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DEPT OF PLANNING AND
COMMUNITY DEVELOPMENT

Stormwater Plan for:

Wapati Way Private Road
Skamania County, Washington

February 26, 2007

Prepared by:
PLS Engineering
604 N. 16th Avenue
Kelso, WA 98626

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TECHNICAL APPENDICES

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CERTIFICATE OF ENGINEER

Wapati Way Private Road
Stormwater Plan

The technical information and data contained in this report were prepared by the professional engineer listed below.

Prepared by: Andrew J. Gunther, P.E. 2/28/07

ANDREW J. GUNTHER
STATE OF WASHINGTON
39644
REGISTERED
PROFESSIONAL ENGINEER
EXPIRES: NOV. 10, 2007

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SECTION A – PROJECT OVERVIEW

The proposed Wapati Way private road serves a series of three four lot short plats located in the northwest quadrant of Section 26 and the southwest quadrant of Section 23, T. 3 N. R. 8 E. in Skamania County, Washington. The project is generally bounded along its west and south sides by the US Forest Service 90 Road and is located immediately overlooking the Swift Reservoir. The project entails the widening and paving of an existing gravel logging road and construction of driveways to serve the 12 proposed residential lots. The access point onto the USFS 90 Road will also be slightly realigned to improve safety at the intersection. Some modification of the grades of the existing logging road was also necessary to result in a finished roadway with a maximum grade of 15%. The area covered by the project generally drains in a south and west direction toward the Swift Reservoir. Ground slopes are primarily in the vicinity of 15% to 20% in the developing portions of the site. Site topography can be seen on the basin map submitted with this report. The contours are based on USGS mapping.

At the time of preparation of this report and the associated Stormwater Plan drawings, the paving and widening of the logging road has already taken place. Additionally, roadside ditches have been constructed with a gravel lining to the base of the ditches. Rock check dams have been constructed along the roadside ditches with a maximum spacing of approximately 100 feet between check dams. A series of four cross-culverts has been installed periodically along the site's access road diverting the runoff from the road widening from the roadside ditches into downstream undisturbed areas. Much of the work that has taken place was performed following the general recommendations of the County Engineer. The Stormwater Plan that is submitted with this report for the most part attempts to minimize significant changes to the improvements already constructed and instead tries to augment the existing facilities to improve the performance of the system in place.

The general purpose of this report and the Stormwater Plan provided herewith is to address SEPA conditions imposed on each of the short plats that required preparation of a Stormwater Plan. The specific items to be covered in the Stormwater Plan are not well defined by any of the approval documents pertaining to the projects. In response to inquiries from PLS Engineering, County Staff has indicated that the typical storm accounted for in the preparation of a Stormwater Plan is the 25-year storm event. Additionally, the MDNS conditions associated with the conversion from forestry use to non-forestry use included a condition requiring that any new stormwater runoff generated from future development shall be contained on site. These general guidelines have been used as the basis for the stormwater improvements proposed in the Stormwater Plan as discussed in this report.

SECTION B – EXISTING STORMWATER SYSTEM

As previously mentioned, there is already a fairly well developed drainage system designed for the roadway improvements and this Stormwater Plan proposes to maintain the majority of these improvements, building on the constructed system in an effort to improve on the stormwater controls already in place. In general, the existing drainage system consists of

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roadside ditches along the edge of the roadway with minimum depths typical at or greater than 2' below the road grade. The roadside ditches are lined with gravel in the base to minimize the potential for soil erosion. At the time of visiting the site, it was not clear whether a fabric was provided beneath the rock, but it did not appear that the soil under the rock lining was eroding from the base of the ditch. The depth of the ditches is sufficient to contain the peak flows in the 25-year storm event without overtopping onto the roadway.

Periodic check dams have been installed along the length of the ditches, typically with spacing of less than 100 feet. The check dams generally are constructed of rock with average dimension of greater than 6" diameter. The sizing of the check dams appears to generally comply with the recommendations made by BMP C207 of the 2005 Western Washington Manual. Although the check dams are not installed at the frequency that would be recommended by the Western Washington Manual, they are sufficient in number to help control the energy of the stormwater in the ditches and to help in sediment removal from the runoff.

