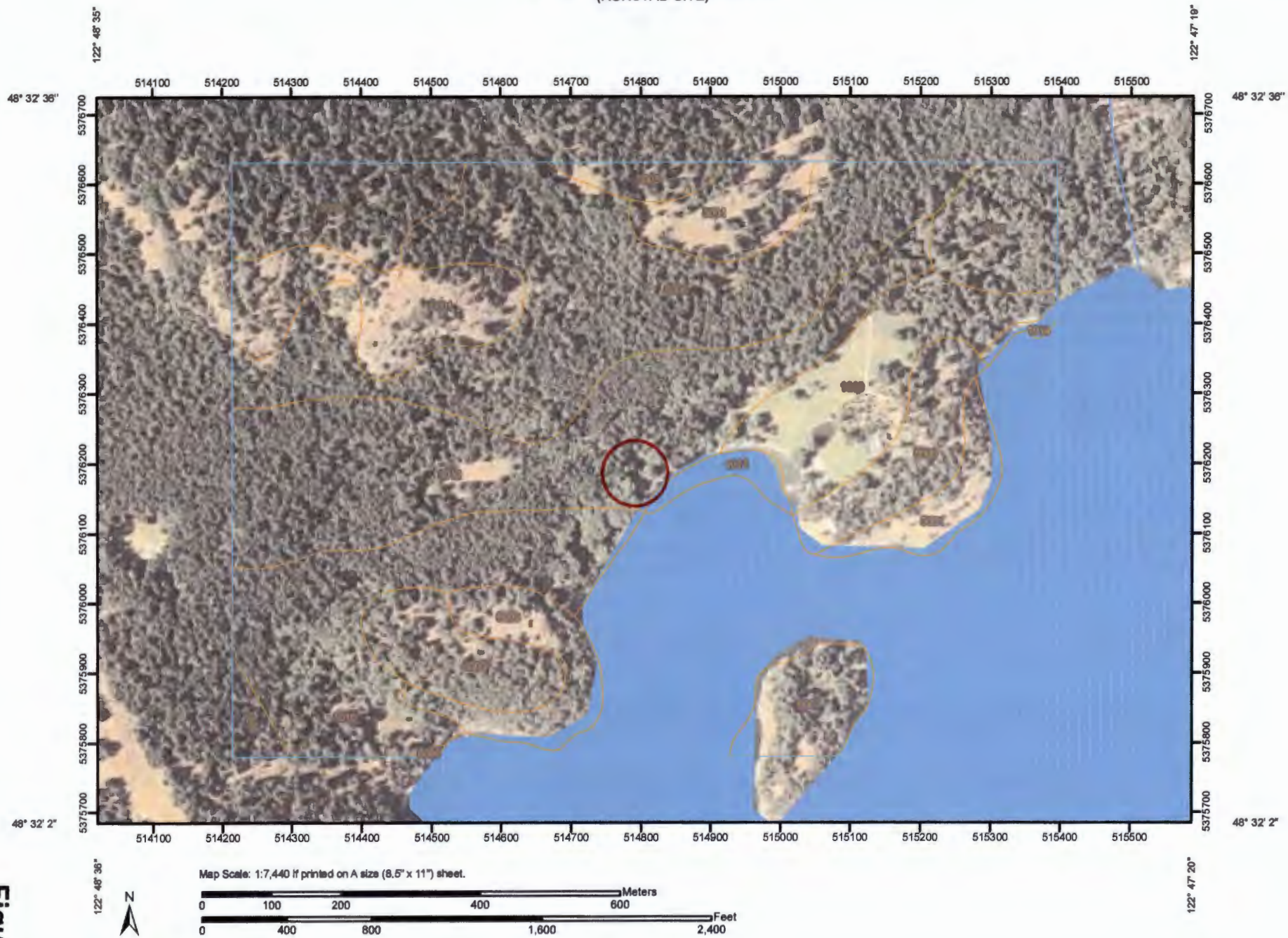
Permanent Stormwater Control Plan

The following discussion of compliance with stormwater control requirements describes means to be used for stormwater control at the proposed new house and garage at this site. Figures 4 and 5 indicate the proposed development improvements and runoff control provisions to meet plan objectives in Requirements #3 through #10. The applicability of each requirement and proposed plan features are as summarized below:

1. Source Control of Pollution (Requirement #3):

The presence of a home or cabin does not normally represent a significant potential pollution source, and no activity proposed relative to this new construction would be expected to introduce any new source of pollution other than normal household septic waste that will be handled in a new state-of-the-art permitted septic system. In addition, other site activities will be unchanged from what has historically occurred for the other existing estate improvements, with maintenance supplies and equipment being stored at existing locations off the home site where they are already stored and used for other estate maintenance.

Soil Map—San Juan County, Washington
(RUNSTAD SITE)



USDA Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

6/23/2010
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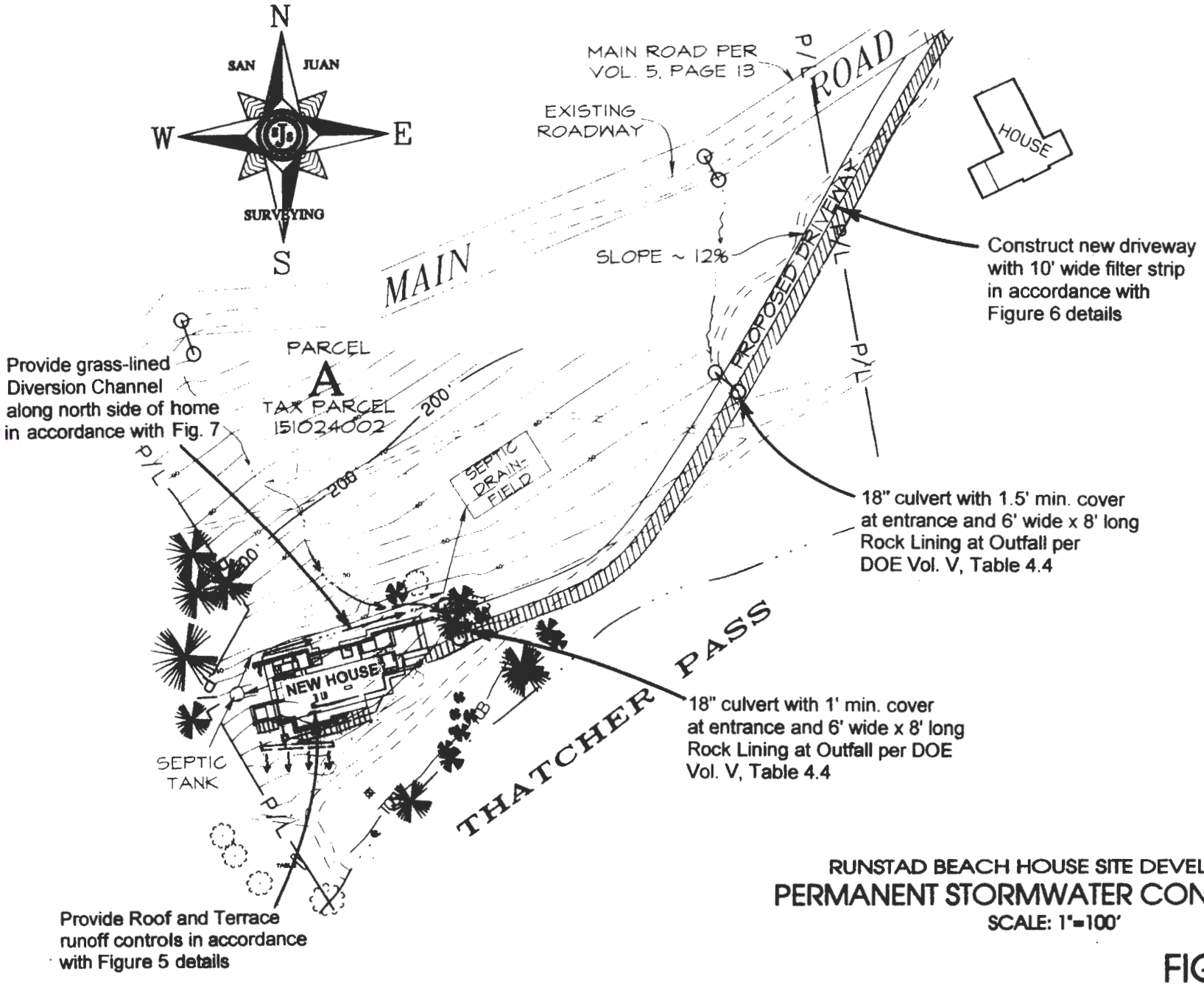
Figure 3



RUNSTAD BEACH HOUSE SITE DEVELOPMENT

PERMANENT STORMWATER CONTROL PLAN

SCALE: 1"=100'

FIGURE 4

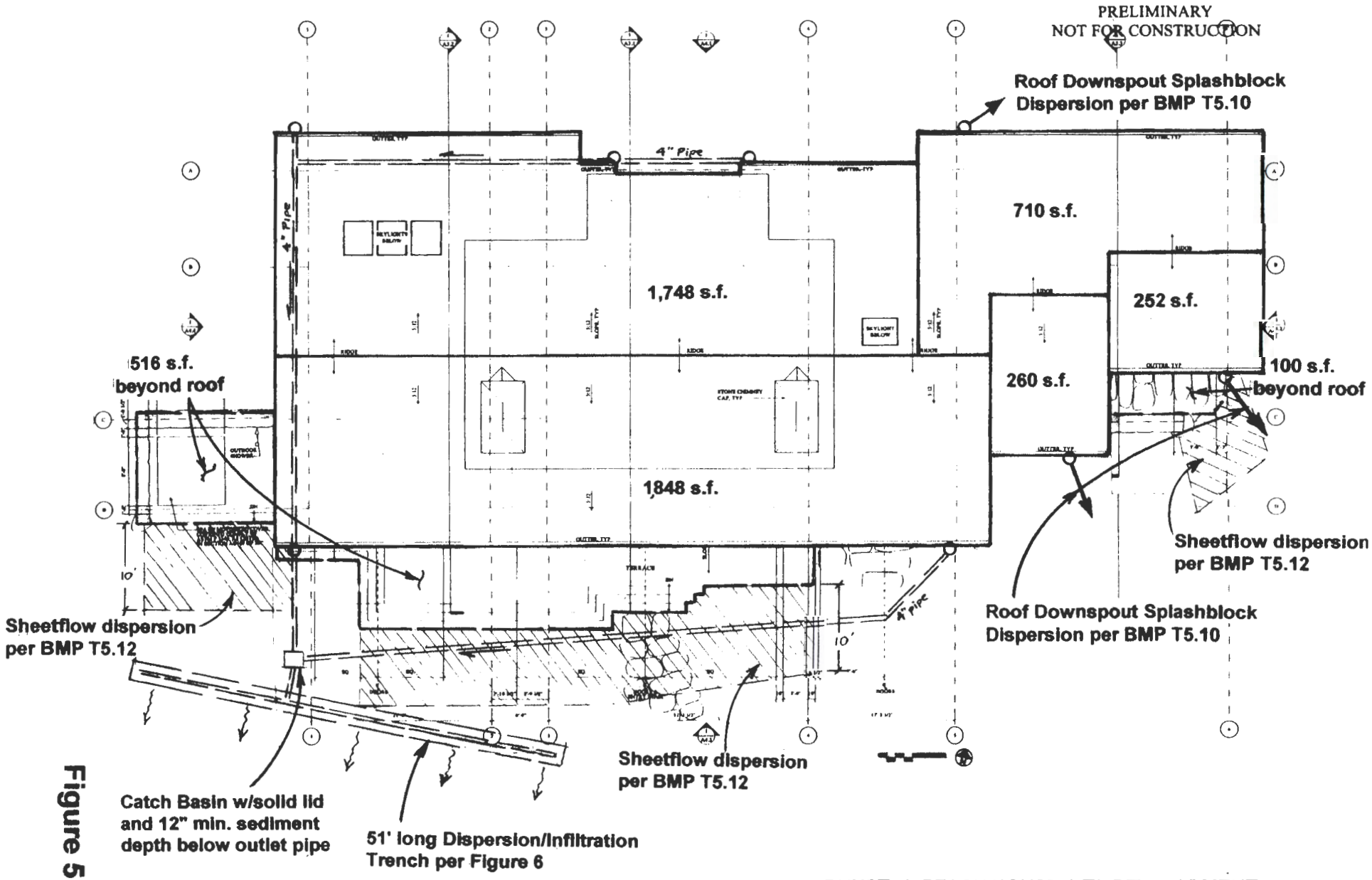


Figure 5

RUNSTAD BEACH HOUSE SITE DEVELOPMENT

House Roof/Terrace Runoff Control

Scale: 1/16" = 1' – 0"

2. Preservation of Natural Drainage Systems and Outfalls (Requirement #4):

Drainage from the project will be dispersed in the vicinity of the improvements in a manner similar to the existing natural sheet runoff pattern across the home site. Much of the hillside north of the home collects in an existing drainage swale from a main access road culvert and is routed toward the east end of the home site. This drainage route will be channeled to a new culvert beneath the driveway at the east end of the home and maintain its current route south toward the shoreline. Similarly, a significant portion of the watershed above the upper portion of the proposed driveway also collects in a swale that discharges from an existing road culvert and will also be routed through a new culvert across the proposed driveway to maintain its existing flow pattern toward the shore. The new driveway will maintain any residual sheet flow from the hillside by avoiding ditch construction and routing cross-flow toward the grass vegetated slope on its downhill side.

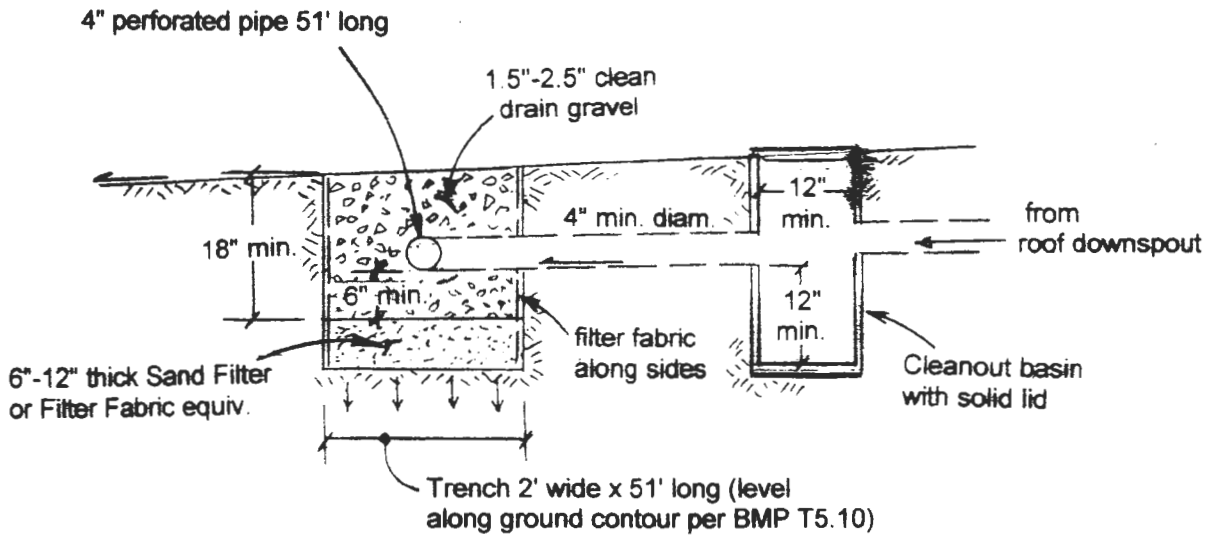
3. On-site Stormwater Management (Requirement #5):

The total proposed new impervious cover for the site is 11,738 sq. ft., with 6,300 sq. ft. of this being the new driveway. The driveway impervious surface area (PGIS) does exceed the threshold requiring treatment, but the wide grassy hillside slope downgradient will provide effect treatment as discussed in Section 4 regarding Requirement #6. Soil classification for the site identifies it as a Hydrologic Soil Group A (high infiltration potential) site; however, the geotechnical report for the site (copy in Appendix A) notes a presence of less permeable clay material in many shallow depth areas, making reliance on widespread infiltration capability unreliable. Since no fresh water resources exists at or downgradient from the site that would make flow control necessary, all aspects of stormwater control will focus on dispersion of runoff to avoid erosion and basic treatment of driveway runoff.

Roof runoff will be handled by a combination of techniques conforming to options available in DOE's BMP T5.10, as noted in Figure 5. The small roof segments at the garage (east) end will be handled at downspout splashblocks. The remainder of the house roof will be routed to a 51 ft. long dispersion /infiltration trench sufficient for the 3,596 sq. ft. area (based on 10 lin.ft. per 700 sq. ft. of roof area, per BMP T5.10). The trench will be designed to incorporate infiltration trench standards (mostly adding filter material) described in DOE Volume III, Section 3.3.11 to maximize infiltration potential anticipated, while still relying on dispersion criteria as a primary control mechanism. The infiltration potential and lack of other nearby impervious runoff will overcome the 50 ft. length limitation in BMP T5.10. The proposed trench detail is indicated in Figure 6.

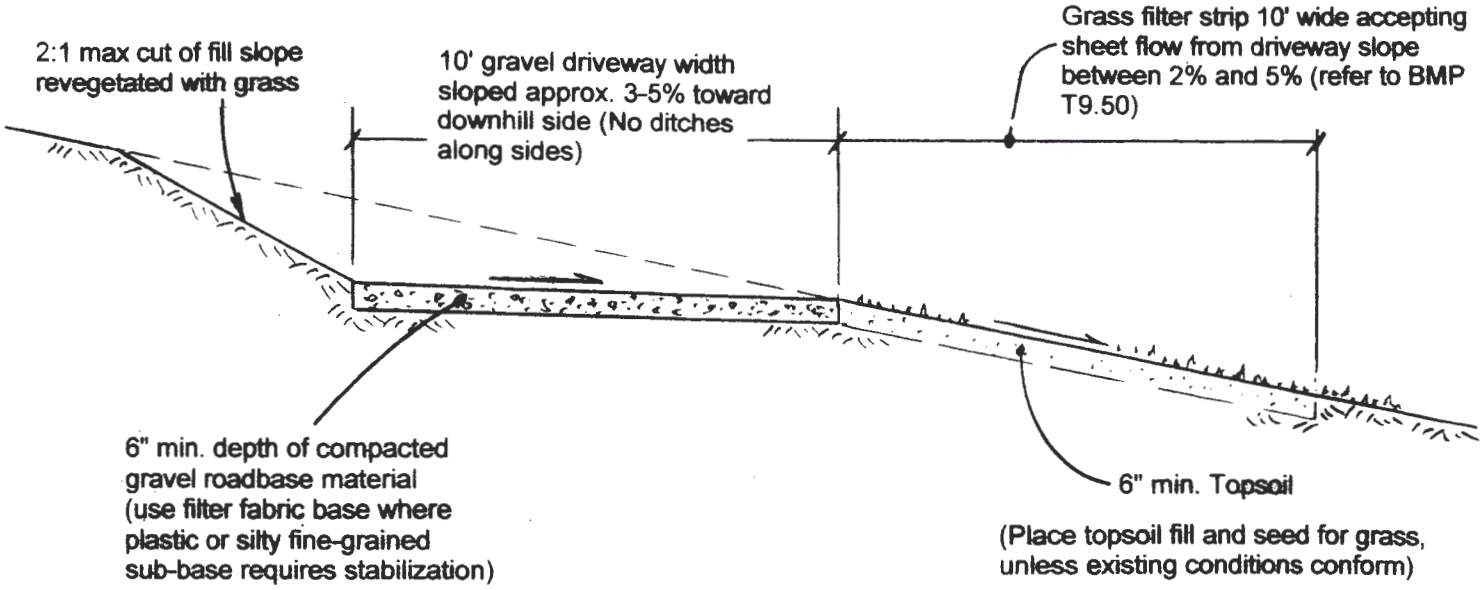
Driveway, deck and pathway runoff will be dispersed as sheet flow into adjacent vegetation in accordance with BMP T5.12.

In addition to control of runoff from new impervious surfaces, a primary need at this location will be diversion of potential runoff from two hillside tributaries and drainage channels immediately above the home site and the driveway. Analysis



Dispersion/Infiltration Trench or Sump

Scale: 1/2" = 1' – 0"



Driveway Section

Scale: 1/4" = 1' – 0'

RUNSTAD BEACH HOUSE SITE DEVELOPMENT

Construction Details

Figure 6

of these conditions using a unit hydrograph analysis of peak runoff (copy of analysis provided in Appendix A) indicates the 100-yr, 24-hr peak runoff for the 14.3 ac. tributary above the home site and the 17.6 ac. tributary above the proposed driveway is 9.2 c.f.s. and 11.3 c.f.s., respectively. The GeoTest report suggested that some measures might be taken to mitigate some of the runoff above the home site through improvements along the existing main access road; however, the effectiveness of this is not certain and the approach taken here is to conservatively provide for total flows estimated. Hydraulic analysis indicates that 18" diam. culverts are needed at both locations with entrance conditions requiring at least 0.75' of cover at the homesite culvert and 1.5' of cover along the upper driveway to avoid overtopping. The outfalls from culverts will be protected with rock in accordance with DOE Vol. V, Section 4.5.3. In addition, a diversion channel is proposed to be constructed along the uphill side of the home as part of the site preparation work. This and specific requirements to maintain channel capacity from the hillside channel to the culvert around the east end of the home are indicated in Figure 7. The channel improvements will be stabilized during construction with grass cover in accordance with BMPs C120 and C201.

4. Runoff Treatment (Requirement #6):

The proposed new pollution-generating impervious surface (PGIS) for the new driveway is estimated at 6,300 sq. ft., which exceeds the DOE basic treatment threshold. Fortunately, the driveway will be constructed along a grassy hillside that is mostly at or near a 20% sideslope and will be developed as a minor "cut" rather than cut and fill (detail shown on Figure 6) in order to protect the existing grassy vegetated slope integrity along the downhill side of the driveway. This will make it possible to provide filter strip treatment of driveway sheetflow runoff in accordance with BMP T9.50 along this lightly-traveled driveway.