A series of culverts has been installed along the side of the roadway. In some cases, these culverts were constructed to pass water under driveways, while in other cases, the culverts are used to divert runoff out of the roadside ditches into undisturbed vegetation, thereby reducing the quantity of runoff in the roadside ditches and keeping the runoff in its natural drainage areas. Seven of the primary culverts along the roadway have been numbered on the first page of the Stormwater Plan submitted with this report. The culverts are numbered sequentially from the upper end of the site to the bottom of the site at the road intersection with the USFS 90 Road. As will be further discussed later in this report, each of the seven culverts is modeled hydraulically in the HydroCAD calculations provided in the appendix to this report. These calculations show that the culverts have capacity to convey the incoming flows under gravity flow conditions. The seven culverts are briefly discussed below.

Culvert 1 as identified on the stormwater plan is a 12" culvert crossing under the driveway to lot 2 of the upper short plat. Culvert 2 is another 12" culvert. This culvert drains south away from the roadside ditch and outlets into the natural drainage path for runoff from the upper section of the site. A riprap outlet pool has been constructed at the outlet of this culvert to provide energy dissipation for the runoff before it enters natural vegetation that has been left undisturbed on this site. The flow leaving culvert 2 drains overland, ultimately reentering the roadside drainage system to the south, near the lower end of the site.

Culvert 3 is located approximately 500 to 600 feet downstream from culvert 2. It is another 12" culvert used to divert runoff west from the roadside ditch into the pre-existing natural drainage area for this runoff. The culvert is located at an intersection of the site's access road with a pre-existing logging road that extends north off the project site. Because of the steep fill slope where culvert 3 leaves the edge of the road, a pipe chute has been extended to the base of the fill slope to convey this runoff past the base of the fill. This culvert outlets into natural vegetation remaining on the site.

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Culvert 4 is found approximately 1,150-1,200' further down the roadway. This culvert is an 18" culvert running south under the roadway and removes runoff from the roadside ditch and outlets to the natural vegetation downstream. Riprap has been installed at the outlet of this culvert in an effort to control potential erosion. The roadside ditch upstream of culvert 4 appears to convey the most flow of any of the ditches on the site. As a result, in the hydraulic and hydrologic modeling found in the appendix to this report, this section of ditch was modeled to verify its conveyance capacity.

Culvert 5 is approximately 370' down the road from culvert 4. This is another 18" culvert draining south across the road before it outlets to natural vegetation downstream. The outlet of this culvert is not well located in that it outlets onto the fill slope for the roadway. It does not appear to be adequately protected from erosion. Additionally, this culvert does not appear to be necessary. It is only 370' down the road from the previous culvert and is approximately 650' from the intersection of the site access road with USFS 90 Road. The roadside ditch downstream from this culvert has adequate capacity to convey the 25-year flows even if this culvert was eliminated. As a result, the Stormwater Plan submitted with this report proposes to plug this culvert and allow the tributary flow to continue to drain in the roadside ditch down to the bottom of the site. The stormwater runoff energy can more adequately by controlled in an engineered structure near the bottom of the site.

Two culverts, numbered 6 and 7 on the Stormwater Plan, direct stormwater from the last section of roadside ditch to a riprap area immediately prior to the existing 18" culvert (culvert 8 on the stormwater plan) that directs runoff under the 90 Road into the downstream drainage system.

In addition to the existing drainage system described in this section, several best management practices have been followed in the development of this site to date. The developer has worked to minimize the removal of existing vegetation, primarily clearing trees only as needed for cut and fill slopes along the roadway construction and as needed to provide building pads for the future houses on the site. Additionally, care was taken to provide cover of the disturbed slopes in an effort to protect the slopes until vegetation is more fully established.

SECTION C – PROPOSED STORMWATER SYSTEM IMPROVEMENTS

Several revisions and additions to the existing construction are proposed to improve the overall functionality of the drainage system for the site. These include the addition of individual stormwater systems on each building lot, plugging of one of the site's culverts that does not currently have a well protected outlet, and the addition of a stilling well structure between culvert 7 and the existing culvert 8 at the bottom of the site where stormwater leaves the site, crossing under the 90 Road. Each of these items is discussed in additional detail in this section of the report.