5. Flow Control (Requirement #7):

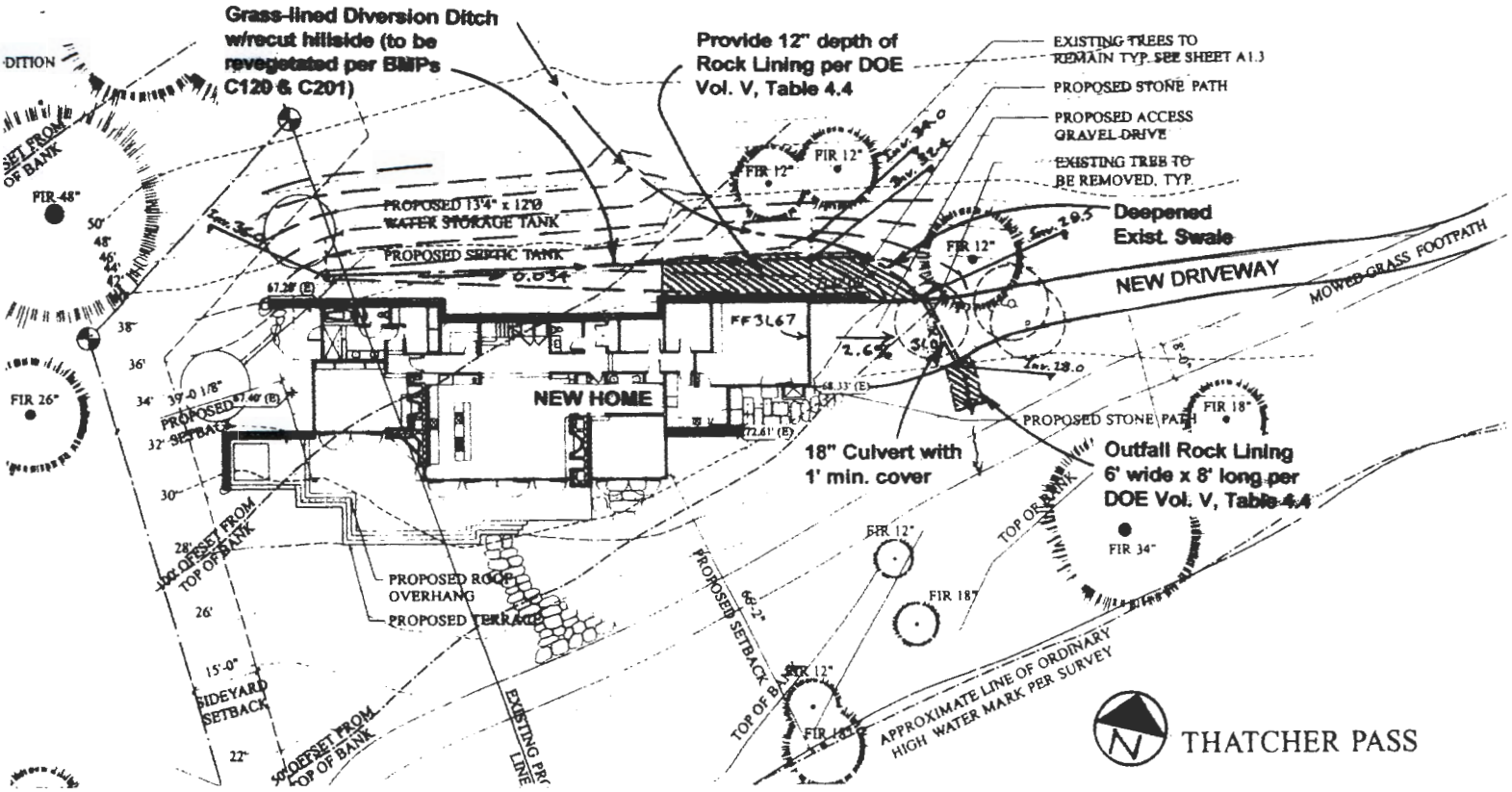
The project does not effect fresh water resources on site or downgradient; so no requirement for flow control is present. No specific flow controls beyond dispersal of runoff are required or proposed.

6. Wetlands Protection (Requirement #8):

No wetlands of concern have been identified on site or downstream to the shoreline discharge; therefore, Minimum Requirement #8 does not apply.

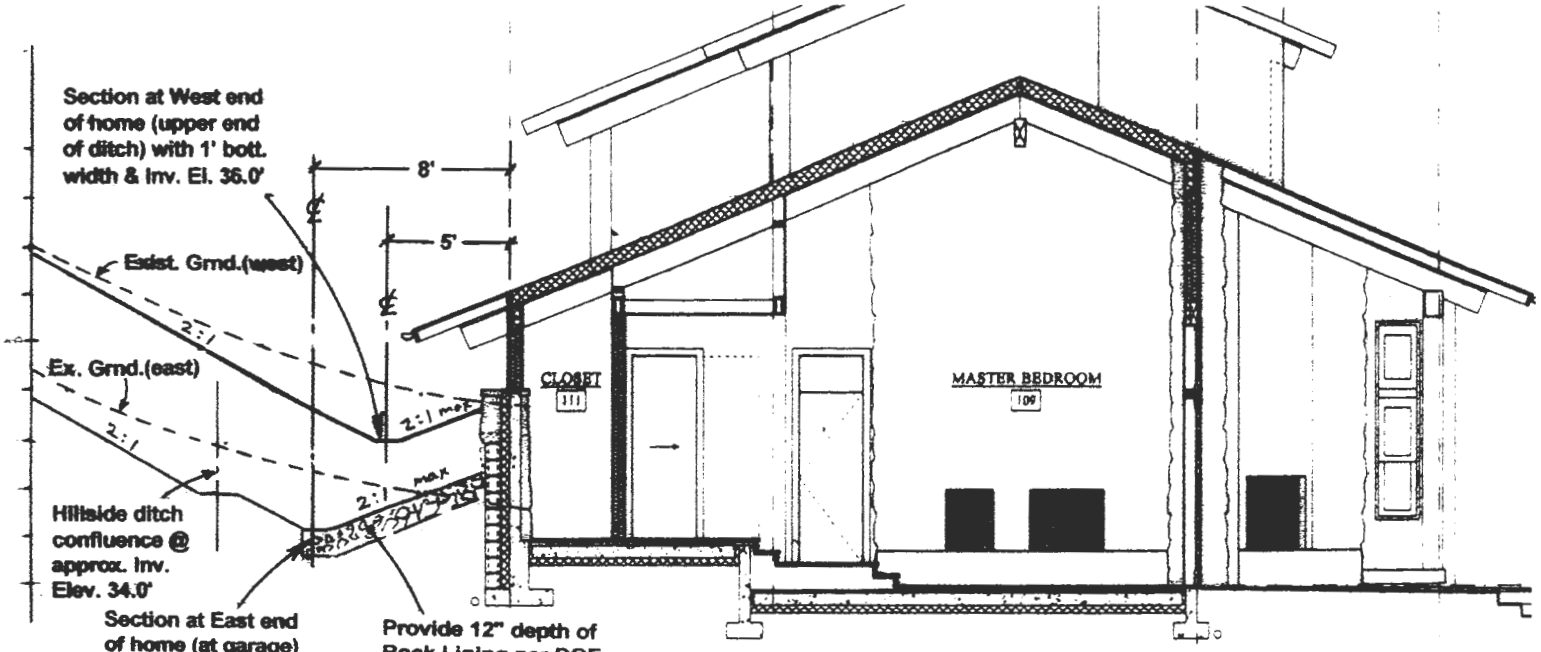
7. Basin/Watershed Planning (Requirement #9):

We are not aware of any current basin or watershed planning effort that would effect the actions proposed at this site. For this reason, no special considerations are proposed to address Basin/Watershed Planning compliance mentioned in Minimum Requirement #9.



Plan View

1"= 40'



Section

1/8" = 1'-0"

RUNSTAD BEACH HOUSE SITE DEVELOPMENT

Diversion Ditch along Uphill Wall

Figure 7

8. Operations and Maintenance (Requirement #10):

Operation and Maintenance to assure effectiveness of the control measures proposed will require the following:

a. Roof gutters and downspouts shall be maintained to assure their effectiveness in collecting runoff and conveying it to dispersion facilities. Gutter cleaning shall occur at least annually in the fall.

b. The catch basin structures set ahead of the roof downspout discharge lines to collect debris from roof drains prior to entering the perforated-pipe and subsurface drain material shall be inspected and cleaned as needed -- at least annually in the fall.

c. Culverts beneath the driveway or paths shall be kept clear of debris and sediment.

d. Crushed rock or gravel flow spreading areas shall be maintained to assure creation of sheet flow conditions into vegetative buffers. Debris and sediment shall be cleaned at least annually in the fall to the extent necessary to maintain intended flow patterns.

e. The vegetated cover at grass channels, dispersion zones and filter strips (as required in the appropriate BMP) shall be maintained in a manner that preserves their effectiveness in treating and dispersing flow.

RUNSTAD BEACH HOUSE
Blakely Island, WA

Construction Stormwater Pollution Prevention Plan

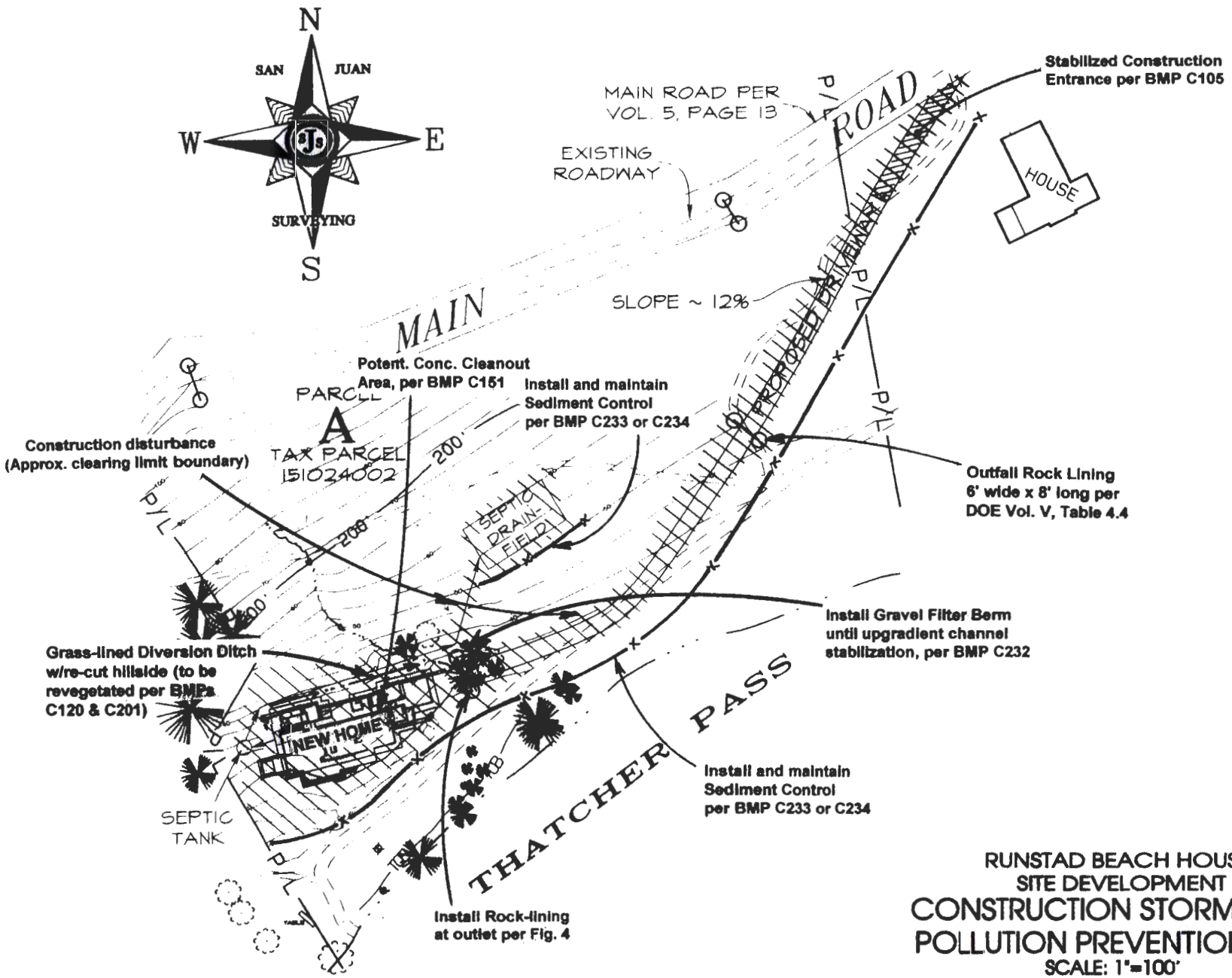
Minimum Requirement #2 is the creation of a Construction Stormwater Pollution Prevention (SWPP) Plan that will be composed of 12 elements as herein described. The contractor will be given a copy of this plan (including Appendix C copies of the DOE Best Management Practices referenced) upon its approval to further clarify work limits and requirements. Figure 8 provides a reference for the location of specifically-located measures discussed in this plan.

1. Mark Clearing Limits
   All construction activity shall be confined to the building, driveway, and septic drainfield sites. The boundary for the anticipated disturbed area is indicated in Figure 8. Access will be limited to the permanent driveway location. Establishment of silt fence sediment barriers or security fence marking will sufficiently mark the clearing and construction limits. Security fence will consist of bright-colored plastic security fencing or metal mesh fencing strung between metal or wood posts to a height of at least 30". All clearing activity and stockpiling of equipment and material for construction will be confined to the designated construction site.

2. Establish Construction Access
   Access will be restricted off the existing main access road to the proposed new gravel-stabilized driveway in from the east end of the home site. This driveway will be stabilized in the vicinity of the work site to conform to the stable entrance requirements of BMP C105. In the event that any sediment or other materials fall from trucks or equipment onto the driveway, this material will be cleaned-up the same day.

3. Control Flow Rates
   The upland hillside tributaries represents significant enough potential inflow sources that completion of work during the dry season when virtually no runoff is common for 3 or 4 months provides that best means for control of flow rates, in that permanent culvert and diversion channel improvements can be in place and stabilized before inflow occurs. Prior to this, any unusual flow that does occur would be anticipated to be small enough that the normal sediment control measures provided around the disturbed work areas (Item No. 4, below) will be sufficient to provide control.

4. Install Sediment Controls
   Sediment control is to be provided by use of filter fabric silt fence (BMP C233) or a vegetated strip (BMP C234) at the downgradient sides of the construction area. Locations for sediment controls along the downhill side of the work area are indicated in Figure 8.



RUNSTAD BEACH HOUSE
SITE DEVELOPMENT

CONSTRUCTION STORMWATER POLLUTION PREVENTION PLAN

SCALE: 1"=100'

FIGURE 8

5. Stabilize Soils

Exposed areas of disturbed soil shall be stabilized using the DOE-approved best management practices (BMPs) as necessary to meet the following required time limitations for exposed soils on site, whether at final grade or not:

- From October 1 through April 30, no soils shall remain exposed and unworked for more than 2 days.
- From May 1 to September 30, no soils shall remain exposed and unworked for more than 7 days.

Applicable practices that are available to stabilize soils include BMPs from the DOE manual that are included in the appendix. The following practices are specified for the work at this site:

Mulching of future lawn or landscape areas
Plastic Covering or stockpiled soil or other erodible material
Early application of gravel base material on future driveway or concrete slab surfaced areas
Dust Control as needed to address any residual issues that occur with the above controls in place.

Stockpiles of soil or other erodible material shall be located where they are least likely to experience erosion from runoff in the surrounding area and shall be given special erosion control consideration (covering, etc.) due to the added sedimentation potential created by the pile side slopes.

6. Protect Slopes

The home will be designed to fit the natural topography to the extent possible. However, some minor grading along slopes on uphill side of the new driveway and for the diversion channeling behind the new home will create slopes that will need to be revegetated. Slopes along the driveway are expected to be short and present no significant issues. More attention will be needed for the work behind the home. Precautions at the home site excavation and at soil stockpiles will be implemented to minimize slope erosion. Where exposed earth slopes occur, they shall be protected in an appropriate manner such as the following:

a) Minimize the continuous length of slopes with terraces or diversions and reduce slope steepness or roughen surface to reduce velocity.
b) Divert flow away from slope at top
c) Contain downslope collected flows in pipes, slope drains, or protected channels
d) Provide drainage to remove ground water intersecting the slope surface or exposed soil areas.
e) Excavated material shall be placed on the uphill side of trenches, consistent with safety and space considerations
f) Check dams shall be placed at regular intervals within trenches that are cut down a slope
g) Stabilize soils on slopes, as specified in Element Item 5.

7. Protect Drain Inlets
No drain inlets are proposed for the site.

8. Stabilize Channels and Outlets
The new channel work behind the home will be revegetated with grass, but some attention to stabilization per Section 6 above and BMP C201 will need to be applied to avoid erosion if not stabilized prior to the wet season. New culverts across driveways will be provided with rock outfall protection per DOE Vol. V, Sect. 4.5.3 during there construction (see notes on Figure 4). Where disturbed ground is present upgradient, a gravel berm consistent with BMP C232 will be maintained until stable vegetative cover is provided.

9. Control Pollutants
All materials used during construction that represent potential sources of pollution shall be stored in a manner that prevents their introduction into storm water. In general, this means they need to be stored in covered areas not subject to direct runoff or flow from surrounding area runoff. More specifically:
   a) Pollutants, including waste material and demolition debris, shall be handled and disposed of in a manner that does not cause contamination of stormwater
   b) Cover, containment, and protection from vandalism shall be provided for all chemicals, liquid products, petroleum products, and non-inert wastes present on the site
   c) Maintenance and repair of heavy equipment and vehicles involving oil changes, hydraulic system drain down, solvent and de-greasing cleaning operations, fuel tank drain down and removal, and other activities which may result in discharge or spillage of pollutants to the ground or into stormwater runoff must be conducted using spill prevention measures, such as drip pans. Contaminated surfaces shall be cleaned immediately following any discharge or spill incident. Emergency repairs may be performed on-site using temporary plastic placed beneath and, if raining, over the vehicle.
   d) Application of agricultural chemicals, including fertilizers and pesticides, shall be conducted in a manner and at application rates that will not result in loss of chemical to stormwater runoff. Manufacturers' recommendations shall be followed for application.
   e) Management of pH-modifying sources shall prevent contamination of runoff and stormwater collected on the site. These sources include, but are no limited to bulk cement, fly ash, new concrete washing and curing waters, waste streams generated from concrete grinding and sawing, exposed aggregate processes, and concrete pumping and mixing waters. Concrete handling shall conform to procedures in BMP C151, which requires all washdown water or other discharged material that may contain Portland cement residue to be discharged into confined formed areas destined for future concrete placement. This would include the footprint for the home and garage.

10. Control De-Watering

No de-watering operations are anticipated; however, in the event that unforeseen water is encountered in foundation or utility trench work that necessitates de-watering, all water will be discharged to a temporary sediment trap prior to release as part of the site runoff. The sediment trap shall conform to BMP C240 for sediment removal prior to discharge. Such excavations shall be completed in a way that prevents overland runoff from entering them (selective placement of spoils), such that only the de-watering pump discharge represents the inflow to the trap. Considering that the de-watering rate will be limited to groundwater inflow seepage rate to the trench and typical de-watering pump capacity would not be expected to exceed 5 gpm, the criteria in BMP C240 indicate that a 23 sq. ft. surface area for the trap would be sufficient. Where such a trap is needed, it is proposed that a 6 ft. x 6 ft. surface area be created to maintain the 6 ft. gravel discharge width specified in BMP C240.

11. Maintain BMPs

The primary controls during construction will be sediment controls on downgradient boundaries of the work area. Frequent inspection of these facilities and immediate repair of deficiencies, cleaning of sediment buildup, etc. will assure reasonable control at the site. All control features shall be inspected at least weekly and maintained in accordance with the appropriate BMP.

12. Manage the Project

Specific construction activity shall not occur until a site plan has been approved by the San Juan County Building Department or septic siting approval obtained from the San Juan County Health Department. In addition, a copy of any county approval shall be provided to the contractor for implementation. A copy of any permit provisions and this plan shall be kept at the site throughout construction. Any modification of the SWPP plan must be approved by San Juan County.

Utility companies and subcontractors shall be advised of permit and SWPP plan provisions prior to working at the site.

Site design features were developed to minimize adverse stormwater effects permanently and during construction; therefore, few if any specific treatment features are anticipated that require ongoing regular inspection. However, San Juan County reserves the right to request sampling and analysis of stormwater discharge to ensure compliance with DOE standards, and reserves the right to request that the party engaged in construction retain a Certified Professional in Erosion and Sediment Control to be on call for consulting and inspection. (This certification is provided by several regional programs such as are provided by the Washington State Department of Transportation (WSDOT) and Associated General Contractors (AGC).

APPENDIX A

SUPPLEMENTAL SITE INFORMATION

NRCS Soil mapping reference material
GeoTest Site Soil Investigation
Hydrologic & Hydraulic Evaluation of upgradient watersheds

Runstad Site

1:4800

This data has been compiled for San Juan County. Various official and unofficial sources were used to gather this information. Every effort was made to ensure the accuracy of this data, however, no guarantee is given or implied as to the accuracy of said data.