Under existing conditions, the majority of the building lots and their associated driveways are located downhill from the site's main access road. There is currently no drainage system on

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the lots to help control runoff from the driveways or future houses. To address this issue, individual stormwater systems are proposed on each lot to infiltrate the roof runoff from the new houses in the 25-year storm event. This will serve to offset the slight increase in runoff from the remainder of the lot due to the driveway construction and the minimal clearing that has been performed on the lots as needed to create home sites.

The proposed stormwater system will consist of Infiltrator High Capacity stormwater chamber units. The Infiltrator Units have a base width of 34", an effective length of 75", and a height of 16". The roof downspout system for the home to be constructed on each lot should be connected directly to the Infiltrator chambers with storm piping. The roof drain system should also allow for overflow of the system to splash blocks. A typical detail is included on page 2 of the Stormwater Plan submitted with this report. Based on an estimated infiltration rate of 4"/hour in the sandy loam soils on the upper portion of the site, calculations have been performed to determine the number of Infiltrator units required to infiltrate the 25-year storm runoff from a selection of assumed roof areas including 1,000 square feet, 1,500 square feet, and 1,800 square feet. Further discussion of site soils is included later in this report. Soils data obtained from the National Resource Conservation Service on-line soil site is included in Appendix E. The design calculations related to the infiltration systems is contained in Appendix C. This appendix includes three spreadsheets documenting the incremental storage and infiltration disposal rates of the Infiltrator unit systems sized for 1,000, 1,500 and 1,800 square foot roof areas. It also includes a HydroCAD hydraulic/hydrologic model of runoff conditions for each of these lot areas (see Basins 1S, 2S, and 3S in model corresponding to 1,000 square feet, 1,500 square feet, and 1,800 square feet of roof area) entering the stormwater system on the lot (see ponds 1P, 2P, and 3P in model). As shown by the calculations in Appendix C, a total of 5 Infiltrator units will be required for a roof area of 1,000 square feet. Roof areas of 1,500 square feet and 1,800 square feet will require 9 and 10 Infiltrator units, respectively. Because house locations will not be known until the lots are sold and ready house plans have been developed, the Infiltrator units should be installed by the homeowners or homebuilders concurrently with home construction.

As mentioned previously, the second change to the existing drainage system for this site will be to plug the upstream end of culvert 5 as identified on sheet 1 of the Stormwater Plan. This culvert does not currently outfall to a stabilized location and instead daylights above a fill slope created when the roadway was regraded. The flow that previously entered culvert 5 can better be managed at the bottom of the site through the new stilling well discussed in the following paragraph.

The final modification to the stormwater system will be the addition of a type 2 60" catch basin that will connect the new 18" culvert 7 to the existing 18" culvert number 8 which directs flow off the site under the USFS 90 Road. This stilling well is sized and designed consistently with the guidelines of HEC 14 from the Federal Highway Administration. Documentation from HEC 14 as well as design calculations are provided in Appendix D to this report. A riser will be installed on the end of the existing 18" culvert number 8 so that its effective outlet elevation at the top of the riser will be above the incoming elevation from

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culvert 7. The elevation difference will create an effective energy dissipater for flow from culvert 7 prior to the runoff being conveyed off-site.

With the exception of the individual house roof runoff proposed for infiltration, detention of the remaining site runoff is not proposed. As mentioned previously, site construction has attempted to minimize the removal of existing vegetation and the modifications to groundcover for the site. The main change to pre-development runoff conditions is the slight widening of the existing logging road and modifying it from gravel to paved surfacing. Energy dissipation will be provided at the lower end of the site prior to the runoff crossing under the 90 Road. After crossing the road, the runoff discharges to a well stabilized drainage path then enters Swift Reservoir a short distance downstream. Swift Reservoir is a large, artificially controlled water body which has its elevations controlled by Pacificorp in order to generate power. Since the water elevations are controlled by artificial means, detention of the runoff from the site immediately upstream of the reservoir does not yield a stormwater quantity control benefit to the reservoir.