Map Unit Legend

San Juan County, Washington (WA055)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
1010	Deadmanbay-Morancreek complex, 2 to 15 percent slopes	38.1	15.4%
1014	Beaches-Endoaquents, tidal-Xerorthents association, 0 to 5 percent slopes	2.6	1.0%
2010	Whidbey-Hoypus complex, 2 to 15 percent slopes	7.4	3.0%
3012	Hoypus sandy loam, 10 to 40 percent slopes	37.0	14.9%
5000	Cady-Rock Outcrop complex, 5 to 30 percent slopes	17.1	6.9%
5001	Rock Outcrop-Haro complex, 25 to 75 percent slopes	22.3	9.0%
5006	Cady-Doebay-Rock Outcrop complex, 25 to 75 percent slopes	43.1	17.4%
5007	Haro-Hiddenridge-Rock Outcrop complex, 5 to 30 percent slopes	5.9	2.4%
5008	Doebay-Cady-Rock Outcrop complex, 10 to 30 percent slopes	12.2	4.9%
5009	Haro-Hiddenridge-Rock Outcrop complex, 25 to 75 percent slopes	7.3	2.9%
Subtotals for Soil Survey Area		**192.9**	**77.6%**
Totals for Area of Interest		**248.4**	**100.0%**

Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — San Juan County, Washington				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
1010	Deadmanbay-Morancreek complex, 2 to 15 percent slopes	C	38.1	15.4%
1014	Beaches-Endoaquents, tidal-Xerorthents association, 0 to 5 percent slopes	D	2.6	1.0%
2010	Whidbey-Hoypus complex, 2 to 15 percent slopes	B	7.4	3.0%
3012	Hoypus sandy loam, 10 to 40 percent slopes	A	37.0	14.9%
5000	Cady-Rock Outcrop complex, 5 to 30 percent slopes	D	17.1	6.9%
5001	Rock Outcrop-Haro complex, 25 to 75 percent slopes	D	22.3	9.0%
5006	Cady-Doebay-Rock Outcrop complex, 25 to 75 percent slopes	D	43.1	17.4%
5007	Haro-Hiddenridge-Rock Outcrop complex, 5 to 30 percent slopes	D	5.9	2.4%
5008	Doebay-Cady-Rock Outcrop complex, 10 to 30 percent slopes	D	12.2	4.9%
5009	Haro-Hiddenridge-Rock Outcrop complex, 25 to 75 percent slopes	D	7.3	2.9%
Subtotals for Soil Survey Area			**192.9**	**77.6%**
Totals for Area of Interest			**248.4**	**100.0%**

San Juan County, Washington

3012—Hoypus sandy loam, 10 to 40 percent slopes

Map Unit Setting

Elevation: 0 to 400 feet
Mean annual precipitation: 20 to 35 inches
Mean annual air temperature: 48 to 50 degrees F
Frost-free period: 200 to 240 days

Map Unit Composition

Hoypus and similar soils: 95 percent
Minor components: 5 percent

Description of Hoypus

Setting

Landform: Hillslopes
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Glacial outwash

Properties and qualities

Slope: 10 to 40 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Low (about 3.5 inches)

Interpretive groups

Land capability classification (irrigated): 7e
Land capability (nonirrigated): 6e
Ecological site: Pseudotsuga menziesii-Arbutus menziesii/ Holodiscus discolor/Goodyera oblongifolia (F002XN901WA)

Typical profile

0 to 1 inches: Slightly decomposed plant material
1 to 5 inches: Sandy loam
5 to 20 inches: Loamy sand
20 to 36 inches: Very gravelly loamy sand
36 to 60 inches: Extremely gravelly sand

Minor Components

Rock outcrop

Percent of map unit: 5 percent

Data Source Information

Soil Survey Area: San Juan County, Washington
Survey Area Data: Version 10, Sep 28, 2009

GEOTECHNICAL ENGINEERING EVALUATION

Proposed New "Beach House" Residence

Runstad – Whaleback Estate
Blakely Island, Washington

August 17, 2010

Prepared for

Jon Runstad

GEOTEST

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Bellingham, Washington

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August 17, 2010
Job No. 10-0351

Jon Runstad
C/o Sullivan Conrad Architects
1305 East Jefferson Street
Seattle, WA 98122

Attn.: Jon Runstad

Re: Geotechnical Engineering Evaluation *for*
Proposed New "Beach House" Residence
Runstad - Whaleback Estate
Blakely Island, Washington
Unplatted Parcel, Proposed Parcel A (10.62 Acres)

Dear Mr. Runstad,

As requested, GeoTest Services, Inc. is pleased to submit this report summarizing the results of our geotechnical engineering evaluation for the proposed single family residence "Beach House" to be located on the proposed 10.62 acre Parcel A lot on Blakely Island, Washington (see Figure 1, Vicinity Map). The purpose of this evaluation is to establish general subsurface conditions beneath the site from which conclusions and recommendations for foundation design and general site development can be formulated. Specifically, our scope of services included the following tasks:

- Near surface exploration of soil and groundwater conditions underlying the site by excavating four exploratory test pits with a tractor mounted backhoe.
- Laboratory testing on representative samples in order to classify and evaluate the engineering characteristics of the soils encountered.
- Provide this written report containing a description of subsurface soil and groundwater conditions, test pit logs, findings and recommendations pertaining to site preparation and earthwork, fill and compaction, wet weather earthwork, erosion control, seismic design, foundation recommendations, concrete slab-on-grade construction, foundation and site drainage/infiltration potential, utilities, temporary and permanent slopes, slope stability, roof downspout runoff control, geotechnical consultation and construction monitoring.

PROJECT DESCRIPTION

We understand that there are plans to construct a new wood frame single family residence referenced as the "Beach House". The residence will be generally one story with a partial second story loft. The structure will be supported by a conventional shallow cast-in-place concrete foundation with slab-on-grade floor. The proposed structure will be located approximately 50 feet back from the shoreline along a small un-

named bay along Thatcher Pass. The proposed residence main finish floor elevation is still undetermined at this time, however it will most likely be located at approximately elevation 30 based on the preliminary topographic site plan, dated June 18, 2010, provided by Sullivan Conard Architects. The proposed new driveway will consist of a single lane gravel drive that splits from the main road near the existing caretaker's residence and traverses the existing slope terminating at the east end of the residence.

SITE CONDITIONS

This section discusses the general surface and subsurface conditions observed at the project site at the time of our field investigation. Interpretations of the site conditions are based on the results of our review of available information, site reconnaissance, subsurface explorations, laboratory testing, and our experience in the project vicinity.

General Geologic Conditions

Geologic information for the project site was obtained from the interactive *Geologic Map of Washington State*, published by the Washington State Department of Natural Resources (DNR). According to the DNR map, subsurface soils within the project area consist of Pleistocene continental glacial till (Qgt) deposited during the Vashon Stade of Fraser glaciation. Soils defined as glacial till typically consist of a dense, unsorted mixture of boulders, cobbles, gravel, and sand in a matrix of silt and clay with some lenses of sorted, stratified sand and gravel. This unit typically exhibits low permeability and high shear strength, characteristics resulting from compaction by the weight of a glacier. Based on our subsurface explorations within the project site, the near surface soils consist of a mix of variable depths of regraded fill and shallow silty sand deposits associated with adjacent surface drainage features, which are intern underlain by the mapped glacial till deposits. We anticipate that the majority of the proposed residence foundation elements will be bearing on the less dense alluvial deposits and/or weathered till horizons.

Soil Survey

According to the United States Department of Agriculture (USDA) Natural Resource Conservation Service website, the subject property slope is mapped as Hoypus Sandy Loam (3012), 10 to 40 percent slopes. According to the Soil Survey, the Hoypus Sandy Loam is considered a "low" erosion hazard and has an erosion factor K (susceptibility of a soil to sheet and rill erosion by water) of 0.05. Values of K range from 0.02 to 0.69, and, the higher the value, the more susceptible the soil is to water erosion. Native site soils observed on the property slope were generally consistent with the Soil Survey.

Coastal Zone Atlas

According to the Coastal Zone Atlas (Washington State Department of Ecology), the subject property is mapped as being located within a stable shoreline slope area.

Surface Conditions

The property consists of a south facing shoreline slope and terraced area within a currently unplatted lot within the Runstad – Whaleback Estate on the south side of Blakely Island. The proposed residence is located at the base of a forested slope with

minimal underbrush and prevalent field grass. The proposed residence location is setback approximately 50 feet from the active shoreline slope, which was observed to vary from approximately 6 to 10 feet in height. The shoreline is part of an unnamed cove that is relatively protected from large wave storm events. Accordingly, we anticipate that the toe of the shoreline slope is subject to a low erosion rate. Please refer to the attached Site and Exploration Plan, Figure 2, for more detail.

The topography of the site slopes down to the south at a relatively constant slope from the main road that crosses the upper approximate third of the property. The slope inclination was measured to be approximately 23 degrees or approximately 40 to 45 percent. The property then becomes relatively flat, generally less than 10 percent, from the toe of the slope to the existing shoreline embankment.

Vegetation within the upslope portions of the site consists of a sparse evergreen forest with an understory composed of mostly field grass with few native shrubs. Based on our observations of the site slope, no indications of large scale slides or slumps appeared to have occurred in the past. Due to the presence of rock cliffs located upslope and off the subject property to the north, some overland rock boulders have tumbled down the slope throughout its history. No significant surface boulders were observed near the base of the slope and it would appear that the potential for new boulders to reach the proposed home location would be low as long as the slope remains forested.

At the time of our subsurface investigation, surface water was not observed on the site slope. However, a seasonal stream ravine is present immediately above the eastern portion of the proposed residence/garage location. We understand that this ravine will support overland water flow in the wetter winter and early spring seasons depending on rain fall events. Accordingly, we recommend that improvements to the main road drainage system, located upslope and at the head of the ravine, be implemented in the site development plan. We also recommend that appropriate site grading and creek capture and diversion measures be included in the design and construction of the proposed home location in order to sufficiently divert the seasonal creek around the proposed home location. We anticipate that with appropriate design and construction methodology that this can be successfully implemented.

Within the observed areas of the property slope, no obvious signs of recent slope failure, significant erosion, or evidence of significant soil creep (usually evidenced by a significant number of pistol-butted trees) were observed. Normal surficial soil movement (creep), as is typical will any soil slope at the observed inclination, should be anticipated throughout the live of property and would not be considered a hazard.

Subsurface Soil Conditions

Subsurface conditions were explored by excavating four test pit explorations (TP-1 through TP-4) on July 1, 2010. The test pits were advanced to depths between 2 and 5.5 feet below ground surface (BGS). Approximate locations of these explorations are depicted on Figure 2, Site and Exploration Plan.

Approximately 6 to 8 inches of topsoil/forest duff was observed on the site, except within test pit TP-1 where approximately 1 foot of fill was present at the ground surface. Within test pit TP-1, we encountered approximately 1 foot of soft, brown/gray, wet, sandy clay fill (CL) overlying approximately 1.5 feet of relic topsoil (OL). At a depth of approximately

3 feet BGS, we encountered an approximate 10 inch thick layer of medium stiff, moist, gray clay (CL). Below a depth of approximately 3.5 to 4 feet BGS, we encountered dense, brown, moist gravelly, very silty sand (SM-glacial till) with cobbles and boulders to the full exploration depth of approximately 5 feet BGS. Within the remaining test pits and below the surficial topsoil, we encountered medium dense, brown to gray, moist, gravelly very silty sand (SM-weathered glacial till) with significant cobbles and boulders to the full depths of exploration except within test pit TP-3 where limited cobbles and boulders were encountered. Our exploration depths were generally limited due to the presence of the cobbles during excavation. Please reference the attached test pit logs, Figures A-2 and A-3, within Appendix A for more detail.

Groundwater

In general groundwater was not observed within our explorations except for isolated perched seepage lenses within test pit TP-1 at depths of 1 and 3.5 feet BGS. The observed seepage was perched within the relic topsoil layer and above the glacial till contact at depth. Accordingly, it is our opinion that perched groundwater conditions both within the upper near surface slope soils and/or above the dense glacial till at deeper contacts between various soil horizons will be encountered during site development. Accordingly, all site development is recommended to account for drainage provisions during the design and construction phases.

The groundwater conditions reported on the test pit logs are for the specific locations and dates indicated, and therefore may not necessarily be indicative of other locations and/or times. Groundwater levels and/or seepage rates are not static and it is anticipated that groundwater conditions will vary depending on local subsurface conditions, season, precipitation, changes in land use both on and off site, and other factors.

CONCLUSIONS AND RECOMMENDATIONS

Based upon evaluation of the data collected during this investigation, it is our opinion that subsurface conditions at the site are suitable for the proposed development, provided the recommendations contained herein are incorporated into the project design.

We recommend that all topsoil, fill and the upper soft portions of the native soil (generally 2 to 4 feet) be removed from below all structural areas and that footings be placed on native, medium dense/dense glacial till soils or on a suitably prepared gravel pad over till soils.

Reuse of portions the native sand and gravel as structural fill is considered feasible. However, cobbles and boulders greater than 12 inches should be removed from any replaced fill soils. We do not recommend the re-use of fine grained clayey native soils as structural fill under load bearing areas due to their high clay content. Re-use of suitable non-organic native soils with high fines contents is considered feasible in non-structural areas and/or other landscaped areas.

Site Preparation and Earthwork

Portions of the site to be occupied by proposed residential foundations, retaining walls or slab-on-grades should be prepared by removing any topsoil, fill, unsuitable native soils and/or significant accumulations of organics from the areas to be developed. Prior to placement of any structural fill, the exposed subgrade under all areas to be developed should be recompacted to a dense and unyielding condition and proof rolled with a loaded dump truck, large self-propelled vibrating roller, or equivalent piece of equipment applicable to the size of the excavation. The purpose of this effort is to identify possible loose or soft soil deposits and recompact the soil exposed during site excavation activities.

Proof rolling should be carefully observed by qualified geotechnical personnel. Areas exhibiting significant deflection, pumping, or over-saturation that cannot be readily compacted should be overexcavated to firm soil. Overexcavated areas should be backfilled with compacted granular material placed in accordance with subsequent recommendations for structural fill. During periods of wet weather, proof rolling could damage the exposed subgrade. Under these conditions, qualified geotechnical personnel should observe subgrade conditions to determine if proof rolling is feasible.

Fill and Compaction

Structural fill used to obtain final elevations for foundations elements, soil-supported floor slabs or driveway fills must be properly placed and compacted. In general, any suitable, non-organic, predominantly granular soil may be used for fill material provided the material is properly moisture conditioned prior to placement and compaction, and the specified degree of compaction is obtained. Excavated site material containing topsoil, wood, organic material, or other debris will not be suitable for reuse as structural fill and should be properly disposed offsite.

Due to the site topography, we do not recommend that any fills be placed on the site slopes other than those necessary to properly support the proposed driveway and/or other applicable foundation elements. All fills on the site should be appropriately retained and/or sloped. We recommend low-impact design methodology be utilized as much as possible to mitigate against the potential for slope instability associated with large cuts and fills.

Reuse of Onsite Soil

Generally, any granular site soils with relatively low fines contents are suitable for reuse. However, due to the anticipated limited nature of the planned site excavations within the residence footprint, reuse of applicable portions of suitable site soils appears limited.

Site soils containing more than approximately 5 percent fines are considered moisture sensitive, and may be very difficult to compact to a firm and unyielding condition when over the optimum moisture content by more than approximately 2 percent. The optimum moisture content is that which allows the greatest dry density to be achieved at a given level of compactive effort.

Imported Structural Fill

We recommend that imported structural fill consist of clean, well-graded sandy gravel, gravelly sand, or other approved naturally occurring granular material (pit run) with at least 40 percent retained on the No. 4 sieve, or a well-graded crushed rock. Structural fill for dry weather construction may contain on the order of 10 percent fines (that portion passing the U.S. No. 200 sieve) based on the portion passing the U.S. No. 4 sieve. Soil containing more than about 5 percent fines cannot consistently be compacted to a dense, non-yielding condition when the water content is greater than optimum.

Accordingly, we recommend that imported structural fill with less than 5 percent fines be used during wet weather conditions. Due to wet weather or wet site conditions, soil moisture contents could be high enough that it may be very difficult to compact even "clean" imported select granular fill to a firm and unyielding condition. Soils with over-optimum moisture contents should be scarified and dried back to more suitable moisture contents during periods of dry weather or removed and replaced with fill soils at a more suitable range of moisture contents.

Backfill and Compaction

Structural fill should be placed in horizontal lifts 8 to 10 inches in loose thickness and thoroughly compacted. All structural fill placed under load bearing areas should be compacted to at least 95 percent of the maximum dry density, as determined using test method ASTM D 1557. The top of the compacted structural fill should extend outside all foundations and other structural improvements a minimum distance equal to the thickness of the fill beneath the foundation elements. We recommend that compaction be tested periodically during the placement of the fill pad, as applicable.

Wet Weather Earthwork

The onsite near surface native soils are moisture sensitive. It is our experience that moisture sensitive native and/or imported soil is particularly susceptible to degradation during wet weather. As a result, it may be difficult to control the moisture content of the site soils during the wet season. If construction is accomplished during wet weather, we recommend that structural fill consist of imported, clean, well-graded sand or sand and gravel as described above. If fill is to be placed or earthwork is to be performed in wet weather or under wet conditions, the contractor may reduce soil disturbance by:

- Limiting the size of areas that are stripped of topsoil and left exposed
- Accomplishing earthwork in small sections
- Limiting construction traffic over unprotected soil
- Sloping excavated surfaces to promote runoff
- Limiting the size and type of construction equipment used
- Providing gravel "working mats" over areas of prepared subgrade
- Removing wet surficial soil prior to commencing fill placement each day
- Sealing the exposed ground surface by rolling with a smooth drum compactor or rubber-tired roller at the end of each working day
- Providing up-gradient perimeter ditches or low earthen berms and using temporary sumps to collect runoff and prevent water from ponding and damaging exposed subgrades.

Erosion Control

The following recommendations are intended to prevent excessive erosion from occurring during and after the construction phase of the project:

- All clearing and grading activities for the proposed development will need to incorporate Best Management Practices (BPMs) for erosion control in compliance with current San Juan County codes and standards. This report does not include an Erosion Control and Sediment Plan for the proposed development. This type of plan is typically prepared by a licensed civil engineer and goes beyond the scope of our geotechnical evaluation of the site.

- We recommend leaving as much of the existing vegetation both upslope and/or downslope of the proposed improvements as possible. Leaving the existing vegetation and planting additional brush and vegetation as soon as is reasonably possible on subject slopes or within disturbed areas will help maintain near surface slope stability by providing a stable root base within the near surface soils. Removal of vegetation and trees, without proper mitigation, may increase the risk of failure for the surficial soils during periods of wet weather.

- Proper drainage controls have a significant effect on reducing excessive erosion. Therefore, we recommend that drainage features include collection of all roof water, footing drain and any other drainage features. Discharge from these facilities should be directed into a suitable drainage system. All surface water and any collected drainage water should not be allowed to run down the face of site slopes or outlet onto or near the top of the site slopes.

- All areas disturbed by construction practices should be vegetated or otherwise protected to limit the potential for erosion as soon as practical during and after construction. Areas requiring immediate protection from the effects of erosion should be covered with either plastic, mulch or erosion control netting/blankets. Areas requiring permanent stabilization should be seeded with an approved grass seed mixture, or hydroseeded with an approved seed-mulch-fertilizer mixture. We recommend that appropriate silt fencing be incorporated into the construction plan for erosion control.

- Typically, subsurface conditions may result in the concentration of seepage within particular soil zones. Two zones of potential near surface seepage are anticipated: first, at the contact between the surficial fill/topsoil and the underling silty native soils and second, at the weathered/unweathered native contact above the dense glacial till horizon. To intercept seepage and to limit erosion on cut slopes and excavated areas that intercept groundwater seepage, it may be necessary to place gravel drainage material or other mitigation methods over the selected seepage zones. The need for drainage mitigation methods can best be determined during construction and will most likely require field fitting.

Based on observations made during our site visit and assuming that the above recommendations are incorporated into project construction, as well as appropriate maintenance being carried out for the life of the project, it is our opinion that it is possible to prevent significant erosion from occurring during site grading activities.

Seismic Design Considerations

The Pacific Northwest is seismically active and the site could be subject to ground shaking from a moderate to major earthquake. Consequently, moderate levels of earthquake shaking should be anticipated during the design life of the project, and the proposed residence structure should be designed to resist earthquake loading using appropriate design methodology. The general absence of saturated sand conditions below the site effectively precludes seismically induced soil liquefaction. In addition, due to the generally stable slope conditions, it is anticipated that the residence location would not be subject to seismically induced landslides, lateral spreading, or other ground failure. However, impacts from a large magnitude seismic event can be somewhat unpredictable.

Based on the seismic design provisions of the 2006 International Building Code, structures comprising support within the generally dense (glacial till) or a suitably prepared gravel pad should be designed for Site Class D, stiff soil profile, according to Site Class Definitions, Table 1613.5.2. The corresponding values for calculating a design response spectrum for the assumed soil profile type is considered appropriate for the site.

Foundation Support and Settlement

It should be anticipated that 1.5 to 4 feet of uncontrolled fill, loose/soft organic topsoil, relic topsoil and/or significantly weathered upper portions of the native soil may have to be removed to reach suitable bearing conditions at the project site.

Foundation support for the proposed improvements may be provided by continuous or isolated spread footings founded on:

- Proof-rolled, undisturbed, medium dense/dense, moist, gravelly, very silty sand (glacial till) or on properly compacted structural fill placed directly over suitably prepared undisturbed native soil. We recommend that qualified geotechnical personnel verify that suitable bearing conditions have been reached prior to placement of structural fill or foundation formwork.

To provide proper support, we recommend that all existing uncontrolled fill, topsoil and relic topsoil, and loose/soft, upper weathered portions of the native soil be removed from beneath the residence foundation area(s) or replaced with properly compacted structural fill as described above. In areas requiring overexcavation to competent native soil, the limits of the overexcavation should extend laterally beyond the edge of each side of the footing a distance equal to the depth of the excavation below the base of the footing.

In addition, we recommend that all foundation elements for the proposed residence bear entirely on similar soil conditions in order to help reduce the potential for differential settlement between varying foundation elements.

All continuous and isolated spread footings should be founded a minimum of 18 inches below the lowest adjacent final grade for freeze/thaw protection. The footings should be sized in accordance with the structural engineer's prescribed design criteria and seismic considerations.

Allowable Bearing Capacity

Assuming the above foundation support criteria are satisfied, continuous or isolated spread footings founded directly on the near surface native medium dense/dense, moist, gravelly, very silty sand (weathered glacial till) may be proportioned using a maximum net allowable soil bearing pressure of 2,000 pounds per square ft (psf). For foundations placed on imported granular structural fill placed directly over suitably prepared undisturbed native soils, a net allowable soil bearing pressure of 2,500 psf may be utilized in design.

The term "net allowable bearing pressure" refers to the pressure that can be imposed on the soil at foundation level resulting from the total of all dead plus live loads, exclusive of the weight of the footing or any backfill placed above the footing. The net allowable bearing pressure may be increased by one-third for transient wind or seismic loads.

Foundation Settlement

Settlement of shallow foundations depends on foundation size and bearing pressure, as well as the strength and compressibility characteristics of the underlying soil. Assuming construction is accomplished as previously recommended and for the maximum allowable soil bearing pressure recommended above, we estimate the total settlement of residence foundations should be less than about one inch and differential settlement between two adjacent load-bearing components supported on competent soil should be less than about one half the total settlement. The soil response to applied stresses caused by building and other loads is expected to be predominantly elastic in nature, with most of the settlement occurring during construction as loads are applied.

Resistance to Lateral Loads

Passive earth pressures developed against the sides of building foundations, in conjunction with friction developed between the base of the footings and the supporting subgrade, will resist lateral loads transmitted from the structure to its foundation. For design purposes, the passive resistance of well-compacted fill placed against the sides of foundations may be considered equivalent to a fluid with a density of 250 pounds per cubic ft. The recommended value includes a safety factor of about 1.5 and is based on the assumption that the ground surface adjacent to the structure is level in the direction of movement for a distance equal to or greater than twice the embedment depth. The recommended value also assumes drained conditions that will prevent the buildup of hydrostatic pressure in the compacted fill. In design computations, the upper 12 inches of passive resistance should be neglected if the soil is not covered by floor slabs or pavement. If future plans call for the removal of the soil providing resistance, the passive resistance should not be considered.

An allowable coefficient of base friction of 0.25 for undisturbed native soil and an allowable coefficient of base friction of 0.30 for import structural fill, applied to vertical dead loads only, may be used between the underlying soil and the base of the footing. However, if passive and frictional resistance are considered together, one half the recommended passive soil resistance value should be used since larger strains are required to mobilize the passive soil resistance as compared to frictional resistance. A safety factor of about 1.5 is included in the base friction design value. We do not recommend increasing the coefficient of friction to resist seismic or wind loads.

The lateral earth pressures that develop against subsurface building and retaining walls will depend on the method of backfill placement, degree of compaction, slope of backfill, type of backfill material, provisions for drainage, magnitude and location of any adjacent surcharge loads, and the degree to which the wall can yield laterally during or after placement of backfill. If the wall is allowed to rotate or yield so the top of the wall moves an amount equal to or greater than about 0.001 to 0.002 times its height (a yielding wall), the soil pressure exerted will be the active soil pressure. When a subsurface wall is restrained against lateral movement or tilting (a nonyielding wall), the soil pressure exerted is the at-rest soil pressure. Wall restraint may develop if a rigid structural network is constructed prior to backfilling or the wall is inherently stiff.