SECTION D – HYDROLOGIC AND HYDRAULIC ANALYSIS

Proposed site runoff conditions as well as existing runoff conditions for the typical residential lot on the project were modeled using HydroCAD version 6.10 utilizing SCS TR-20 methodology for hydrograph routing. The main storm modeled in this report was the Type 1-A 24-hour, 25-year storm event. A total rainfall depth for this storm of 8.25" was selected using the NOAA Washington State Isopluvial Maps included in Appendix E of this report. Runoff curve numbers (CN's) were selected using Table III-1.3 from the *Stormwater Management Manual for the Puget Sound Basin*, based on existing and proposed ground cover conditions and assuming Hydrologic Soil Group (HSG) B soils. A copy of Table III-1.3 is included in Appendix E.

The main hydrologic and hydraulic analysis of the site is provided in Appendix B of this report using the basins identified on the Basin Map in Appendix A. Basins were delineated based on the area draining to each individual culvert represented as a reach in the HydroCAD model in Appendix B. In general, ditch sections were not modeled. However, one ditch was modeled to represent the highest flow in any of the ditches on site. This ditch has been modeled as reach 9 in the HydroCAD model and receives flow from basins 1, 2, 5, and 6. The ditch was modeled conservatively using a one foot base width, a 15% longitudinal slope (consistent with the road grade), a Manning's 'n' value of 0.035 typical for rock lined manmade channels, and side slopes of 2 horizontal:1 vertical. Based on this information, the peak 25-year flow depth in the ditch is 0.67', easily verifying the capacity of the ditch to retain the 25-year peak flow within its banks.

SECTION E – SOILS INFORMATION

Soils information obtained from the National Resource Conservation Service online soil mapping site is provided in Appendix E. The NRCS mapping identifies the soils on the site as predominately Cinnamon sandy loam with some areas of Swift cindery loam along the west

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side of the access road and some potential areas of Swift rock outcrop at the lower end of the site. Each of these soils is classified as HSG B soils by the NRCS.

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APPENDICES

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APPENDIX A

BASIN MAP

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APPENDIX B

MAIN SITE HYDROCAD MODEL

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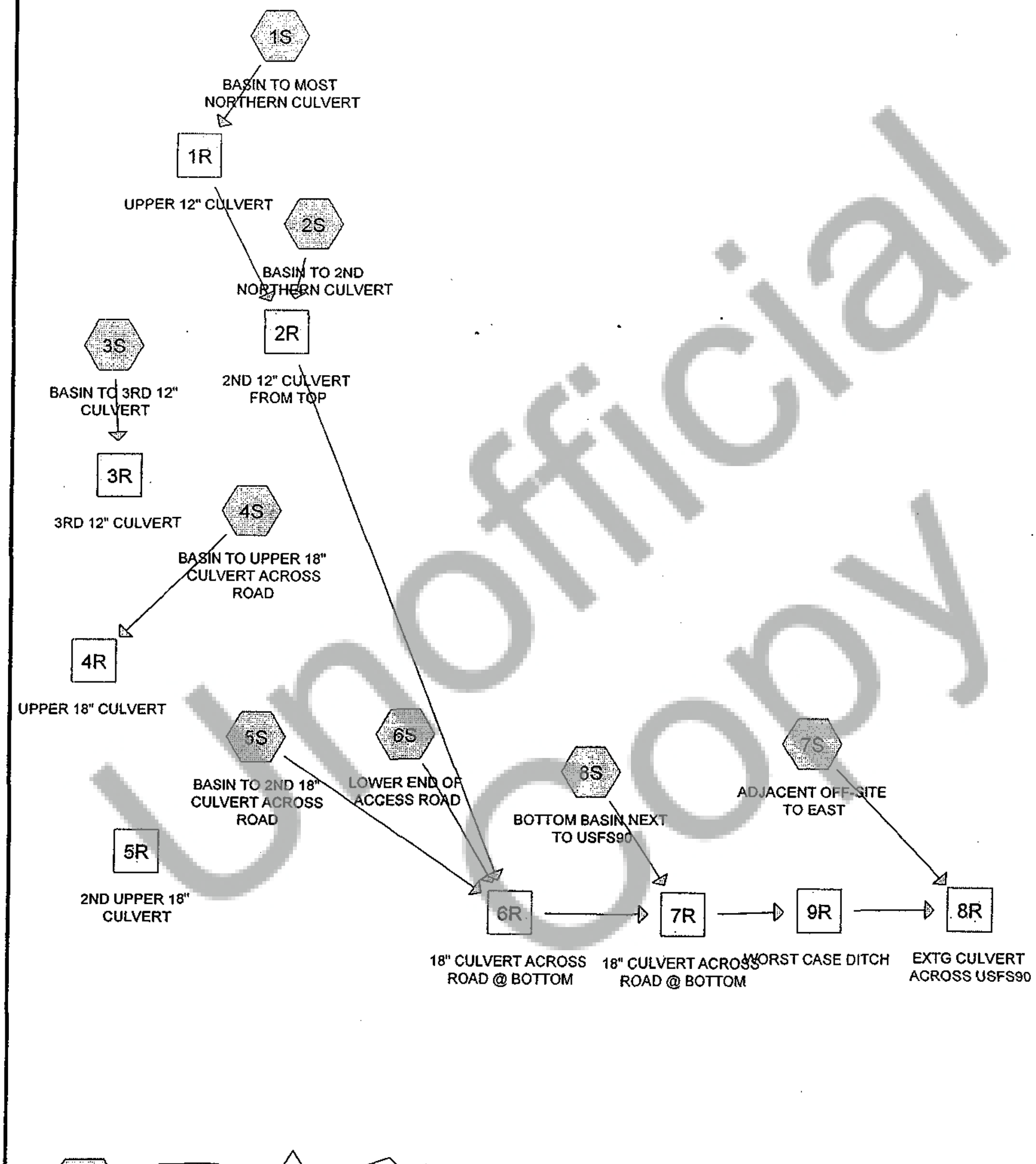