We recommend that yielding walls with level backfill under drained conditions be designed for an equivalent fluid density of 35 pounds per cubic ft (pcf) for structural backfill (pit run) in active soil conditions. Nonyielding walls with level backfill under drained conditions should be designed for an equivalent fluid density of 55 pcf for at-rest conditions. Design of subsurface walls should include appropriate lateral pressures caused by surcharge loads located within a horizontal distance equal to or less than the height of the wall. For uniform surcharge pressures, a uniformly distributed lateral pressure equal to 35 percent and 50 percent of the vertical surcharge pressure should be added to the lateral soil pressures for yielding and nonyielding walls, respectively.

Concrete Slabs-on-Grade

Conventional slab-on-grade floor construction is considered feasible for the planned site improvements. Floor slabs may be supported on properly prepared native subgrade or on properly placed and compacted structural fill placed over properly prepared native soil. Prior to placement of the structural fill, the native soil should be approved as recommended in the *Site Preparation and Earthwork* section of this report.

We recommend that interior concrete slab-on-grade floors be underlain by a minimum of 6 inches of compacted, clean, free-draining gravel with less than 5 percent passing the U.S. Standard No. 200 sieve (based on a wet sieve analysis of that portion passing the U.S. Standard No. 4 sieve). The purpose of this layer is to provide uniform support for the slab, provide a capillary break, and act as a drainage layer. To help reduce the potential for water vapor migration through floor slabs, at a minimum a continuous impermeable membrane of 6- to 10-mil polyethylene sheeting with tape-sealed joints should be installed below the slab. The American Concrete Institute (ACI) guidelines suggest that the slab may either be poured directly on the vapor retarding membrane or on a granular curing layer placed over the vapor retarding membrane depending on conditions anticipated during construction. We recommend that the architect or structural engineer specify if a curing layer should be used. If moisture control within the building is critical, we recommend an inspection of the vapor retarding membrane to verify that all openings have been properly sealed. Use of waterproofing additives to the concrete and/or a thicker vapor barrier membrane can also be considered depending on the level of moisture protection desired.

Due to the location of the seasonal ravine within the upslope portion of the property located behind the residence, it may also be advisable to include design provisions for under-slab gravel drainage ditches that will help reduce the potential for ponded water to collect beneath the proposed residence location.

Exterior concrete slabs-on-grade, such as driveway slabs and/patios, may be supported directly on undisturbed native or on properly placed and compacted structural fill; however, long-term performance will be enhanced if exterior slabs are placed on a layer of clean, durable, well-draining granular material.

Foundation and Site Drainage

To reduce the potential for groundwater and surface water to seep into interior spaces we recommend that an exterior footing drain system be constructed at the applicable areas around the perimeter of new residence foundation as shown in the Typical Footing and Wall Drain Section, Figure 3. The drain should consist of a minimum 4-inch diameter perforated pipe, surrounded by a minimum 12 inches of filtering media with the discharge sloped to carry water to a suitable collection system. The filtering media may consist of open-graded drain rock wrapped by a nonwoven geotextile fabric (such as Mirafi 140N, Synthetic Industries 351, or equivalent) or a graded sand and gravel filter. The drainage backfill should be carried up the back of the foundation wall to within approximately 1 foot of the finished grade and contain less than 3 percent by weight passing the U.S. Standard No. 200 sieve (based on a wet sieve analysis of that portion passing the U.S. Standard No. 4 sieve). The invert of the footing drain pipe should be placed at approximately the same elevation as the bottom of the footing or 12 inches below the adjacent floor slab grade, whichever is deeper, so that water will not seep through walls or floor slabs. The footing drain should discharge to an approved drain system and include cleanouts to allow periodic maintenance and inspection.

Positive surface gradients should be provided adjacent to the proposed residence to direct surface water away from the foundation and toward suitable drainage facilities. Roof drainage should not be introduced into the perimeter footing drains, but should be separately discharged directly to the stormwater collection system or other appropriate outlet. Pavement and sidewalk areas should be sloped and drainage gradients should be maintained to carry all surface water away from the structure towards the local stormwater collection system. Surface water should not be allowed to pond and soak into the ground surface near the structure or paved areas during or after construction. Construction excavations should be sloped to drain to sumps where water from seepage, rainfall, and runoff can be collected and pumped to a suitable discharge facility.

Based on our review of the upslope portions of the seasonal drainage ravine, it would appear that a significant portion of the runoff volume could be collected and diverted by improving the drainage collection at the main road culvert crossing located upslope of the residence location. Redirection and/or regrading of existing surface water runoff paths and roadside ditches could divert a significant portion of the seasonal runoff. If significant near surface seepage is encountered, installation of a French drain cut off trench could also be implemented into the drainage improvement design.

At the residence location, a suitable overland water runoff collection point, such as a concrete pond or other feature is recommended such that the seasonal runoff is suitably diverted into a stream channel or culvert system that directs the runoff around the residence location. We recommend that the designed collection and/or diversion system not be located beneath any portion of the residence and/or garage foundation elements in order to avoid long term maintenance and/or replacement conflicts.

Utilities

It is important that utility trenches be properly backfilled and compacted to minimize the possibility of cracking or localized loss of foundation, slab-on-grade or driveway support. It is anticipated that excavations for new underground utilities will be in medium dense slightly to very gravelly silty sand with significant cobbles and/or boulders (native soils).

Trench backfill in improved areas (beneath structures, slabs or driveway) should consist of structural fill as defined earlier in this report with all oversized cobbles and/or boulders removed. Outside of improved areas, trench backfill may consist of re-used onsite native fill. Trench backfill should be placed and compacted in accordance with the report section *Fill and Compaction*.

Actual trench configurations should be the responsibility of the contractor. All applicable local, state, and federal safety codes should be followed. All open cuts should be monitored by the contractor during excavation for any evidence of instability. If instability is detected, the contractor should flatten the side slopes or install temporary shoring. If groundwater or groundwater seepage is present, and the trench is not properly dewatered, the soil within the trench zone may be prone to caving, channeling, and running. Trench widths may be substantially wider than under dewatered conditions.

Temporary and Permanent Slopes

Actual construction slope configurations and maintenance of safe working conditions, including temporary excavation stability, shall be the responsibility of the contractor, who is able to monitor the construction activities and has direct control over the means and methods of construction. All applicable local, state, and federal safety codes should be followed. All open cuts should be monitored during and after excavation for any evidence of instability. If instability is detected, the contractor should flatten the side slopes or install temporary shoring.

Temporary excavations in excess of 4 ft should be shored or sloped in accordance with Safety Standards for Construction Work Part N, WAC 296-155-657.

Temporary unsupported excavations in the generally medium dense native soils encountered at the project site are classified as a Type C soil according to WAC 296-155-657 and may be sloped as steep as 1½H:1V. All soils encountered are classified as Type C soil in the presence of groundwater seepage. Flatter slopes or temporary shoring may be required in areas where groundwater flow is present and unstable conditions develop.

Temporary slopes and excavations should be protected as soon as possible using appropriate methods to prevent erosion from occurring during periods of wet weather.

We recommend that permanent cut or fill slopes be designed for inclinations of 2H:1V or flatter. All permanent cut slopes should be vegetated or otherwise protected to limit the potential for erosion as soon as practical after construction.

Landslide Hazard and Slope Stability

Based on the information gathered during our geotechnical evaluation, it is our opinion that geologically hazardous areas – specifically landslide hazard conditions are minimal above the proposed home site. No obvious signs of recent or historic instability or evidence of severe soil creep were observed on the property slope at the time of our evaluation. Due to the presence of relatively dense native glacial deposits observed and interpreted to underlie the near surface soil horizon at the site, a deep-seated rotational type failure affecting the proposed residence improvements appears unlikely to occur.

Rotational failures can extend down into the subsurface to substantial depths. These failures typically leave geomorphic evidence of their existence on the slope. Typical indicators are head scarps, tension cracks, sag ponds, seepage zones, hummocky ground surface and slump blocks. Obvious visual indications of large scale slope instability, such as those referenced above, or signs of excessive soil creep, as indicated by excessive numbers or curvatures of pistol-butted tree trunks, were not observed within the subject property.

The occasional rock toppled boulder was observed within the upper slope portion of the property, however it is our opinion that the potential for an overland rolled boulder to reach the residence location is minimal provided the slope remains forested.

We recommend leaving as much of the existing vegetation on the slope as possible. Leaving the existing vegetation and planting additional brush and vegetation will help maintain near surface slope stability by providing a stable root base within the near surface soils. Removal of vegetation and trees, without proper mitigation, may increase the risk of failure for the surficial soils during periods of wet weather.

Surface water runoff should not be allowed to flow over the face of site slopes. To reduce the chance of initiating instability, drain water collected from impervious surfaces should be tightlined to a suitable discharge point located at the base of the site slope.

Due to the apparent global stability at the subject site and assuming the above mentioned recommendations are carried out for the life of the project, it is our opinion that large scale landslides are unlikely to occur which would affect the site of the proposed new residence construction.

Stormwater/Roof Downspout Runoff Control

We recommend that all roof downspout runoff and/or any other collected drainage water for the proposed residence and site development be either tightlined to the base of the shoreline slope, outlet into a suitable overland water course or discharged within a property designed infiltration trench, dispersion trench and/or point discharge (splash block) location.

From the explorations excavated at the site, three representative soil samples were selected and mechanically tested for grain size distribution and interpretation according to the United States Department of Agriculture (USDA) soil textural classification. Subsurface infiltration rates corresponding to the United States Department of Agriculture (USDA) soil textural classification were obtained from the 2005 Washington

State Department of Ecology *Stormwater Management Manual for Western Washington*, Table 3.7, and are reproduced in Table 1 below.

TABLE 1
Test Pit Soil Sample Infiltration Rates
Based On The 2005 DOE Stormwater Management Manual Table 3.7

Test Pit Number	Sample Depth (ft)	Classification (USDA)	Geologic Unit	Infiltration Rate (Inches/Hour)
TP-1	4.5	Sandy Loam	Glacial Till	0.25
TP-2	2	Sandy Loam	Glacial Till	0.25
TP-3	4	Sand	Local Alluvium	2

Note: Listed infiltration rates are long term (design) rates as stated in Table 3.7.

Based on the USDA textural classifications above and our interpretations of our soil logs, we recommend a long-term design infiltration rate of 2 inches per hour be utilized for preliminary stormwater design purposes within the area of test pit TP-3. Although an infiltration rate of 0.25 can be obtained by sieve correlation of the glacial till unit, it is our experience that the glacial till unit will perch groundwater and the actual infiltration rate of glacial till is much slower in the in-situ condition. Accordingly, a small infiltration trench and/or drywell appears feasible within the area of test pit TP-3, however dispersion trenches, splash blocks and/or other direct discharge methods should be utilized within the other planned stormwater discharge locations around the proposed new residence.

Geotechnical Consultation and Construction Monitoring

GeoTest Services recommends that we be allowed to review the earthwork and foundation portions of the design drawings and specifications prior to the start of construction. The purpose of the review is to verify that the recommendations presented in this report have been properly interpreted and incorporated in the final design and specifications.

We recommend that geotechnical construction monitoring services be provided. These services should include observation by GeoTest personnel during, foundation element construction, applicable fill placement/compaction activities and subgrade preparation operations to verify that design conditions are obtained beneath the proposed residence improvements. We also recommend that periodic field density testing be performed, where applicable, to verify that the appropriate degree of compaction is obtained. The purpose of these services would be to observe compliance with the design concepts, specifications, and recommendations of this report, and in the event subsurface conditions differ from those anticipated before the start of construction, provide revised recommendations appropriate to the conditions revealed during construction. GeoTest Services would be pleased to provide these services for you.

GeoTest Services is also available to provide a full range of materials testing and special inspection during construction as required by the local building department and the International Building Code. This may include specific construction inspections on materials such as reinforced concrete, structural steel and other aspects of the planned

construction. These services are supported by our fully accredited materials testing laboratory.

USE OF THIS REPORT

GeoTest Services has prepared this report for the exclusive use of Jon Runstad and his design consultants for specific application to the design of the proposed "Beach House" residence to be located on the proposed 10.62 acre parcel A within the Runstad – Whaleback Estate on Blakely Island, Washington. Use of this report by others is at the user's sole risk. This report is not applicable to other sites. Our services have been conducted in accordance with generally accepted practices of the geotechnical engineering profession; no other warranty, either express or implied, is made as to the professional advice included in this report.

Our site explorations indicate subsurface conditions at the dates and locations indicated. It is not warranted that they are representative of subsurface conditions at other locations and times. The analyses, conclusions, and recommendations contained in this report are based on site conditions to the limited depth of our explorations at the time of our exploration program, a brief geological reconnaissance of the area, and review of published geological information for the site. We assume that the explorations are representative of the subsurface conditions throughout the site during the preparation of our recommendations. If variations in subsurface conditions are encountered during construction, we should be notified for review of the recommendations of this report, and revision of such if necessary. If there is a substantial lapse of time between submission of this report and the start of construction, or if conditions change due to construction operations at or adjacent to the project site, we recommend that we review this report to determine the applicability of the conclusions and recommendations contained herein.

The earthwork contractor is responsible to perform all work in conformance with all applicable WISHA/OSHA regulations. GeoTest Services, Inc. should not be assumed to be responsible for job site safety on this project, and this responsibility is specifically disclaimed.

We appreciate the opportunity to provide geotechnical services on this project and look forward to assisting you during the construction phase. If you have any questions regarding the information contained in this report, or if we may be of further service, please contact the undersigned.

Respectfully Submitted,
GeoTest Services, Inc.

Dan Sorenson, L.E.G.
Engineering Geologist

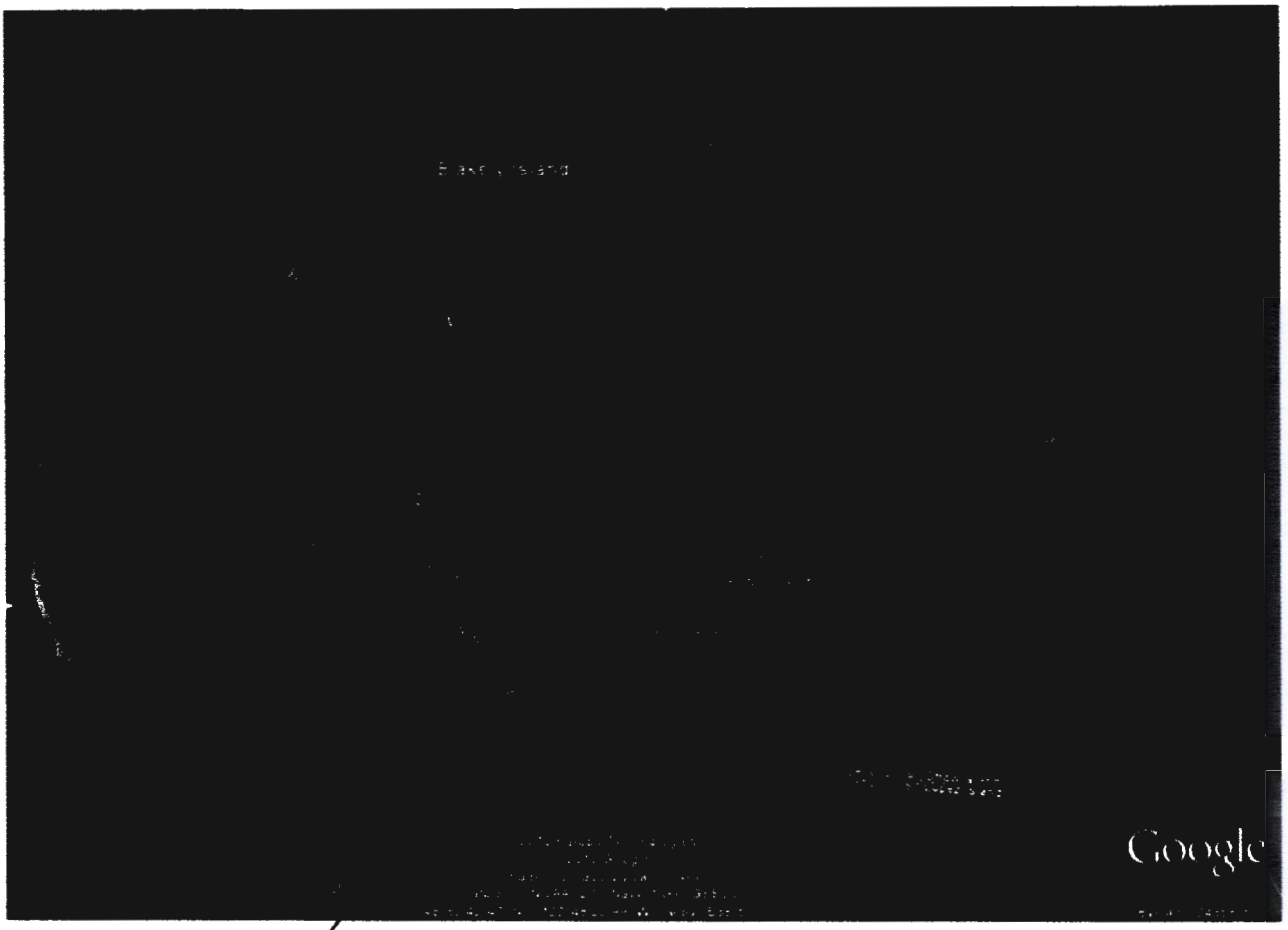
Dong-Soo Lee, P.E.
Geotechnical Engineer

Attachments:	Figure 1	Site Vicinity Map
	Figure 2	Site and Exploration Plan
	Figure 3	Typical Footing and Wall Drain Section
	Appendix A	Field Explorations and Laboratory Testing

References:

Washington State Department of Natural Resources, Accessed May 2009. Washington Interactive Geologic Map, Division of Geology and Earth Resources – Washington's Geological Survey.

Soil Survey website, Skagit County Area, WA, prepared by the USDA National Resource Conservation Service. http://www.or.nrcs.usda.gov/pnw_soil/wa_reports.html.



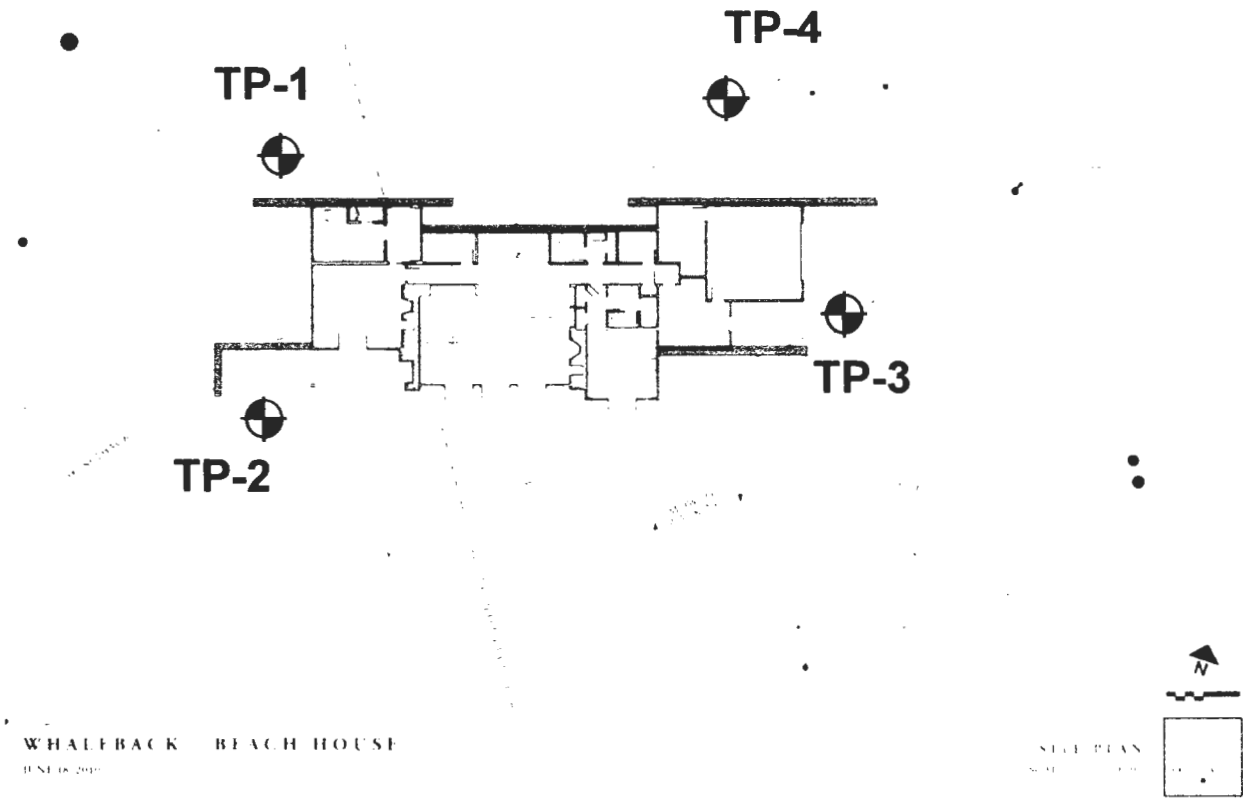
Reference Map Provided By
Google Earth

PROJECT LOCATION

NORTH

GEOTEST SERVICES, INC.
741 Marine Drive
Bellingham, WA 98225
phone: (360) 733-7318
fax: (360) 733-7418

Date: 8-17-10	By: DS	Scale: NONE	Project
SITE VICINITY MAP **BEACH HOUSE LOCATION** **RUNSTAD - WALEBACK ESTATE** **BLAKELY ISLAND, WASHINGTON**			**10-0351** Figure **1**



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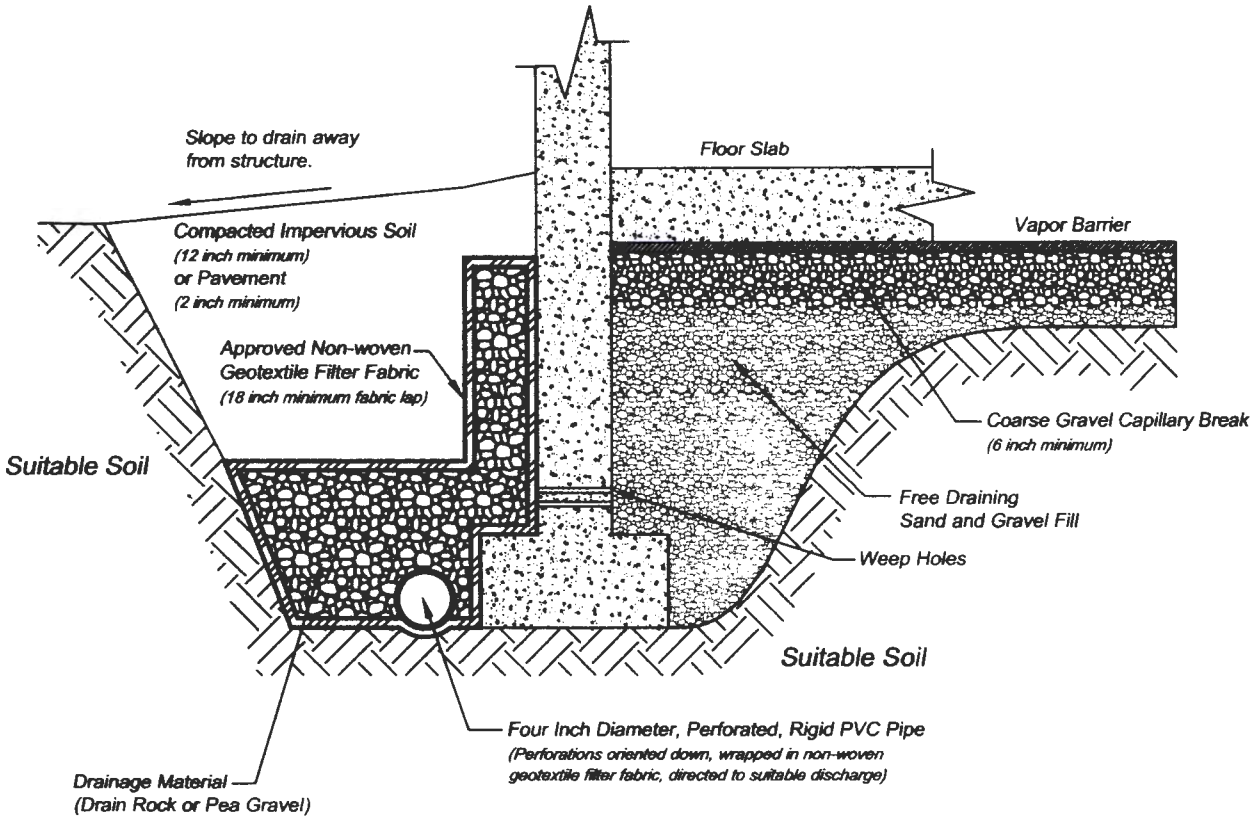
fax: (360) 733-7418

Date: 8-17-10	By: DS	Scale: As Shown	Project
SITE AND EXPLORATION PLAN **BEACH HOUSE LOCATION** **RUNSTAD - WALEBACK ESTATE** **BLAKELY ISLAND, WASHINGTON**			**10-0351** Figure **2**

SHALLOW FOOTINGS WITH INTERIOR SLAB-ON-GRADE



Notes:
Footings should be properly buried for frost protection in accordance with International Building Code or local building codes.
(Typically 18 inches below exterior finished grades)

GEOTEST SERVICES, INC.
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Date: 8-17-10	By: DS	Scale: NONE	Project
TYPICAL FOOTING & WALL DRAIN SECTION			**10-0351**
Beach House Location			Figure
Runstad - Waleback Estate			**3**
Blakely Island, Washington			

APPENDIX A

FIELD EXPLORATIONS AND LABORATORY TESTING

APPENDIX A
FIELD EXPLORATIONS AND LABORATORY TESTING

Subsurface conditions at the site were explored on July 1, 2010. The exploration program consisted of excavating 4 test pits (TP-1 through TP-4) at the approximate locations illustrated on the Site and Exploration Plan, Figure 2 of this report. The test pits were advanced with a tractor mounted backhoe to depths ranging between 2 and 5.5 feet below the existing ground surface. The backhoe was supplied by the owner. The explorations were located in the field by taping from existing property features shown the referenced plan. Exploration locations should be considered accurate to the degree implied by the methods used.

The field explorations were coordinated and monitored by an engineering geologist from our staff who obtained representative soil samples, maintained a detailed record of observed subsurface soil and groundwater conditions, and described the soil encountered by visual and textural examination. Each representative soil type observed was described using the soil classification system shown on Figure A-1, in general accordance with ASTM D 2488, *Standard Recommended Practice for Description of Soils (Visual-Manual Procedure)*. Logs of the test pit explorations are presented on Figures A-2 and A-3. These logs represent our interpretation of subsurface conditions identified during the field explorations. The stratigraphic contacts shown on the individual test pit logs represent the approximate boundaries between soil types; actual transitions may be more gradual. Also, the soil and groundwater conditions depicted are only for the specific date and locations reported, and therefore, are not necessarily representative of other locations and times.

Representative soil samples encountered in the test pit explorations were obtained at selected intervals, placed in sealed plastic bags, and transported to our laboratory for further classification and testing. Laboratory tests were performed on representative soil samples to characterize certain physical properties of the site soil. The laboratory testing program was limited to visual inspection to confirm field soil descriptions, determination of natural moisture content and soil grain size distribution.

The natural moisture contents of selected soil samples were determined in general accordance with ASTM D 2216 test procedures. The results from the moisture determinations are indicated on the summary logs, adjacent to the corresponding samples. Grain size analyses of selected soil samples were conducted in general accordance with ASTM D 422 test procedures. The results are presented in the form of grain size distribution curves on Figure A-4.

Soil Classification System

MAJOR DIVISIONS			GRAPHIC SYMBOL	USCS LETTER SYMBOL	TYPICAL DESCRIPTIONS[1][2]
COARSE-GRAINED SOIL (More than 50% of material is larger than No. 200 sieve size)	GRAVEL AND GRAVELLY SOIL (More than 50% of coarse fraction retained on No. 4 sieve)	CLEAN GRAVEL (Little or no fines)		GW	Well-graded gravel; gravel/sand mixture(s); little or no fines
				GP	Poorly graded gravel; gravel/sand mixture(s); little or no fines
		GRAVEL WITH FINES (Appreciable amount of fines)		GM	Silty gravel; gravel/sand/silt mixture(s)
				GC	Clayey gravel; gravel/sand/clay mixture(s)
	SAND AND SANDY SOIL (More than 50% of coarse fraction passed through No. 4 sieve)	CLEAN SAND (Little or no fines)		SW	Well-graded sand; gravelly sand; little or no fines
				SP	Poorly graded sand; gravelly sand; little or no fines
		SAND WITH FINES (Appreciable amount of fines)		SM	Silty sand; sand/silt mixture(s)
				SC	Clayey sand; sand/clay mixture(s)
FINE-GRAINED SOIL (More than 50% of material is smaller than No. 200 sieve size)	SILT AND CLAY (Liquid limit less than 50)			ML	Inorganic silt and very fine sand; rock flour; silty or clayey fine sand or clayey silt with slight plasticity
				CL	Inorganic clay of low to medium plasticity; gravelly clay; sandy clay; silty clay; lean clay
				OL	Organic silt; organic, silty clay of low plasticity
	SILT AND CLAY (Liquid limit greater than 50)			MH	Inorganic silt; micaceous or diatomaceous fine sand
				CH	Inorganic clay of high plasticity; fat clay
				OH	Organic clay of medium to high plasticity; organic silt
	HIGHLY ORGANIC SOIL			PT	Peat; humus; swamp soil with high organic content

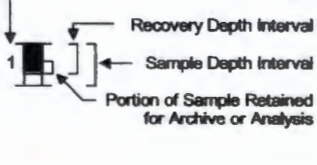
OTHER MATERIALS	GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
PAVEMENT		AC or PC	Asphalt concrete pavement or Portland cement pavement
ROCK		RK	Rock (See Rock Classification)
WOOD		WD	Wood, lumber, wood chips
DEBRIS		DB	Construction debris, garbage

Notes:
1. Soil descriptions are based on the general approach presented in the *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*, as outlined in ASTM D 2488. Where laboratory index testing has been conducted, soil classifications are based on the *Standard Test Method for Classification of Soils for Engineering Purposes*, as outlined in ASTM D 2487.
2. Soil description terminology is based on visual estimates (in the absence of laboratory test data) of the percentages of each soil type and is defined as follows:

Primary Constituent: > 50% - "GRAVEL," "SAND," "SILT," "CLAY," etc.
Secondary Constituents: > 30% and ≤ 50% - "very gravelly," "very sandy," "very silty," etc.
> 12% and ≤ 30% - "gravelly," "sandy," "silty," etc.
Additional Constituents: > 5% and ≤ 12% - "slightly gravelly," "slightly sandy," "slightly silty," etc.
≤ 5% - "trace gravel," "trace sand," "trace silt," etc., or not noted.

Drilling and Sampling Key

SAMPLE NUMBER & INTERVAL



SAMPLER TYPE

Code	Description
a	3.25-inch O.D., 2.42-inch I.D. Split Spoon
b	2.00-inch O.D., 1.50-inch I.D. Split Spoon
c	Shelby Tube
d	Grab Sample
e	Other - See text if applicable
1	300-lb Hammer, 30-inch Drop
2	140-lb Hammer, 30-inch Drop
3	Pushed
4	Other - See text if applicable

Groundwater

▽ ATD — Approximate water elevation at time of drilling (ATD) or on date noted. Groundwater levels can fluctuate due to precipitation, seasonal conditions, and other factors.

Field and Lab Test Data

Code	Description
PP = 1.0	Pocket Penetrometer, tsf
TV = 0.5	Torvane, tsf
PID = 100	Photoionization Detector VOC screening, ppm
W = 10	Moisture Content, %
D = 120	Dry Density, pcf
-200 = 60	Material smaller than No. 200 sieve, %
GS	Grain Size - See separate figure for data
AL	Atterberg Limits - See separate figure for data
GT	Other Geotechnical Testing
CA	Chemical Analysis

GEOTEST

Beach House
Runstad - Whaleback Estate
Blakely Island, Washington

Soil Classification System and Key

Figure A-1

8/17/10 X:\0-PROJECTS GEO\00000-PROJECTS 2010-GEO\FULL GEO EVALUATIONS\RUNSTAD RESIDENCES - 10-0351 - BLAKELY ISLAND\RUNSTAD RESIDENCES - 10-0351 - BLAKELY ISLAND.GPJ SOIL CLASS SHEET

TP-1

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Determined
0					CL	Soft, brown gray, wet, sandy, CLAY (Uncontrolled Fill)
	1	d	W = 37		OL	Soft, dark brown, moist, organic, SILT / SILTY SAND (Relic Topsoil)
2					CL	Medium stiff, gray, moist, sandy, CLAY (Apparent Glacial Drift)
4	2	d	W = 11 GS		SM	Dense, brown, damp, gravelly, very silty, SAND (Glacial Till) with cobbles and boulders
6						

Slight groundwater seepage encountered at 1.5 ft.

Slight groundwater seepage encountered at 3.5 ft.

Test Pit Completed 07/01/10
Total Depth of Test Pit = 5.0 ft.

TP-2

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Determined
0					OL	Soft, dark brown, moist, organic, sandy, CLAY (Topsoil)
	3	d	W = 10 GS		SM	Medium dense, brown and gray, damp, gravelly, very silty, SAND (Weathered Glacial Till) with significant cobbles and boulders Difficult digging due to boulders
2						
4						
6						

Groundwater not encountered.

Test Pit Completed 07/01/10
Total Depth of Test Pit = 4.0 ft.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

10-0351 8/17/10 X:\0-PROJECTS GEO\00000-PROJECTS 2010-GEO\FULL GEO EVALUATIONS\RUNSTAD RESIDENCES - 10-0351 - BLAKELY ISLAND\RUNSTAD RESIDENCES - 10-0351- BLAKELY ISLAND.GPJ TEST PIT LOG

GEOTEST	Beach House Runstad - Whaleback Estate Blakely Island, Washington	Log of Test Pits	Figure A-2

TP-3

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Determined
0					OL	Soft, dark brown, moist, organic, sandy, CLAY (Topsoil)
					SM	Loose to medium dense, red-brown, damp, silty SAND (Weathered Alluvial Horizon)
					SP-SM	Medium dense, brown and gray, damp, slightly silty, gravelly SAND (Apparent Local Alluvial Deposit) with gravel and cobbles
2						
4	4	d	W = 8 GS			
6						

Groundwater not encountered.

Test Pit Completed 07/01/10
Total Depth of Test Pit = 5.5 ft.

TP-4

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Determined
0					SM	Medium dense, light brown, damp, gravelly, very silty, SAND (Glacial Till) with cobbles and boulders
2						Test pit terminated at 2 feet BGS due to boulders
4						
6						

Groundwater not encountered.

Test Pit Completed 07/01/10
Total Depth of Test Pit = 2.0 ft.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

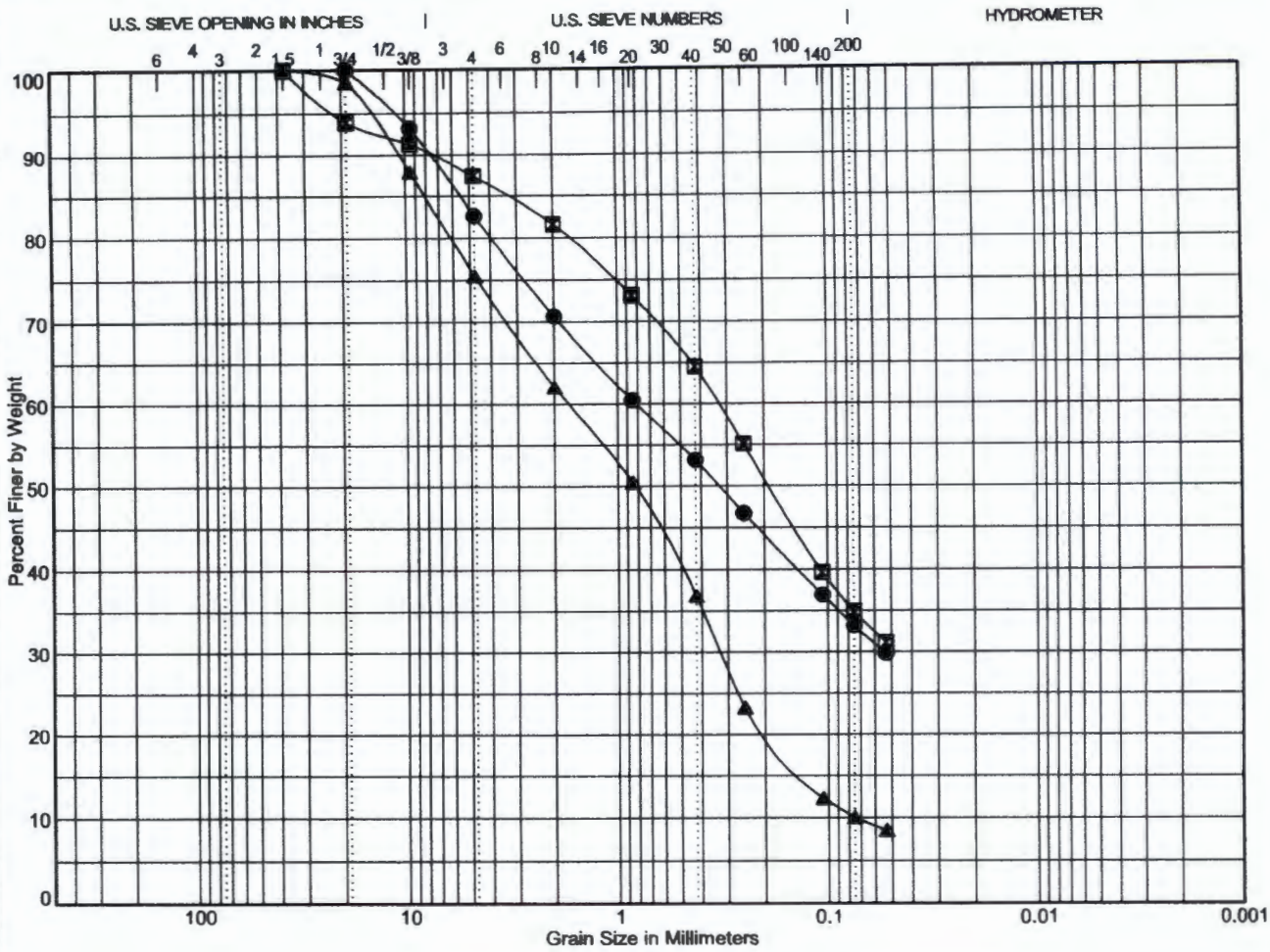
10-0351 8/17/10 X:\0-PROJECTS GEO\00000-PROJECTS 2010-GEO\FULL GEO EVALUATIONS\RUNSTAD RESIDENCES - 10-0351 - BLAKELY ISLAND\RUNSTAD RESIDENCES - 10-0351- BLAKELY ISLAND.GPJ TEST PIT LOG

GEOTEST

Beach House
Runstad - Whaleback Estate
Blakely Island, Washington

Log of Test Pits

Figure A-3



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	TP-1	4.5	Gravelly, very silty, fine to coarse SAND (SM)					
⊠	TP-2	2.0	Gravelly, very silty, fine to coarse SAND (SM)					
▲	TP-3	4.0	Slightly silty, gravelly, fine to coarse SAND (SP-SM)				0.84	23.20

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	TP-1	4.5	19	0.815	0.328	0.054		0.0	17.3	12.1	17.5	20.0	33.2
⊠	TP-2	2.0	37.5	0.33	0.189			6.1	6.5	5.7	17.1	29.6	34.9
▲	TP-3	4.0	37.5	1.716	0.83	0.326	0.074	1.4	23.1	13.4	25.3	26.7	10.1

$C_c = D_{30}^2/(D_{60} * D_{10})$ To be well graded: $1 < C_c < 3$ and

$C_u = D_{60}/D_{10}$ $C_u > 4$ for GW or $C_u > 6$ for SW

GEOTEST

Beach House
Runstad - Whaleback Estate
Blakely Island, Washington

Grain Size Test Data

Figure A-4

10-0351 8/17/10 X:\0-PROJECTS GEO\00000-PROJECTS 2010-GEO\FULL GEO EVALUATIONS\RUNSTAD RESIDENCES - 10-0351 - BLAKELY ISLAND\RUNSTAD RESIDENCES - 10-0351- BLAKELY ISLAND.GPJ GRAIN SIZE W/STATS

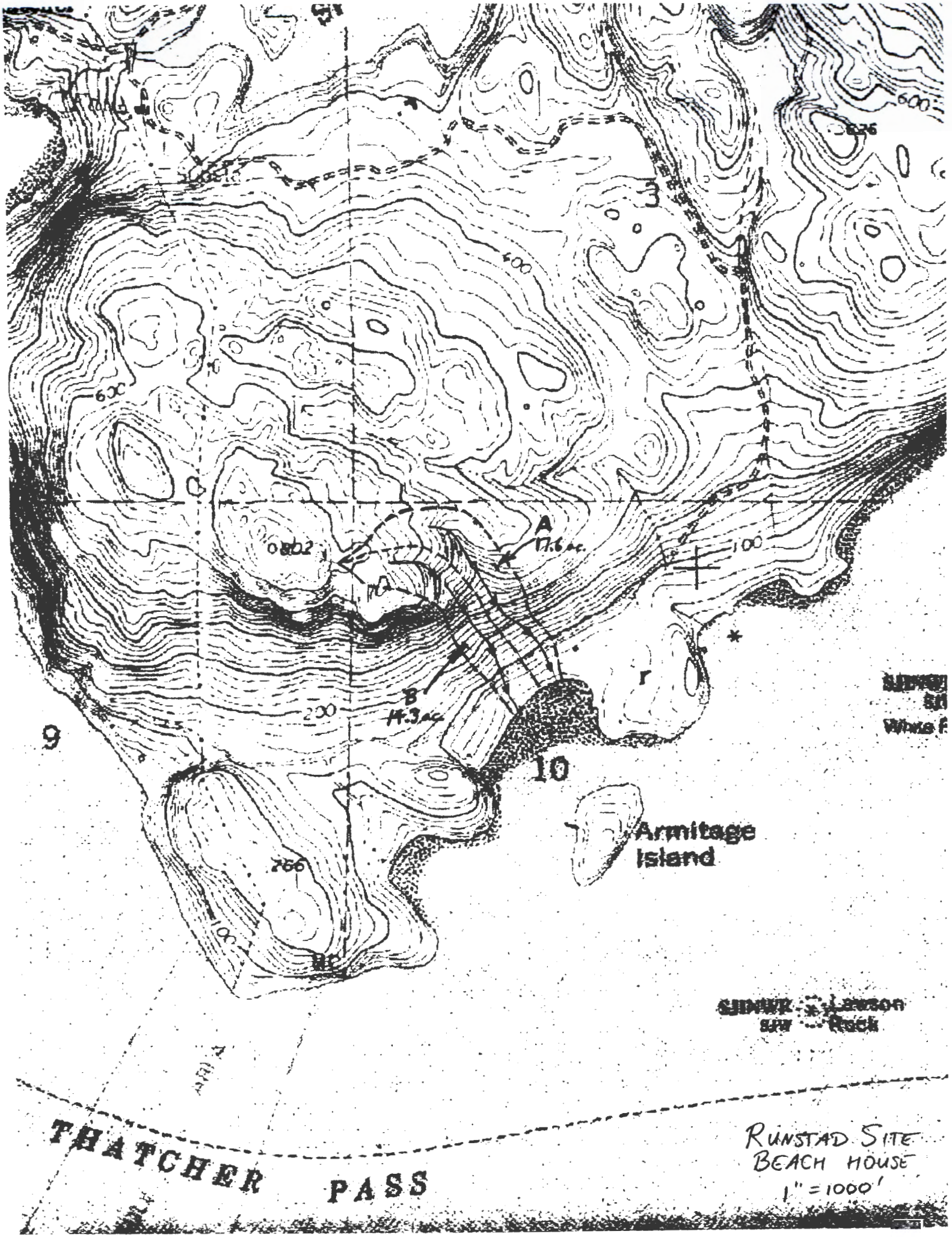

A
17.6 ac.
B
14.3 ac.
9
10
3
Armitage Island
THATCHER PASS
RUNSTAD SITE
BEACH HOUSE
1" = 1000'

Table 2.3
Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas

(Sources: TR 55, 1986, and Stormwater Management Manual, 1992. See Section 2.1.1 for explanation)

Cover type and hydrologic condition.	CNs for hydrologic soil group A	B	C	D
Curve Numbers for Pre-Development Conditions				
Pasture, grassland, or range-continuous forage for grazing:				
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77
Curve Numbers for Post-Development Conditions				
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[1]				
Fair condition (grass cover on 50% - 75% of the area).	77	85	90	92
Good condition (grass cover on >75% of the area)	68	80	86	90
Impervious areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs[2], driveways, etc. (excluding right-of-way)	98	98	98	98
Porous Pavers and Permeable Interlocking Concrete (assumed as 85% impervious and 15% lawn)				
Fair lawn condition (weighted average CNs).	95	96	97	97
Good lawn condition (weighted average CNs).	94	95	96	97
Paved	98	98	98	98
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range-continuous forage for grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods: Assume Steep & rocky also acts similar				
Poor (Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning).	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77

Single family residential[3]: Dwelling Unit/Gross Acre	Should only be used for subdivisions > 50 acres	Average Percent impervious area[3,4]	
1.0 DU/GA		15	Separate curve number shall be selected for pervious & impervious portions of the site or basin
1.5 DU/GA		20	
2.0 DU/GA		25	
2.5 DU/GA		30	
3.0 DU/GA		34	
3.5 DU/GA		38	
4.0 DU/GA		42	
4.5 DU/GA		46	
5.0 DU/GA		48	
5.5 DU/GA		50	
6.0 DU/GA		52	
6.5 DU/GA		54	
7.0 DU/GA		56	
7.5 DU/GA		58	
PUD's, condos, apartments, commercial businesses, industrial areas & & subdivisions < 50 acres	%impervious must be computed	Separate curve numbers shall be selected for pervious and impervious portions of the site	

For a more detailed and complete description of land use curve numbers refer to chapter two (2) of the Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986).