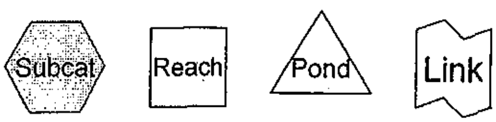

Drainage Diagram for marble[1]

Prepared by Hopper Dennis Jellison, PLLC 2/28/2007

HydroCAD® 8.00 s/n 000668 © 2006 HydroCAD Software Solutions LLC

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Time span=0.00-24.00 hrs, dt=0.25 hrs, 97 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: BASIN TO MOST NORTHERN CULVERT Runoff Area=66,000 sf Runoff Depth>5.49"
Tc=15.0 min CN=77 Runoff=2.02 cfs 0.693 af

Subcatchment 2S: BASIN TO 2ND NORTHERN CULVERT Runoff Area=54,500 sf Runoff Depth>5.25"
Tc=15.0 min CN=75 Runoff=1.58 cfs 0.548 af

Subcatchment 3S: BASIN TO 3RD 12" CULVERT Runoff Area=87,200 sf Runoff Depth>5.72"
Tc=15.0 min CN=79 Runoff=2.81 cfs 0.955 af

Subcatchment 4S: BASIN TO UPPER 18" CULVERT ACROS Runoff Area=366,700 sf Runoff Depth>5.49"
Tc=15.0 min CN=77 Runoff=11.23 cfs 3.850 af

Subcatchment 5S: BASIN TO 2ND 18" CULVERT ACROSS R Runoff Area=151,050 sf Runoff Depth>5.13"
Tc=15.0 min CN=74 Runoff=4.25 cfs 1.484 af

Subcatchment 6S: LOWER END OF ACCESS ROAD Runoff Area=197,560 sf Runoff Depth>5.25"
Tc=15.0 min CN=75 Runoff=5.72 cfs 1.985 af

Subcatchment 7S: ADJACENT OFF-SITE TO EAST Runoff Area=406,700 sf Runoff Depth>5.02"
Tc=15.0 min CN=73 Runoff=11.09 cfs 3.903 af

Subcatchment 8S: BOTTOM BASIN NEXT TO USFS90 Runoff Area=7,000 sf Runoff Depth>5.86"
Tc=5.0 min CN=80 Runoff=0.24 cfs 0.078 af

Reach 1R: UPPER 12" CULVERT Avg. Depth=0.27' Max Vel=11.57 fps Inflow=2.02 cfs 0.693 af
D=12.0" n=0.012 L=30.0' S=0.1020 '/' Capacity=12.33 cfs Outflow=2.02 cfs 0.693 af

Reach 2R: 2ND 12" CULVERT FROM TOP Avg. Depth=0.37' Max Vel=13.38 fps Inflow=3.60 cfs 1.241 af
D=12.0" n=0.012 L=51.0' S=0.0973 '/' Capacity=12.04 cfs Outflow=3.59 cfs 1.240 af

Reach 3R: 3RD 12" CULVERT Avg. Depth=0.37' Max Vel=10.83 fps Inflow=2.81 cfs 0.955 af
D=12.0" n=0.012 L=44.0' S=0.0655 '/' Capacity=9.87 cfs Outflow=2.81 cfs 0.955 af

Reach 4R: UPPER 18" CULVERT Avg. Depth=0.74' Max Vel=12.99 fps Inflow=11.23 cfs 3.850 af
D=18.0" n=0.012 L=38.0' S=0.0413 '/' Capacity=23.13 cfs Outflow=11.22 cfs 3.850 af

Reach 5R: 2ND UPPER 18" CULVERT Avg. Depth=0.00' Max Vel=0.00 fps
D=18.0" n=0.012 L=37.0' S=0.0949 '/' Capacity=35.05 cfs Outflow=0.00 cfs 0.000 af

Reach 6R: 18" CULVERT ACROSS ROAD Avg. Depth=0.66' Max Vel=18.10 fps Inflow=13.56 cfs 4.709 af
D=18.0" n=0.012 L=76.0' S=0.0887 '/' Capacity=33.89 cfs Outflow=13.55 cfs 4.709 af

Reach 7R: 18" CULVERT ACROSS ROAD Avg. Depth=0.89' Max Vel=12.58 fps Inflow=13.77 cfs 4.787 af
D=18.0" n=0.012 L=79.0' S=0.0334 '/' Capacity=20.80 cfs Outflow=13.75 cfs 4.787 af

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Reach 8R: EXTG CULVERT ACROSS USF Avg. Depth=1.50' Max Vel=14.75 fps Inflow=24.81 cfs 8.689 af
D=18.0" n=0.012 L=80.0' S=0.0405 '/' Capacity=22.90 cfs Outflow=23.31 cfs 8.688 af

Reach 9R: WORST CASE DITCH Avg. Depth=0.67' Max Vel=8.80 fps Inflow=13.75 cfs 4.787 af
n=0.035 L=100.0' S=0.1500 '/' Capacity=165.05 cfs Outflow=13.72 cfs 4.785 af

Total Runoff Area = 30.687 ac Runoff Volume = 13.496 af Average Runoff Depth = 5.28"
93.98% Pervious Area = 28.839 ac 6.02% Impervious Area = 1.847 ac

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Subcatchment 1S: BASIN TO MOST NORTHERN CULVERT

Runoff = 2.02 cfs @ 8.02 hrs, Volume= 0.693 af, Depth> 5.49"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
4,125	98	PAV'T
24,000	80	OTHER CLEARED AREA
37,875	72	FORESTED
66,000	77	Weighted Average
61,875		Pervious Area
4,125		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, ESTIMATED TRAVEL TIME**

Subcatchment 2S: BASIN TO 2ND NORTHERN CULVERT

Runoff = 1.58 cfs @ 8.03 hrs, Volume= 0.548 af, Depth> 5.25"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
3,900	98	PAV'T
8,000	80	OTHER CLEARED AREA
42,600	72	FORESTED
54,500	75	Weighted Average
50,600		Pervious Area
3,900		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, ESTIMATED TRAVEL TIME**

Subcatchment 3S: BASIN TO 3RD 12" CULVERT

Runoff = 2.81 cfs @ 8.02 hrs, Volume= 0.955 af, Depth> 5.72"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
11,830	98	PAV'T
36,000	80	OTHER CLEARED AREA
39,370	72	FORESTED
87,200	79	Weighted Average

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75,370	Pervious Area
11,830	*Impervious Area*