[1] Composite CN's may be computed for other combinations of open space cover type.

[2] Where roof runoff and driveway runoff are infiltrated or dispersed according to the requirements in Chapter 2, the average percent impervious area may be adjusted in accordance with the procedure described under "Flow Credit for Roof Downspout Infiltration" and "Flow Credit for Roof Downspout Dispersion" in Chapter 2.

[3] Assumes roof and driveway runoff is directed into street/storm system.

[4] All the remaining pervious area (lawn) are considered to be in good condition for these curve numbers.

Runoff Hydrograph for Area: Max Driveway Cross Drainage (100yr-24hr

Area (A,ac.)= 17.600 Rainfall (P)= 3.60 Pot.Max.Nat.Detention (S)*= 2.048

[based upon 24-hr. Design Storm Hyetograph in Table III-1.1 of Stormwater Manag.Man. for the Puget Sound Basin]

Time (min.)	%Precip.	Rainfall p(in./10min.)	Cum. Rain Pr (in.)	Cum. Rain. Excess Qd (in.) **	Runoff Q (cfs)***	Cum.Vol. (ac.ft.)****
0	0.00	0	0.000	0.000	0.000	0.00
10	0.40	0.0144	0.014	0.000	0.000	0.00
20	0.40	0.0144	0.029	0.000	0.000	0.00
30	0.40	0.0144	0.043	0.000	0.000	0.00
40	0.40	0.0144	0.058	0.000	0.000	0.00
50	0.40	0.0144	0.072	0.000	0.000	0.00
60	0.40	0.0144	0.086	0.000	0.000	0.00
70	0.40	0.0144	0.101	0.000	0.000	0.00
80	0.40	0.0144	0.115	0.000	0.000	0.00
90	0.40	0.0144	0.130	0.000	0.000	0.00
100	0.40	0.0144	0.144	0.000	0.000	0.00
110	0.50	0.018	0.162	0.000	0.000	0.00
120	0.50	0.018	0.180	0.000	0.000	0.00
130	0.50	0.018	0.198	0.000	0.000	0.00
140	0.50	0.018	0.216	0.000	0.000	0.00
150	0.50	0.018	0.234	0.000	0.000	0.00
160	0.50	0.018	0.252	0.000	0.000	0.00
170	0.60	0.0216	0.274	0.000	0.000	0.00
180	0.60	0.0216	0.295	0.000	0.000	0.00
190	0.60	0.0216	0.317	0.000	0.000	0.00
200	0.60	0.0216	0.338	0.000	0.000	0.00
210	0.60	0.0216	0.360	0.000	0.000	0.00
220	0.60	0.0216	0.382	0.000	0.000	0.00
230	0.70	0.0252	0.407	0.000	0.000	0.00
240	0.70	0.0252	0.432	0.000	0.026	0.00
250	0.70	0.0252	0.457	0.001	0.089	0.00
260	0.70	0.0252	0.482	0.002	0.151	0.00
270	0.70	0.0252	0.508	0.004	0.210	0.01
280	0.70	0.0252	0.533	0.007	0.268	0.01
290	0.82	0.02952	0.562	0.011	0.384	0.01
300	0.82	0.02952	0.592	0.015	0.457	0.02
310	0.82	0.02952	0.621	0.020	0.527	0.03
320	0.82	0.02952	0.651	0.025	0.595	0.03
330	0.82	0.02952	0.680	0.032	0.660	0.04
340	0.82	0.02952	0.710	0.038	0.722	0.05
350	0.95	0.0342	0.744	0.047	0.912	0.06
360	0.95	0.0342	0.778	0.056	0.989	0.08
370	0.95	0.0342	0.813	0.066	1.063	0.09
380	0.95	0.0342	0.847	0.077	1.134	0.11
390	0.95	0.0342	0.881	0.088	1.202	0.12
400	0.95	0.0342	0.915	0.100	1.267	0.14
410	1.34	0.04824	0.963	0.118	1.894	0.16
420	1.34	0.04824	1.012	0.137	2.012	0.19
430	1.34	0.04824	1.060	0.157	2.124	0.22
440	1.80	0.0648	1.125	0.185	3.018	0.25
450	1.80	0.0648	1.189	0.215	3.196	0.29
460	3.40	0.1224	1.312	0.276	6.481	0.36
470	5.40	0.1944	1.506	0.382	**11.341**	0.48
480	2.70	0.0972	1.603	0.440	6.092	0.60
490	1.80	0.0648	1.668	0.479	4.200	0.68
500	1.34	0.04824	1.716	0.509	3.194	0.73

Runoff Hydrograph for Area: Max Driveway Cross Drainage (100yr-24hr

Area (A,ac.)= 17.600 Rainfall (P)= 3.60 Pot.Max.Nat.Detention (S)*= 2.048

[based upon 24-hr. Design Storm Hyetograph in Table III-1.1 of Stormwater Manag.Man. for the Puget Sound Basin]

Time (min.)	%Precip.	Rainfall p(in./10min.)	Cum. Rain Pr (in.)	Cum. Rain. Excess Qd (in.) **	Runoff Q (cfs)***	Cum.Vol. (ac.ft.)****
510	1.34	0.04824	1.765	0.540	3.250	0.77
520	1.34	0.04824	1.813	0.571	3.302	0.82
530	0.88	0.03168	1.845	0.591	2.196	0.85
540	0.88	0.03168	1.876	0.612	2.218	0.88
550	0.88	0.03168	1.908	0.633	2.238	0.91
560	0.88	0.03168	1.940	0.654	2.258	0.95
570	0.88	0.03168	1.971	0.676	2.278	0.98
580	0.88	0.03168	2.003	0.697	2.297	1.01
590	0.88	0.03168	2.035	0.719	2.315	1.04
600	0.88	0.03168	2.066	0.741	2.334	1.07
610	0.88	0.03168	2.098	0.763	2.351	1.10
620	0.88	0.03168	2.130	0.785	2.368	1.14
630	0.88	0.03168	2.161	0.808	2.385	1.17
640	0.88	0.03168	2.193	0.830	2.401	1.20
650	0.72	0.02592	2.219	0.849	1.977	1.23
660	0.72	0.02592	2.245	0.867	1.987	1.26
670	0.72	0.02592	2.271	0.886	1.997	1.29
680	0.72	0.02592	2.297	0.905	2.007	1.32
690	0.72	0.02592	2.323	0.924	2.017	1.34
700	0.72	0.02592	2.349	0.943	2.027	1.37
710	0.72	0.02592	2.375	0.962	2.036	1.40
720	0.72	0.02592	2.400	0.981	2.046	1.43
730	0.72	0.02592	2.426	1.001	2.055	1.46
740	0.72	0.02592	2.452	1.020	2.064	1.48
750	0.72	0.02592	2.478	1.040	2.073	1.51
760	0.72	0.02592	2.504	1.059	2.081	1.54
770	0.57	0.02052	2.525	1.075	1.654	1.57
780	0.57	0.02052	2.545	1.090	1.659	1.59
790	0.57	0.02052	2.566	1.106	1.664	1.61
800	0.57	0.02052	2.586	1.121	1.669	1.64
810	0.57	0.02052	2.607	1.137	1.674	1.66
820	0.57	0.02052	2.627	1.153	1.679	1.68
830	0.57	0.02052	2.648	1.169	1.684	1.71
840	0.57	0.02052	2.668	1.185	1.689	1.73
850	0.57	0.02052	2.689	1.201	1.693	1.75
860	0.57	0.02052	2.709	1.216	1.698	1.78
870	0.57	0.02052	2.730	1.232	1.702	1.80
880	0.57	0.02052	2.750	1.248	1.707	1.82
890	0.50	0.018	2.768	1.263	1.501	1.84
900	0.50	0.018	2.786	1.277	1.504	1.87
910	0.50	0.018	2.804	1.291	1.508	1.89
920	0.50	0.018	2.822	1.305	1.511	1.91
930	0.50	0.018	2.840	1.319	1.514	1.93
940	0.50	0.018	2.858	1.334	1.517	1.95
950	0.50	0.018	2.876	1.348	1.521	1.97
960	0.50	0.018	2.894	1.362	1.524	1.99
970	0.50	0.018	2.912	1.376	1.527	2.01
980	0.50	0.018	2.930	1.391	1.530	2.03
990	0.50	0.018	2.948	1.405	1.533	2.05
1000	0.50	0.018	2.966	1.420	1.536	2.08
1010	0.40	0.0144	2.981	1.431	1.231	2.09

Runoff Hydrograph for Area: Max Driveway Cross Drainage (100yr-24hr

Area (A,ac.)= 17.600 Rainfall (P)= 3.60 Pot.Max.Nat.Detention (S)*= 2.048

[based upon 24-hr. Design Storm Hyetograph in Table III-1.1 of Stormwater Manag.Man. for the Puget Sound Basin]

Time (min.)	%Precip.	Rainfall p(in./10min.)	Cum. Rain Pr (in.)	Cum. Rain. Excess Qd (in.) **	Runoff Q (cfs)***	Cum.Vol. (ac.ft.)****
1020	0.40	0.0144	2.995	1.443	1.233	2.11
1030	0.40	0.0144	3.010	1.454	1.235	2.13
1040	0.40	0.0144	3.024	1.466	1.237	2.15
1050	0.40	0.0144	3.038	1.478	1.238	2.16
1060	0.40	0.0144	3.053	1.489	1.240	2.18
1070	0.40	0.0144	3.067	1.501	1.242	2.20
1080	0.40	0.0144	3.082	1.513	1.244	2.21
1090	0.40	0.0144	3.096	1.524	1.246	2.23
1100	0.40	0.0144	3.110	1.536	1.247	2.25
1110	0.40	0.0144	3.125	1.548	1.249	2.27
1120	0.40	0.0144	3.139	1.560	1.251	2.28
1130	0.40	0.0144	3.154	1.571	1.252	2.30
1140	0.40	0.0144	3.168	1.583	1.254	2.32
1150	0.40	0.0144	3.182	1.595	1.256	2.33
1160	0.40	0.0144	3.197	1.607	1.257	2.35
1170	0.40	0.0144	3.211	1.618	1.259	2.37
1180	0.40	0.0144	3.226	1.630	1.261	2.39
1190	0.40	0.0144	3.240	1.642	1.262	2.40
1200	0.40	0.0144	3.254	1.654	1.264	2.42
1210	0.40	0.0144	3.269	1.666	1.265	2.44
1220	0.40	0.0144	3.283	1.678	1.267	2.46
1230	0.40	0.0144	3.298	1.690	1.269	2.47
1240	0.40	0.0144	3.312	1.702	1.270	2.49
1250	0.40	0.0144	3.326	1.714	1.272	2.51
1260	0.40	0.0144	3.341	1.726	1.273	2.53
1270	0.40	0.0144	3.355	1.738	1.275	2.54
1280	0.40	0.0144	3.370	1.750	1.276	2.56
1290	0.40	0.0144	3.384	1.762	1.278	2.58
1300	0.40	0.0144	3.398	1.774	1.279	2.60
1310	0.40	0.0144	3.413	1.786	1.281	2.61
1320	0.40	0.0144	3.427	1.798	1.282	2.63
1330	0.40	0.0144	3.442	1.810	1.283	2.65
1340	0.40	0.0144	3.456	1.822	1.285	2.67
1350	0.40	0.0144	3.470	1.834	1.286	2.69
1360	0.40	0.0144	3.485	1.846	1.288	2.70
1370	0.40	0.0144	3.499	1.858	1.289	2.72
1380	0.40	0.0144	3.514	1.870	1.290	2.74
1390	0.40	0.0144	3.528	1.882	1.292	2.76
1400	0.40	0.0144	3.542	1.894	1.293	2.77
1410	0.40	0.0144	3.557	1.907	1.294	2.79
1420	0.40	0.0144	3.571	1.919	1.296	2.81
1430	0.40	0.0144	3.586	1.931	1.297	2.83
1440	0.40	0.0144	3.600	1.943	1.298	2.85

* formula: S = (1000/CN)-10 [for this steep forested slope, Max CN=83 and S=2.048]

** formula: (Pr-0.2S)**2/(Pr+0.8S); however, if Ptotal<0.2S, Qd=0.00 inches

*** formula: (Rainfall excess-Prev.Rainfall excess, in./10min.)*(1 ft./12in.)*(1 min./60 sec.)*(A acres)*(43,560 sq.ft./acre)

**** formula: (Q + Qprev.)/2*(60 sec./min.)*(10 min.)/(43,560 sq.ft./ac.)+prev.vol.= 0.0138*(Q+Qprev)/2+prev.vol. ac.ft.

Runoff Hydrograph for Area: Max B.House upland flow (100yr-24hr)

Area (A,ac.)= 14.300 Rainfall (P)= 3.60 Pot.Max.Nat.Detention (S)*= 2.048

[based upon 24-hr. Design Storm Hyetograph in Table III-1.1 of Stormwater Manag.Man. for the Puget Sound Basin]

Time (min.)	%Precip.	Rainfall p(in./10min.)	Cum. Rain Pr (in.)	Cum. Rain. Excess Qd (in.) **	Runoff Q (cfs)***	Cum.Vol. (ac.ft.)****
0	0.00	0	0.000	0.000	0.000	0.00
10	0.40	0.0144	0.014	0.000	0.000	0.00
20	0.40	0.0144	0.029	0.000	0.000	0.00
30	0.40	0.0144	0.043	0.000	0.000	0.00
40	0.40	0.0144	0.058	0.000	0.000	0.00
50	0.40	0.0144	0.072	0.000	0.000	0.00
60	0.40	0.0144	0.086	0.000	0.000	0.00
70	0.40	0.0144	0.101	0.000	0.000	0.00
80	0.40	0.0144	0.115	0.000	0.000	0.00
90	0.40	0.0144	0.130	0.000	0.000	0.00
100	0.40	0.0144	0.144	0.000	0.000	0.00
110	0.50	0.018	0.162	0.000	0.000	0.00
120	0.50	0.018	0.180	0.000	0.000	0.00
130	0.50	0.018	0.198	0.000	0.000	0.00
140	0.50	0.018	0.216	0.000	0.000	0.00
150	0.50	0.018	0.234	0.000	0.000	0.00
160	0.50	0.018	0.252	0.000	0.000	0.00
170	0.60	0.0216	0.274	0.000	0.000	0.00
180	0.60	0.0216	0.295	0.000	0.000	0.00
190	0.60	0.0216	0.317	0.000	0.000	0.00
200	0.60	0.0216	0.338	0.000	0.000	0.00
210	0.60	0.0216	0.360	0.000	0.000	0.00
220	0.60	0.0216	0.382	0.000	0.000	0.00
230	0.70	0.0252	0.407	0.000	0.000	0.00
240	0.70	0.0252	0.432	0.000	0.021	0.00
250	0.70	0.0252	0.457	0.001	0.073	0.00
260	0.70	0.0252	0.482	0.002	0.123	0.00
270	0.70	0.0252	0.508	0.004	0.171	0.00
280	0.70	0.0252	0.533	0.007	0.218	0.01
290	0.82	0.02952	0.562	0.011	0.312	0.01
300	0.82	0.02952	0.592	0.015	0.371	0.02
310	0.82	0.02952	0.621	0.020	0.428	0.02
320	0.82	0.02952	0.651	0.025	0.483	0.03
330	0.82	0.02952	0.680	0.032	0.536	0.03
340	0.82	0.02952	0.710	0.038	0.587	0.04
350	0.95	0.0342	0.744	0.047	0.741	0.05
360	0.95	0.0342	0.778	0.056	0.803	0.06
370	0.95	0.0342	0.813	0.066	0.864	0.07
380	0.95	0.0342	0.847	0.077	0.921	0.09
390	0.95	0.0342	0.881	0.088	0.977	0.10
400	0.95	0.0342	0.915	0.100	1.030	0.11
410	1.34	0.04824	0.963	0.118	1.539	0.13
420	1.34	0.04824	1.012	0.137	1.635	0.15
430	1.34	0.04824	1.060	0.157	1.725	0.18
440	1.80	0.0648	1.125	0.185	2.452	0.20
450	1.80	0.0648	1.189	0.215	2.597	0.24
460	3.40	0.1224	1.312	0.276	5.266	0.29
470	5.40	0.1944	1.506	0.382	**9.215**	0.39
480	2.70	0.0972	1.603	0.440	4.949	0.49
490	1.80	0.0648	1.668	0.479	3.413	0.55
500	1.34	0.04824	1.716	0.509	2.596	0.59

Runoff Hydrograph for Area: Max B.House upland flow (100yr-24hr)

Area (A,ac.)= 14.300 Rainfall (P)= 3.60 Pot.Max.Nat.Detention (S)*= 2.048

[based upon 24-hr. Design Storm Hyetograph in Table III-1.1 of Stormwater Manag.Man. for the Puget Sound Basin]

Time (min.)	%Precip.	Rainfall p(in./10min.)	Cum. Rain Pr (in.)	Cum. Rain. Excess Qd (in.) **	Runoff Q (cfs)***	Cum.Vol. (ac.ft.)****
510	1.34	0.04824	1.765	0.540	2.640	0.63
520	1.34	0.04824	1.813	0.571	2.683	0.66
530	0.88	0.03168	1.845	0.591	1.785	0.69
540	0.88	0.03168	1.876	0.612	1.802	0.72
550	0.88	0.03168	1.908	0.633	1.819	0.74
560	0.88	0.03168	1.940	0.654	1.835	0.77
570	0.88	0.03168	1.971	0.676	1.851	0.79
580	0.88	0.03168	2.003	0.697	1.866	0.82
590	0.88	0.03168	2.035	0.719	1.881	0.85
600	0.88	0.03168	2.066	0.741	1.896	0.87
610	0.88	0.03168	2.098	0.763	1.910	0.90
620	0.88	0.03168	2.130	0.785	1.924	0.92
630	0.88	0.03168	2.161	0.808	1.938	0.95
640	0.88	0.03168	2.193	0.830	1.951	0.98
650	0.72	0.02592	2.219	0.849	1.606	1.00
660	0.72	0.02592	2.245	0.867	1.615	1.02
670	0.72	0.02592	2.271	0.886	1.623	1.05
680	0.72	0.02592	2.297	0.905	1.631	1.07
690	0.72	0.02592	2.323	0.924	1.639	1.09
700	0.72	0.02592	2.349	0.943	1.647	1.11
710	0.72	0.02592	2.375	0.962	1.655	1.14
720	0.72	0.02592	2.400	0.981	1.662	1.16
730	0.72	0.02592	2.426	1.001	1.670	1.18
740	0.72	0.02592	2.452	1.020	1.677	1.21
750	0.72	0.02592	2.478	1.040	1.684	1.23
760	0.72	0.02592	2.504	1.059	1.691	1.25
770	0.57	0.02052	2.525	1.075	1.344	1.27
780	0.57	0.02052	2.545	1.090	1.348	1.29
790	0.57	0.02052	2.566	1.106	1.352	1.31
800	0.57	0.02052	2.586	1.121	1.356	1.33
810	0.57	0.02052	2.607	1.137	1.360	1.35
820	0.57	0.02052	2.627	1.153	1.364	1.37
830	0.57	0.02052	2.648	1.169	1.368	1.39
840	0.57	0.02052	2.668	1.185	1.372	1.40
850	0.57	0.02052	2.689	1.201	1.376	1.42
860	0.57	0.02052	2.709	1.216	1.380	1.44
870	0.57	0.02052	2.730	1.232	1.383	1.46
880	0.57	0.02052	2.750	1.248	1.387	1.48
890	0.50	0.018	2.768	1.263	1.220	1.50
900	0.50	0.018	2.786	1.277	1.222	1.52
910	0.50	0.018	2.804	1.291	1.225	1.53
920	0.50	0.018	2.822	1.305	1.228	1.55
930	0.50	0.018	2.840	1.319	1.230	1.57
940	0.50	0.018	2.858	1.334	1.233	1.58
950	0.50	0.018	2.876	1.348	1.236	1.60
960	0.50	0.018	2.894	1.362	1.238	1.62
970	0.50	0.018	2.912	1.376	1.241	1.63
980	0.50	0.018	2.930	1.391	1.243	1.65
990	0.50	0.018	2.948	1.405	1.246	1.67
1000	0.50	0.018	2.966	1.420	1.248	1.69
1010	0.40	0.0144	2.981	1.431	1.000	1.70

Runoff Hydrograph for Area: Max B.House upland flow (100yr-24hr)

Area (A,ac.)= 14.300 Rainfall (P)= 3.60 Pot.Max.Nat.Detention (S)*= 2.048

[based upon 24-hr. Design Storm Hyetograph in Table III-1.1 of Stormwater Manag.Man. for the Puget Sound Basin]

Time (min.)	%Precip.	Rainfall p(in./10min.)	Cum. Rain Pr (in.)	Cum. Rain. Excess Qd (in.) **	Runoff Q (cfs)***	Cum.Vol. (ac.ft.)****
1020	0.40	0.0144	2.995	1.443	1.002	1.72
1030	0.40	0.0144	3.010	1.454	1.003	1.73
1040	0.40	0.0144	3.024	1.466	1.005	1.74
1050	0.40	0.0144	3.038	1.478	1.006	1.76
1060	0.40	0.0144	3.053	1.489	1.008	1.77
1070	0.40	0.0144	3.067	1.501	1.009	1.79
1080	0.40	0.0144	3.082	1.513	1.011	1.80
1090	0.40	0.0144	3.096	1.524	1.012	1.81
1100	0.40	0.0144	3.110	1.536	1.013	1.83
1110	0.40	0.0144	3.125	1.548	1.015	1.84
1120	0.40	0.0144	3.139	1.560	1.016	1.85
1130	0.40	0.0144	3.154	1.571	1.018	1.87
1140	0.40	0.0144	3.168	1.583	1.019	1.88
1150	0.40	0.0144	3.182	1.595	1.020	1.90
1160	0.40	0.0144	3.197	1.607	1.022	1.91
1170	0.40	0.0144	3.211	1.618	1.023	1.93
1180	0.40	0.0144	3.226	1.630	1.024	1.94
1190	0.40	0.0144	3.240	1.642	1.026	1.95
1200	0.40	0.0144	3.254	1.654	1.027	1.97
1210	0.40	0.0144	3.269	1.666	1.028	1.98
1220	0.40	0.0144	3.283	1.678	1.029	2.00
1230	0.40	0.0144	3.298	1.690	1.031	2.01
1240	0.40	0.0144	3.312	1.702	1.032	2.02
1250	0.40	0.0144	3.326	1.714	1.033	2.04
1260	0.40	0.0144	3.341	1.726	1.034	2.05
1270	0.40	0.0144	3.355	1.738	1.036	2.07
1280	0.40	0.0144	3.370	1.750	1.037	2.08
1290	0.40	0.0144	3.384	1.762	1.038	2.10
1300	0.40	0.0144	3.398	1.774	1.039	2.11
1310	0.40	0.0144	3.413	1.786	1.040	2.12
1320	0.40	0.0144	3.427	1.798	1.042	2.14
1330	0.40	0.0144	3.442	1.810	1.043	2.15
1340	0.40	0.0144	3.456	1.822	1.044	2.17
1350	0.40	0.0144	3.470	1.834	1.045	2.18
1360	0.40	0.0144	3.485	1.846	1.046	2.20
1370	0.40	0.0144	3.499	1.858	1.047	2.21
1380	0.40	0.0144	3.514	1.870	1.048	2.23
1390	0.40	0.0144	3.528	1.882	1.050	2.24
1400	0.40	0.0144	3.542	1.894	1.051	2.25
1410	0.40	0.0144	3.557	1.907	1.052	2.27
1420	0.40	0.0144	3.571	1.919	1.053	2.28
1430	0.40	0.0144	3.586	1.931	1.054	2.30
1440	0.40	0.0144	3.600	1.943	1.055	2.31

* formula: S = (1000/CN)-10 [for this steep forested slope, Max CN=83 and S=2.048]

** formula: (Pr-0.2S)**2/(Pr+0.8S); however, if Ptotal<0.2S, Qd=0.00 inches

*** formula: (Rainfall excess-Prev.Rainfall excess, in./10min.)*(1 ft./12in.)*(1 min./60 sec.)*(A acres)*(43,560 sq.ft./acre)

**** formula: (Q + Qprev.)/2*(60 sec./min.)*(10 min.)/(43,560 sq.ft./ac.)+prev.vol.= 0.0138*(Q+Qprev)/2+prev.vol. ac.ft.

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RUNSTAD BEACH HOUSE

HOME DIVERSION CHANNEL

Flow (100 yr, 24 hr Peak for Watershed "B") is 9.2 cfs

Main Channel: Slope is 0.15 down near home

Assume grass cover with $n = 0.30$ max for capacity & $n = 0.025$ for velocity (similar to BMP T9.10 stability, evaluation for a biofilm)

Assume bott. width 1' & 2:1 sideslopes

from King's Handbook, Table 7-11, $K' = \frac{Qn}{b^{8/3} S^{1/2}}$ & K' indicates D/b from table

for Max depth, $K' = \frac{9.2(.3)}{1^{8/3}(.15)^{1/2}} = 7.1263 \rightarrow D/b = 1.463'$ or $D = 1.46'$

Area $= [2(1.46)+1]1.46 = 5.72\ ft^2 \rightarrow vel = \frac{9.2}{5.72} = 1.61$ fps = vel

for Max velocity, $K' = \frac{9.2(.025)}{1^{8/3}(.15)^{1/2}} = 0.59386 \rightarrow D/b = 0.138'$ or $D = 0.138'$

Area $= [2(.138)+1].138 = 0.176\ ft^2$ or $vel = \frac{9.2}{.176} = 52.3$ fps = vel.

Rock lining would be needed to address erosive vel.

Culvert across drive @ home (assume 12" diam)

slope ~ $\frac{0.5'}{14'} = 0.036$ & $n_{corr} = 0.024$

for King's H.B. Table 7-14 K' indicates D/d

$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{9.2(.024)}{1^{8/3}(.036)^{1/2}} = 1.164 \rightarrow D/d > 1.0$

Try 18" diam.

$K' = \frac{9.2(.024)}{(1.5)^{8/3}(.036)^{1/2}} = 0.3947 \rightarrow D/d = 0.71 \rightarrow D = 1.06'$

Look at Entrance Control [AISI Handbook, p 189]

Without headwall, Head = 1.5(1.5) = 2.25' above invert

Area $= \pi(.75)^2 = 1.77\ ft^2$

& $vel_{in} = \frac{9.2}{1.77} = 5.2$ fps

Channel Alongside Home

Conservatively assume only 9.2 cfs flow at head of this channel to see if capacity adequate at reasonable b & cover. $n = 0.20$

Assume $b = 1'$ & SS = 2:1 max & $S = \frac{36-31.35}{130} = 0.036$

from King's H.B. Table 7-11, $K' = \frac{9.2(0.2)}{(1)^{8/3}(.036)^{1/2}} = 9.698 \rightarrow D/b = 1.67 \rightarrow D = 1.67'$

Area $= [2(1.67)+1]1.67 = 7.25\ ft^2 \rightarrow vel = 1.27$ fps GOOD

Non-erosive

It's plot this scale area to show flow to approach $n = 0.2$

DRIVEWAY CROSS DRAINAGE for 100 yr-24 hr Peak of 11.3 cfs

for inlet control conditions, need 18" culv. with head of $HW/D \approx 2$ or HW = 3' above invert

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/8} s^{1/2}$ for Trapezoidal Channels

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼–1	½–1	¾–1	1–1	1½–1	2–1	2½–1	3–1	4–1
.01	.00068	.00068	.00069	.00069	.00069	.00069	.00069	.00069	.00070	.00070
.02	.00213	.00215	.00216	.00217	.00218	.00220	.00221	.00222	.00223	.00225
.03	.00414	.00419	.00423	.00426	.00428	.00433	.00436	.00439	.00443	.00449
.04	.00660	.00670	.00679	.00685	.00691	.00700	.00708	.00716	.00723	.00736
.05	.00946	.00964	.00979	.00991	.01002	.01019	.01033	.01047	.01060	.01086
.06	.0127	.0130	.0132	.0134	.0136	.0138	.0141	.0143	.0145	.0150
.07	.0162	.0166	.0170	.0173	.0175	.0180	.0183	.0187	.0190	.0197
.08	.0200	.0206	.0211	.0215	.0219	.0225	.0231	.0236	.0240	.0250
.09	.0241	.0249	.0256	.0262	.0267	.0275	.0282	.0289	.0296	.0310
.10	.0284	.0294	.0304	.0311	.0318	.0329	.0339	.0348	.0358	.0376
.11	.0329	.0343	.0354	.0364	.0373	.0387	.0400	.0413	.0424	.0448
.12	.0376	.0393	.0408	.0420	.0431	.0450	.0466	.0482	.0497	.0527
.13	.0425	.0446	.0464	.0480	.0493	.0516	.0537	.0556	.0575	.0613
.14	.0476	.0502	.0524	.0542	.0559	.0587	.0612	.0636	.0659	.0706
.15	.0528	.0559	.0585	.0608	.0627	.0662	.0692	.0721	.0749	.0805
.16	.0582	.0619	.0650	.0676	.0700	.0740	.0777	.0811	.0845	.0912
.17	.0638	.0680	.0716	.0748	.0775	.0823	.0866	.0907	.0947	.1026
.18	.0695	.0744	.0786	.0822	.0854	.0910	.0960	.1008	.1055	.1148
.19	.0753	.0809	.0857	.0899	.0936	.1001	.1059	.1115	.1169	.1277
.20	.0812	.0876	.0931	.0979	.1021	.1096	.1163	.1227	.1290	.1414
.21	.0873	.0945	.101	.106	.111	.120	.127	.135	.142	.156
.22	.0934	.1015	.109	.115	.120	.130	.139	.147	.155	.171
.23	.0997	.1087	.117	.124	.130	.141	.150	.160	.169	.187
.24	.1061	.1161	.125	.133	.140	.152	.163	.173	.184	.204
.25	.1125	.1236	.133	.142	.150	.163	.176	.188	.199	.222
.26	.119	.131	.142	.152	.160	.175	.189	.202	.215	.241
.27	.126	.139	.151	.162	.171	.188	.203	.218	.232	.260
.28	.132	.147	.160	.172	.182	.201	.217	.234	.249	.281
.29	.139	.155	.170	.182	.194	.214	.232	.250	.268	.302
.30	.146	.163	.179	.193	.205	.228	.248	.267	.287	.324
.31	.153	.172	.189	.204	.218	.242	.264	.285	.306	.347
.32	.160	.180	.199	.215	.230	.256	.281	.304	.327	.371
.33	.167	.189	.209	.227	.243	.271	.298	.323	.348	.396
.34	.174	.198	.219	.238	.256	.287	.316	.343	.370	.423
.35	.181	.207	.230	.251	.269	.303	.334	.363	.392	.450
.36	.189	.216	.241	.263	.283	.319	.353	.385	.416	.478
.37	.196	.225	.252	.275	.297	.336	.372	.406	.440	.507
.38	.203	.234	.263	.288	.312	.353	.392	.429	.465	.537
.39	.211	.244	.274	.301	.326	.371	.413	.452	.491	.568
.40	.218	.253	.286	.315	.341	.389	.434	.476	.518	.600
.41	.226	.263	.297	.328	.357	.408	.456	.501	.546	.633
.42	.233	.273	.309	.342	.373	.427	.478	.526	.574	.668
.43	.241	.283	.321	.357	.389	.447	.501	.553	.603	.703
.44	.248	.293	.334	.371	.405	.467	.525	.580	.633	.740
.45	.256	.303	.346	.386	.422	.488	.549	.607	.664	.777

from King & Brater Handbook of Hydraulics, 5th edit.

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/8} s^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼–1	½–1	¾–1	1–1	1½–1	2–1	2½–1	3–1	4–1
.46	.264	.313	.359	.401	.439	.509	.574	.636	.696	.816
.47	.271	.323	.372	.416	.457	.531	.599	.665	.729	.856
.48	.279	.334	.385	.432	.474	.553	.625	.695	.763	.897
.49	.287	.344	.398	.447	.493	.575	.652	.725	.797	.939
.50	.295	.355	.412	.463	.511	.598	.679	.757	.833	.983
.51	.303	.366	.425	.480	.530	.622	.707	.789	.869	1.03
.52	.311	.377	.439	.496	.549	.646	.736	.822	.907	1.07
.53	.319	.388	.453	.513	.569	.671	.765	.856	.945	1.12
.54	.327	.399	.467	.531	.589	.696	.795	.891	.984	1.17
.55	.335	.410	.482	.548	.609	.722	.826	.926	1.025	1.22
.56	.343	.422	.497	.566	.630	.748	.857	.963	1.07	1.27
.57	.351	.433	.511	.584	.651	.775	.889	1.000	1.11	1.32
.58	.359	.445	.526	.602	.673	.802	.922	1.038	1.15	1.37
.59	.367	.456	.542	.621	.694	.830	.956	1.077	1.20	1.43
.60	.375	.468	.557	.640	.717	.858	.990	1.117	1.24	1.49
.61	.383	.480	.573	.659	.739	.887	1.02	1.16	1.29	1.54
.62	.391	.492	.588	.678	.762	.916	1.06	1.20	1.33	1.60
.63	.399	.504	.604	.698	.785	.946	1.10	1.24	1.38	1.66
.64	.408	.516	.620	.718	.809	.977	1.13	1.28	1.43	1.72
.65	.416	.529	.637	.738	.833	1.008	1.17	1.33	1.48	1.79
.66	.424	.541	.653	.759	.857	1.04	1.21	1.37	1.53	1.85
.67	.433	.553	.670	.780	.882	1.07	1.25	1.42	1.59	1.91
.68	.441	.566	.687	.801	.907	1.10	1.29	1.47	1.64	1.98
.69	.449	.579	.704	.822	.933	1.14	1.33	1.51	1.69	2.05
.70	.457	.592	.722	.844	.959	1.17	1.37	1.56	1.75	2.12
.71	.466	.604	.739	.866	.985	1.21	1.41	1.61	1.31	2.19
.72	.474	.617	.757	.889	1.012	1.24	1.46	1.66	1.86	2.26
.73	.483	.631	.775	.911	1.039	1.28	1.50	1.71	1.92	2.34
.74	.491	.644	.793	.934	1.067	1.31	1.54	1.77	1.98	2.41
.75	.499	.657	.811	.957	1.095	1.35	1.59	1.82	2.05	2.49
.76	.508	.670	.830	.981	1.12	1.39	1.63	1.87	2.11	2.57
.77	.516	.684	.849	1.005	1.15	1.43	1.68	1.93	2.17	2.65
.78	.525	.698	.868	1.029	1.18	1.46	1.73	1.99	2.24	2.73
.79	.533	.711	.887	1.053	1.21	1.50	1.78	2.04	2.30	2.81
.80	.542	.725	.906	1.078	1.24	1.54	1.83	2.10	2.37	2.90
.81	.550	.739	.925	1.10	1.27	1.58	1.88	2.16	2.44	2.98
.82	.559	.753	.945	1.13	1.30	1.62	1.93	2.22	2.51	3.07
.83	.567	.767	.965	1.15	1.33	1.67	1.98	2.28	2.58	3.16
.84	.576	.781	.985	1.18	1.36	1.71	2.03	2.34	2.65	3.25
.85	.585	.796	1.006	1.21	1.40	1.75	2.08	2.41	2.72	3.35
.86	.593	.810	1.03	1.23	1.43	1.79	2.14	2.47	2.80	3.44
.87	.602	.825	1.05	1.26	1.46	1.84	2.19	2.54	2.87	3.54
.88	.610	.839	1.07	1.29	1.49	1.88	2.25	2.60	2.95	3.63
.89	.619	.854	1.09	1.31	1.53	1.93	2.31	2.67	3.03	3.73
.90	.628	.869	1.11	1.34	1.56	1.98	2.36	2.74	3.11	3.83

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/8} s^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼–1	½–1	¾–1	1–1	1½–1	2–1	2½–1	3–1	4–1
.91	.636	.884	1.13	1.37	1.60	2.02	2.42	2.81	3.19	3.93
.92	.645	.899	1.15	1.40	1.63	2.07	2.48	2.88	3.27	4.04
.93	.653	.914	1.18	1.43	1.67	2.12	2.54	2.95	3.35	4.14
.94	.662	.929	1.20	1.46	1.70	2.17	2.60	3.02	3.44	4.25
.95	.671	.944	1.22	1.49	1.74	2.22	2.66	3.10	3.52	4.36
.96	.680	.960	1.24	1.52	1.78	2.27	2.73	3.17	3.61	4.47
.97	.688	.975	1.27	1.55	1.81	2.32	2.79	3.25	3.70	4.58
.98	.697	.991	1.29	1.58	1.85	2.37	2.85	3.33	3.79	4.70
.99	.706	1.006	1.31	1.61	1.89	2.42	2.92	3.40	3.88	4.81
1.00	.714	1.022	1.33	1.64	1.93	2.47	2.99	3.48	3.97	4.93
1.01	.723	1.04	1.36	1.67	1.97	2.53	3.05	3.56	4.06	5.05
1.02	.732	1.05	1.38	1.70	2.01	2.58	3.12	3.65	4.16	5.17
1.03	.741	1.07	1.41	1.73	2.05	2.63	3.19	3.73	4.26	5.30
1.04	.749	1.09	1.43	1.77	2.09	2.69	3.26	3.81	4.35	5.42
1.05	.758	1.10	1.46	1.80	2.13	2.75	3.33	3.90	4.45	5.55
1.06	.767	1.12	1.48	1.83	2.17	2.80	3.40	3.98	4.55	5.68
1.07	.776	1.14	1.50	1.86	2.21	2.86	3.48	4.07	4.66	5.81
1.08	.784	1.15	1.53	1.90	2.25	2.92	3.55	4.16	4.76	5.94
1.09	.793	1.17	1.56	1.93	2.29	2.98	3.62	4.25	4.86	6.07
1.10	.802	1.19	1.58	1.97	2.34	3.04	3.70	4.34	4.97	6.21
1.11	.811	1.20	1.61	2.00	2.38	3.10	3.78	4.43	5.08	6.35
1.12	.820	1.22	1.63	2.04	2.42	3.16	3.85	4.53	5.19	6.49
1.13	.829	1.24	1.66	2.07	2.47	3.22	3.93	4.62	5.30	6.63
1.14	.837	1.25	1.69	2.11	2.51	3.28	4.01	4.72	5.41	6.77
1.15	.846	1.27	1.71	2.14	2.56	3.35	4.09	4.81	5.52	6.92
1.16	.855	1.29	1.74	2.18	2.61	3.41	4.17	4.91	5.63	7.06
1.17	.864	1.31	1.77	2.22	2.65	3.47	4.25	5.01	5.75	7.21
1.18	.873	1.32	1.79	2.25	2.70	3.54	4.34	5.11	5.87	7.36
1.19	.882	1.34	1.82	2.29	2.75	3.61	4.42	5.21	5.99	7.52
1.20	.891	1.36	1.85	2.33	2.79	3.67	4.51	5.32	6.11	7.67
1.21	.899	1.38	1.88	2.37	2.84	3.74	4.59	5.42	6.23	7.83
1.22	.908	1.40	1.90	2.41	2.89	3.81	4.68	5.52	6.35	7.99
1.23	.917	1.41	1.93	2.44	2.94	3.88	4.77	5.63	6.48	8.15
1.24	.926	1.43	1.96	2.48	2.99	3.95	4.86	5.74	6.61	8.31
1.25	.935	1.45	1.99	2.52	3.04	4.02	4.95	5.85	6.73	8.48
1.26	.944	1.47	2.02	2.56	3.09	4.09	5.04	5.96	6.86	8.64
1.27	.953	1.49	2.05	2.60	3.14	4.16	5.13	6.07	6.99	8.81
1.28	.962	1.51	2.08	2.64	3.19	4.23	5.22	6.18	7.13	8.98
1.29	.971	1.52	2.11	2.69	3.24	4.31	5.32	6.30	7.26	9.16
1.30	.980	1.54	2.14	2.73	3.30	4.38	5.41	6.41	7.40	9.33
1.31	.989	1.56	2.17	2.77	3.35	4.46	5.51	6.53	7.53	9.51
1.32	.997	1.58	2.20	2.81	3.40	4.53	5.61	6.65	7.67	9.69
1.33	1.006	1.60	2.23	2.85	3.46	4.61	5.71	6.77	7.81	9.87
1.34	1.015	1.62	2.26	2.90	3.51	4.69	5.81	6.89	7.96	10.05
1.35	1.024	1.64	2.29	2.94	3.57	4.77	5.91	7.01	8.10	10.24

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/8} s^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼–1	½–1	¾–1	1–1	1½–1	2–1	2½–1	3–1	4–1
1.36	1.03	1.66	2.32	2.98	3.62	4.85	6.01	7.14	8.24	10.4
1.37	1.04	1.68	2.35	3.03	3.68	4.93	6.11	7.26	8.39	10.6
1.38	1.05	1.70	2.38	3.07	3.74	5.01	6.21	7.39	8.54	10.8
1.39	1.06	1.72	2.42	3.11	3.79	5.09	6.32	7.51	8.69	11.0
1.40	1.07	1.74	2.45	3.16	3.85	5.17	6.42	7.64	8.84	11.2
1.41	1.08	1.76	2.48	3.21	3.91	5.25	6.53	7.77	8.99	11.4
1.42	1.09	1.78	2.51	3.25	3.97	5.34	6.64	7.91	9.15	11.6
1.43	1.10	1.80	2.55	3.30	4.03	5.42	6.75	8.04	9.31	11.8
1.44	1.11	1.82	2.58	3.34	4.09	5.51	6.86	8.17	9.46	12.0
1.45	1.11	1.84	2.61	3.39	4.15	5.59	6.97	8.31	9.62	12.2
1.46	1.12	1.86	2.65	3.44	4.21	5.68	7.08	8.45	9.78	12.4
1.47	1.13	1.88	2.68	3.49	4.27	5.77	7.20	8.59	9.95	12.6
1.48	1.14	1.90	2.71	3.53	4.33	5.86	7.31	8.73	10.11	12.8
1.49	1.15	1.92	2.75	3.58	4.39	5.95	7.43	8.87	10.28	13.1
1.50	1.16	1.94	2.78	3.63	4.46	6.04	7.54	9.01	10.45	13.3
1.51	1.17	1.96	2.82	3.68	4.52	6.13	7.66	9.15	10.6	13.5
1.52	1.18	1.98	2.85	3.73	4.58	6.22	7.78	9.30	10.8	13.7
1.53	1.19	2.00	2.89	3.78	4.65	6.31	7.90	9.45	11.0	14.0
1.54	1.20	2.03	2.92	3.83	4.71	6.41	8.02	9.59	11.1	14.2
1.55	1.20	2.05	2.96	3.88	4.78	6.50	8.15	9.74	11.3	14.4
1.56	1.21	2.07	3.00	3.93	4.85	6.60	8.27	9.90	11.5	14.6
1.57	1.22	2.09	3.03	3.98	4.91	6.69	8.40	10.05	11.7	14.9
1.58	1.23	2.11	3.07	4.03	4.98	6.79	8.52	10.20	11.9	15.1
1.59	1.24	2.13	3.11	4.09	5.05	6.89	8.65	10.36	12.0	15.3
1.60	1.25	2.16	3.14	4.14	5.12	6.99	8.78	10.52	12.2	15.6
1.61	1.26	2.18	3.18	4.19	5.18	7.09	8.91	10.7	12.4	15.8
1.62	1.27	2.20	3.22	4.25	5.25	7.19	9.04	10.8	12.6	16.1
1.63	1.28	2.22	3.25	4.30	5.32	7.29	9.17	11.0	12.8	16.3
1.64	1.29	2.24	3.29	4.35	5.40	7.39	9.30	11.2	13.0	16.6
1.65	1.29	2.27	3.33	4.41	5.47	7.50	9.44	11.3	13.2	16.8
1.66	1.30	2.29	3.37	4.46	5.54	7.60	9.57	11.5	13.4	17.1
1.67	1.31	2.31	3.41	4.52	5.61	7.70	9.71	11.7	13.6	17.3
1.68	1.32	2.33	3.45	4.57	5.68	7.81	9.85	11.8	13.8	17.6
1.69	1.33	2.36	3.49	4.63	5.76	7.92	9.99	12.0	14.0	17.9
1.70	1.34	2.38	3.52	4.69	5.83	8.02	10.13	12.2	14.2	18.1
1.71	1.35	2.40	3.56	4.74	5.90	8.13	10.3	12.3	14.4	18.4
1.72	1.36	2.43	3.60	4.80	5.98	8.24	10.4	12.5	14.6	18.7
1.73	1.37	2.45	3.64	4.86	6.06	8.35	10.6	12.7	14.8	18.9
1.74	1.38	2.47	3.68	4.92	6.13	8.46	10.7	12.9	15.0	19.2
1.75	1.39	2.50	3.73	4.98	6.21	8.58	10.8	13.1	15.2	19.5
1.76	1.39	2.52	3.77	5.04	6.29	8.69	11.0	13.2	15.4	19.8
1.77	1.40	2.54	3.81	5.10	6.36	8.80	11.1	13.4	15.7	20.1
1.78	1.41	2.57	3.85	5.16	6.44	8.92	11.3	13.6	15.9	20.3
1.79	1.42	2.59	3.89	5.22	6.52	9.03	11.4	13.8	16.1	20.6
1.80	1.43	2.62	3.93	5.28	6.60	9.15	11.6	14.0	16.3	20.9

Table 7-12. Values of $(1/K')^2$ in Formula $s = (Qn/K'b^{8/3})^2$ for Trapezoidal Channels (*Concluded*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼–1	½–1	¾–1	1–1	1½–1	2–1	2½–1	3–1	4–1
1.86	.453	.131	.0570	.0313	.0199	.01026	.00636	.00437	.00320	.00194
1.87	.448	.129	.0558	.0306	.0194	.01001	.00620	.00425	.00311	.00189
1.88	.442	.126	.0547	.0300	.0190	.00977	.00605	.00415	.00303	.00184
1.89	.437	.124	.0536	.0293	.0185	.00953	.00589	.00404	.00295	.00179
1.90	.432	.122	.0525	.0287	.0181	.00930	.00575	.00394	.00288	.00174
1.91	.426	.120	.0514	.0280	.0177	.00908	.00560	.00384	.00280	.00170
1.92	.421	.118	.0504	.0274	.0173	.00886	.00547	.00374	.00273	.00165
1.93	.417	.116	.0494	.0268	.0169	.00865	.00533	.00365	.00266	.00161
1.94	.412	.114	.0484	.0263	.0165	.00844	.00520	.00356	.00260	.00157
1.95	.407	.112	.0474	.0257	.0162	.00824	.00508	.00347	.00253	.00153
1.96	.402	.110	.0465	.0252	.0158	.00805	.00495	.00338	.00247	.00149
1.97	.398	.108	.0456	.0246	.0154	.00786	.00483	.00330	.00241	.00145
1.98	.393	.106	.0447	.0241	.0151	.00768	.00472	.00322	.00235	.00142
1.99	.389	.104	.0438	.0236	.0148	.00750	.00460	.00314	.00229	.00138
2.00	.384	.103	.0430	.0231	.0144	.00733	.00450	.00306	.00223	.00135
2.01	.380	.1010	.0422	.0226	.0141	.00716	.00439	.00299	.00218	.00131
2.02	.376	.0993	.0413	.0221	.0138	.00699	.00429	.00292	.00213	.00128
2.03	.371	.0977	.0406	.0217	.0135	.00683	.00418	.00285	.00207	.00125
2.04	.367	.0961	.0398	.0212	.0132	.00668	.00409	.00278	.00202	.00122
2.05	.363	.0945	.0390	.0208	.0130	.00653	.00399	.00272	.00198	.00119
2.06	.359	.0929	.0383	.0204	.0127	.00638	.00390	.00265	.00193	.00116
2.07	.355	.0914	.0376	.0200	.0124	.00624	.00381	.00259	.00188	.00113
2.08	.352	.0900	.0369	.0196	.0121	.00610	.00372	.00253	.00184	.00110
2.09	.348	.0885	.0362	.0192	.0119	.00596	.00364	.00247	.00180	.00108
2.10	.344	.0871	.0355	.0188	.0116	.00583	.00355	.00241	.00175	.00105
2.11	.340	.0857	.0348	.0184	.0114	.00570	.00347	.00236	.00171	.00103
2.12	.337	.0843	.0342	.0180	.0112	.00558	.00340	.00230	.00167	.00100
2.13	.333	.0830	.0336	.0177	.0109	.00546	.00332	.00225	.00163	.00098
2.14	.330	.0817	.0329	.0173	.0107	.00534	.00325	.00220	.00160	.00096
2.15	.326	.0804	.0323	.0170	.0105	.00522	.00317	.00215	.00156	.00093
2.16	.323	.0791	.0318	.0167	.01026	.00511	.00310	.00210	.00152	.00091
2.17	.320	.0779	.0312	.0163	.01005	.00500	.00303	.00205	.00149	.00089
2.18	.316	.0767	.0306	.0160	.00985	.00489	.00297	.00201	.00146	.00087
2.19	.313	.0755	.0301	.0157	.00965	.00479	.00290	.00196	.00142	.00085
2.20	.310	.0743	.0295	.0154	.00945	.00469	.00284	.00192	.00139	.00083
2.21	.307	.0732	.0290	.0151	.00926	.00459	.00278	.00188	.00136	.00081
2.22	.304	.0720	.0285	.0148	.00908	.00449	.00272	.00184	.00133	.00079
2.23	.301	.0709	.0280	.0145	.00890	.00440	.00266	.00180	.00130	.00078
2.24	.298	.0698	.0275	.0143	.00872	.00431	.00260	.00176	.00127	.00076
2.25	.295	.0688	.0270	.0140	.00855	.00422	.00255	.00172	.00124	.00074
2.26	.292	.0678	.0265	.0137	.00838	.00413	.00249	.00168	.00122	.00073
2.27	.289	.0667	.0261	.0135	.00822	.00404	.00244	.00165	.00119	.00071
2.28	.286	.0657	.0256	.0132	.00805	.00396	.00239	.00161	.00116	.00069
2.29	.283	.0647	.0252	.0130	.00790	.00388	.00234	.00158	.00114	.00068
2.30	.280	.0638	.0247	.0127	.00774	.00380	.00229	.00154	.00111	.00066

Table 7-13. Values of K for Circular Channels in the Formula

$$Q = \frac{K}{n} D^{5/3} s^{1/2}$$

D = depth of water d = diameter of channel

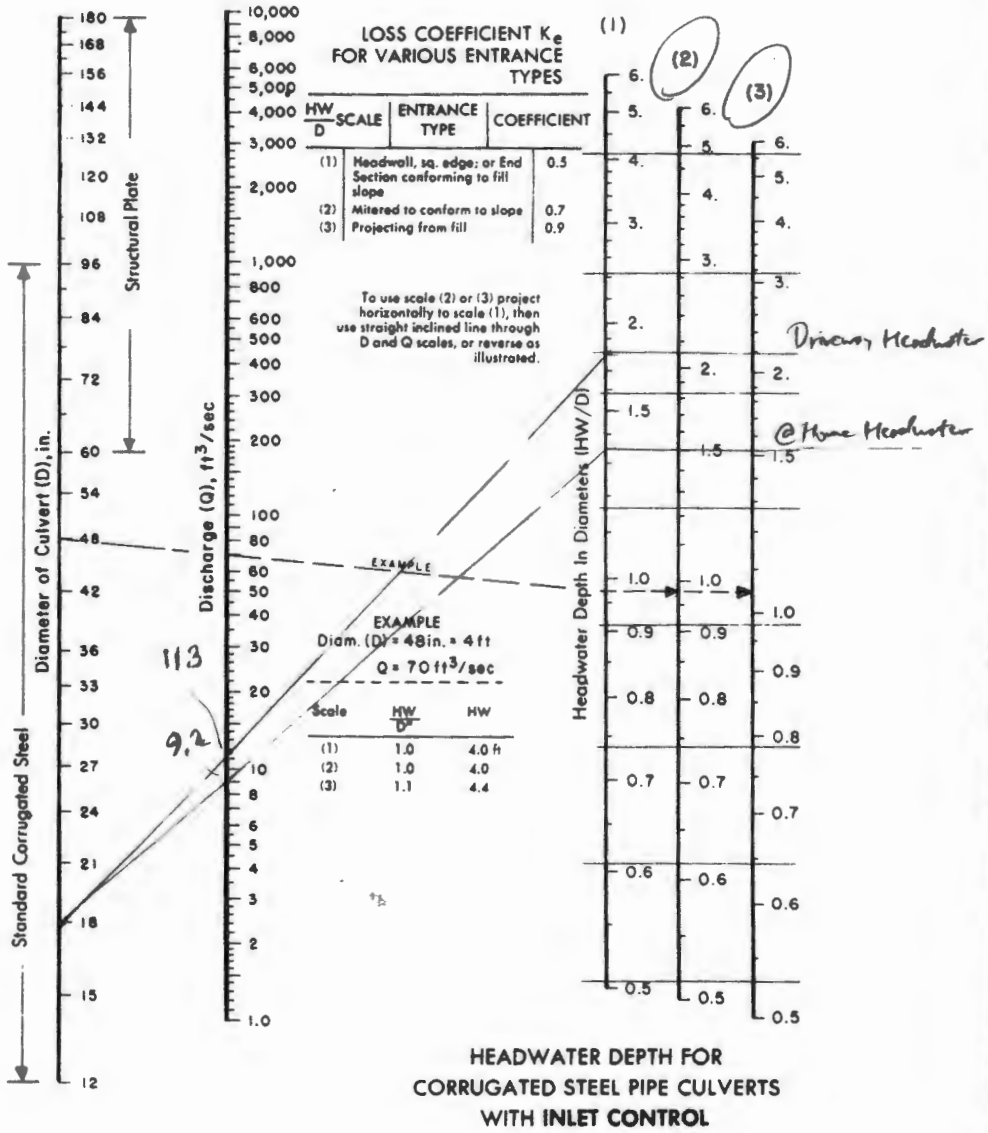
$\frac{D}{d}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0		15.02	10.56	8.57	7.38	6.55	5.95	5.47	5.08	4.76
.1	4.49	4.25	4.04	3.86	3.69	3.54	3.41	3.28	3.17	3.06
.2	2.96	2.87	2.79	2.71	2.63	2.56	2.49	2.42	2.36	2.30
.3	2.25	2.20	2.14	2.09	2.05	2.00	1.96	1.92	1.87	1.84
.4	1.80	1.76	1.72	1.69	1.66	1.62	1.59	1.56	1.53	1.50
.5	1.470	1.442	1.415	1.388	1.362	1.336	1.311	1.286	1.262	1.238
.6	1.215	1.192	1.170	1.148	1.126	1.105	1.084	1.064	1.043	1.023
.7	1.004	.984	.965	.947	.928	.910	.891	.874	.856	.838
.8	.821	.804	.787	.770	.753	.736	.720	.703	.687	.670
.9	.654	.637	.621	.604	.588	.571	.553	.535	.516	.496
1.0	.463									

Table 7-14. Values of K' for Circular Channels in the Formula

$$Q = \frac{K'}{n} d^{5/3} s^{1/2}$$

D = depth of water d = diameter of channel

$\frac{D}{d}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0		.00007	.00031	.00074	.00138	.00222	.00328	.00455	.00604	.00775
.1	.00967	.0118	.0142	.0167	.0195	.0225	.0257	.0291	.0327	.0366
.2	.0406	.0448	.0492	.0537	.0585	.0634	.0686	.0738	.0793	.0849
.3	.0907	.0966	.1027	.1089	.1153	.1218	.1284	.1352	.1420	.1490
.4	.1561	.1633	.1705	.1779	.1854	.1929	.2005	.2082	.2160	.2238
.5	.232	.239	.247	.255	.263	.271	.279	.287	.295	.303
.6	.311	.319	.327	.335	.343	.350	.358	.366	.373	.380
.7	.388	.395	.402	.409	.416	.422	.429	.435	.441	.447
.8	.453	.458	.463	.468	.473	.477	.481	.485	.488	.491
.9	.494	.496	.497	.498	.498	.498	.496	.494	.489	.483
1.0	.463									



HEADWATER DEPTH FOR CORRUGATED STEEL PIPE CULVERTS WITH **INLET CONTROL**

FHWA HEC 5

Figure 4-28 *Inlet control* nomograph for corrugated steel *pipe* culverts. The manufacturers recommended keeping *HW/D* to a maximum of 1.5 and preferably to no more than 1.0.

from AISI's Handbook of Steel Drainage & Construction Products, 3rd Edit.

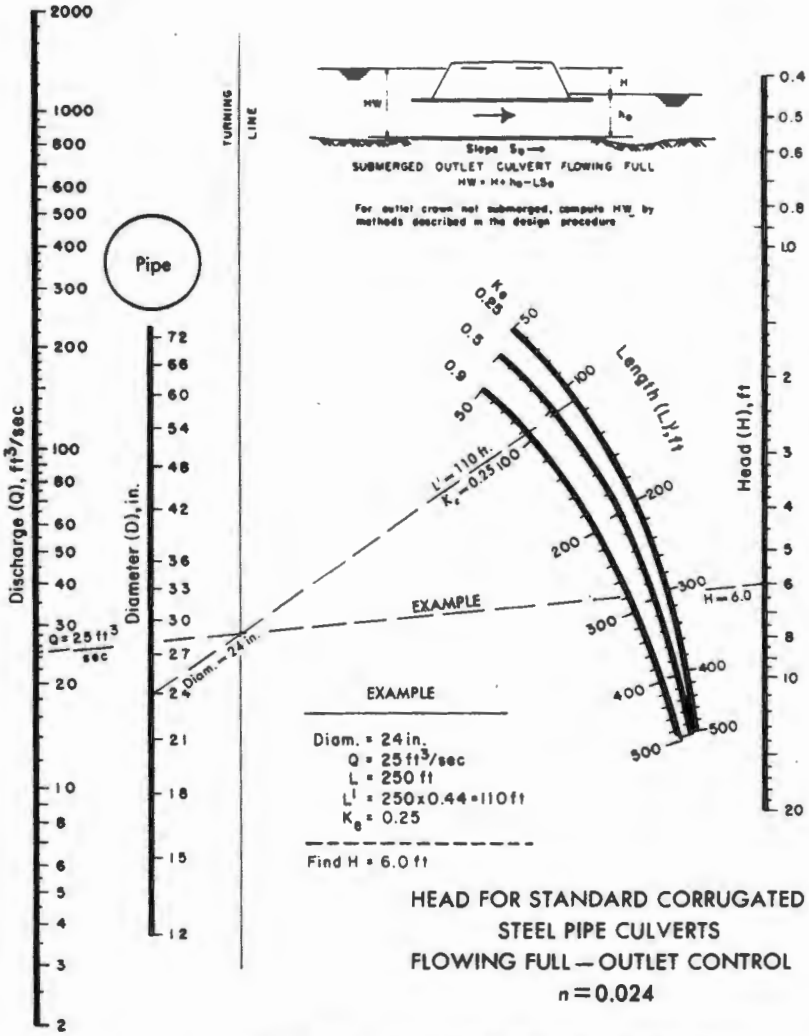
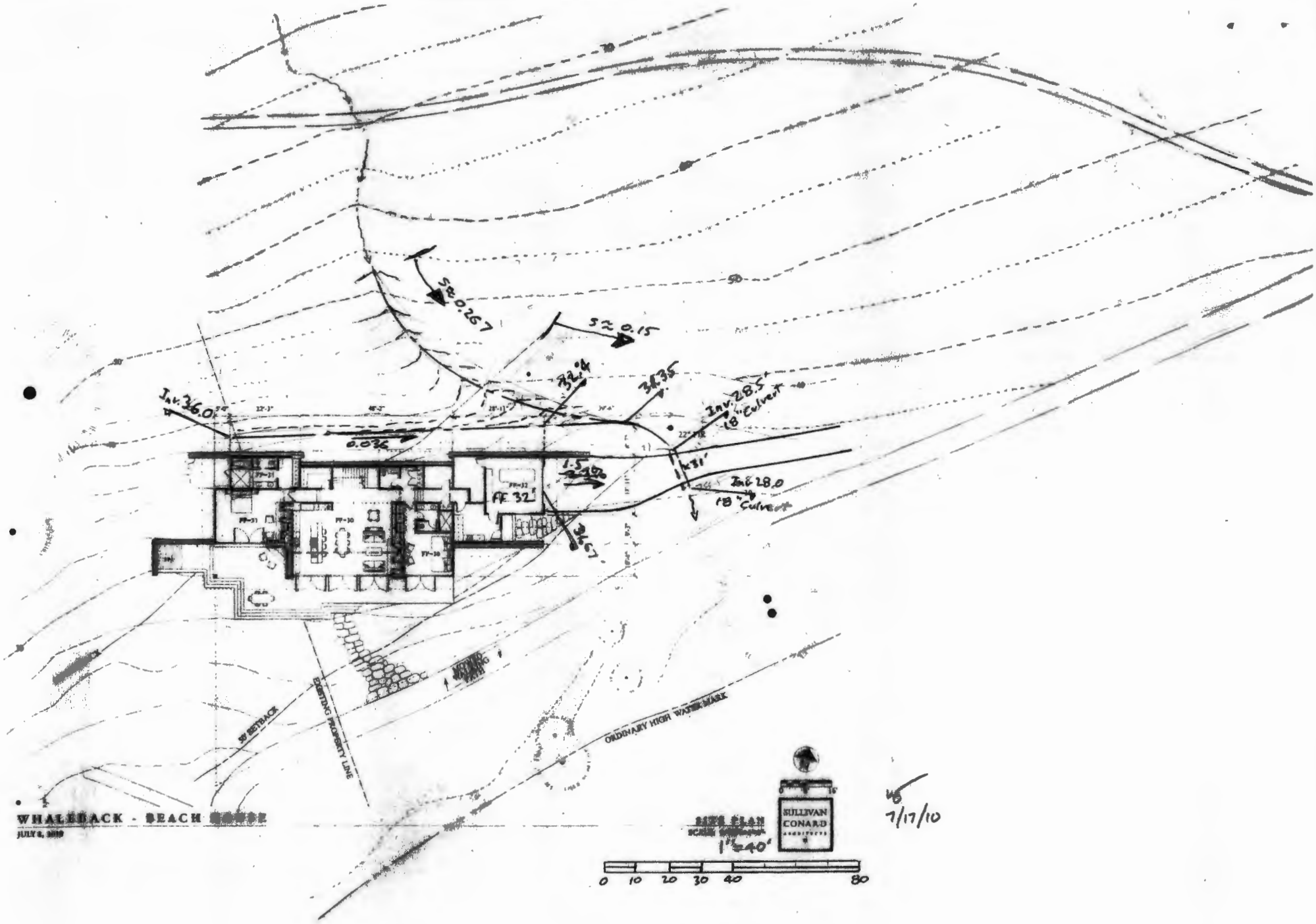


Figure 4-32 *Outlet control.* Head for corrugated steel *pipe* culvert with submerged outlet and culvert flowing full. See note under sketch at top.

Table 4-11 Length Adjustment for Improved Hydraulics

Pipe Diameter, in.	Roughness Factor n' for Helical Corr.*	Length Adjustment Factor $\left(\frac{n'}{n}\right)^2$
12	0.011	0.21
24	0.016	0.44
36	0.019	0.61
48	0.020	0.70

*Other values of roughness, n, are applicable to paved pipe, lined pipe and pipe with 3 × 1 in. corrugations. See Table 4-10. To use the above chart for these types of pipe and pipe-arches, use adjusted length factors computed per equation 14, page 187.



WHALEBACK - BEACH [redacted]

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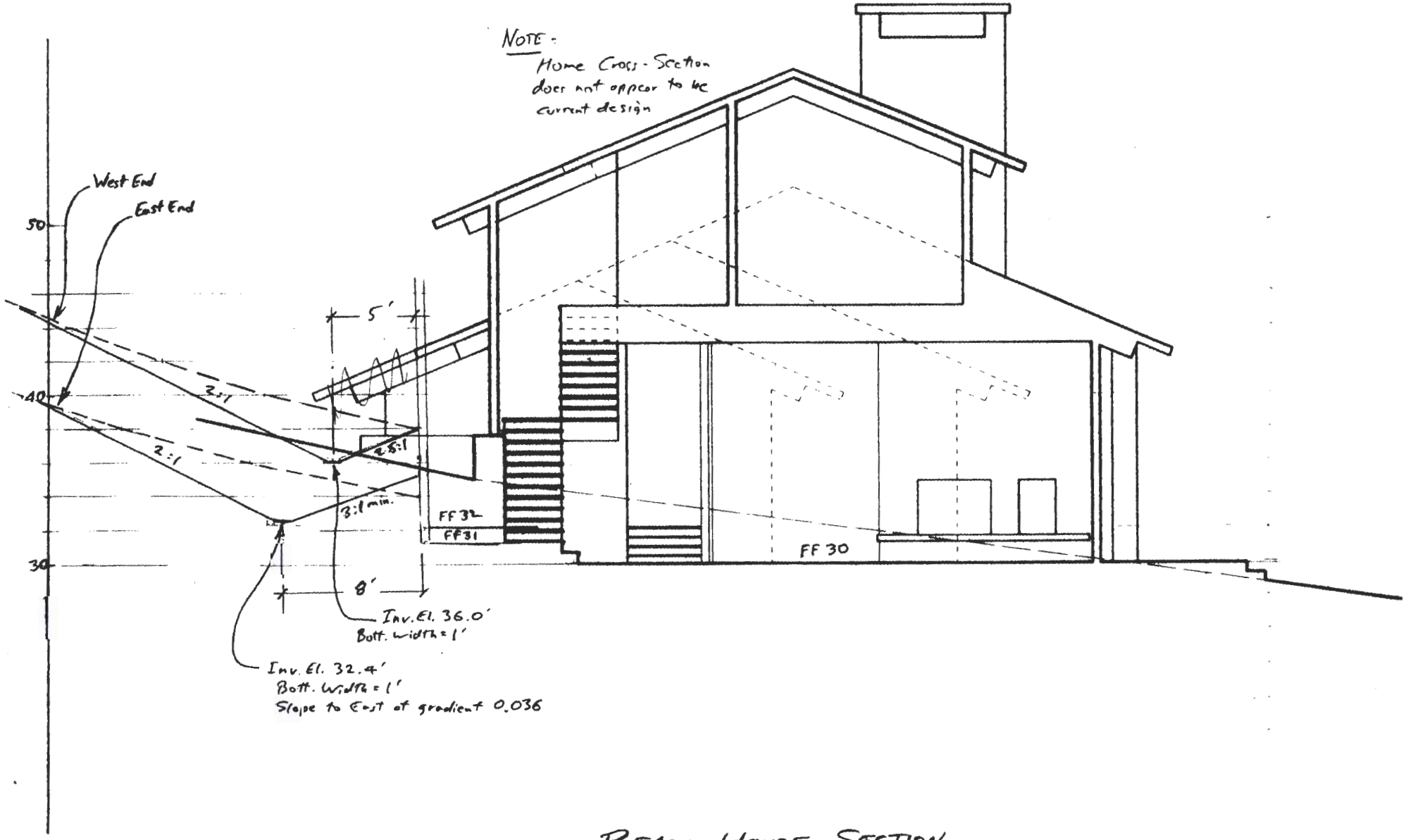

BEACH HOUSE SECTION

1/8" = 1'-0"

0 8 12 16

7/17/10

Fig. 5