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, ESTIMATED TRAVEL TIME**

Subcatchment 4S: BASIN TO UPPER 18" CULVERT ACROSS ROAD

Runoff = 11.23 cfs @ 8.02 hrs, Volume= 3.850 af, Depth> 5.49"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
21,510	98	PAV'T
15,600	98	FUTURE ROOFS/DRIVEWAYS
110,000	80	OTHER CLEARED AREA
219,590	72	FORESTED
366,700	77	Weighted Average
329,590		Pervious Area
37,110		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, ESTIMATED TRAVEL TIME**

Subcatchment 5S: BASIN TO 2ND 18" CULVERT ACROSS ROAD

Runoff = 4.25 cfs @ 8.03 hrs, Volume= 1.484 af, Depth> 5.13"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
7,060	98	PAV'T
15,000	80	OTHER CLEARED AREA
128,990	72	FORESTED
151,050	74	Weighted Average
143,990		Pervious Area
7,060		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, ESTIMATED TRAVEL TIME**

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Subcatchment 6S: LOWER END OF ACCESS ROAD

Runoff = 5.72 cfs @ 8.03 hrs, Volume= 1.985 af, Depth> 5.25"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
10,950	98	PAV'T
50,000	80	OTHER CLEARED AREA
136,610	72	FORESTED
197,560	75	Weighted Average
186,610		Pervious Area
10,950		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, ESTIMATED TRAVEL TIME**

Subcatchment 7S: ADJACENT OFF-SITE TO EAST

Runoff = 11.09 cfs @ 8.03 hrs, Volume= 3.903 af, Depth> 5.02"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
5,500	98	PAV'T
22,000	80	OTHER CLEARED AREA
379,200	72	FORESTED
406,700	73	Weighted Average
401,200		Pervious Area
5,500		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry, ESTIMATED TRAVEL TIME**

Subcatchment 8S: BOTTOM BASIN NEXT TO USFS90

Runoff = 0.24 cfs @ 7.87 hrs, Volume= 0.078 af, Depth> 5.86"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
7,000	80	OTHER CLEARED AREA
7,000		Pervious Area

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Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, ESTIMATED TRAVEL TIME**

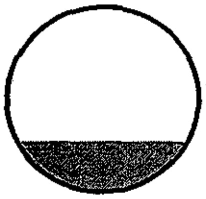
Reach 1R: UPPER 12" CULVERT

Inflow Area = 1.515 ac, Inflow Depth > 5.49"
Inflow = 2.02 cfs @ 8.02 hrs, Volume= 0.693 af
Outflow = 2.02 cfs @ 8.02 hrs, Volume= 0.693 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 11.57 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 6.77 fps, Avg. Travel Time= 0.1 min

Peak Storage= 5 cf @ 8.02 hrs, Average Depth at Peak Storage= 0.27'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 12.33 cfs

12.0" Diameter Pipe, n= 0.012
Length= 30.0' Slope= 0.1020 '/'
Inlet Invert= 1,424.67', Outlet Invert= 1,421.61'



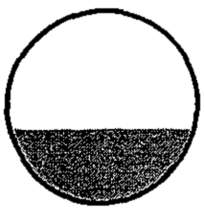
Reach 2R: 2ND 12" CULVERT FROM TOP

Inflow Area = 2.766 ac, Inflow Depth > 5.38"
Inflow = 3.60 cfs @ 8.02 hrs, Volume= 1.241 af
Outflow = 3.59 cfs @ 8.03 hrs, Volume= 1.240 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 13.38 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 7.97 fps, Avg. Travel Time= 0.1 min

Peak Storage= 14 cf @ 8.03 hrs, Average Depth at Peak Storage= 0.37'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 12.04 cfs

12.0" Diameter Pipe, n= 0.012
Length= 51.0' Slope= 0.0973 '/'
Inlet Invert= 1,386.40', Outlet Invert= 1,381.44'



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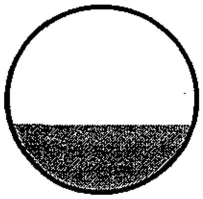
Reach 3R: 3RD 12" CULVERT

Inflow Area = 2.002 ac, Inflow Depth > 5.72"
Inflow = 2.81 cfs @ 8.02 hrs, Volume= 0.955 af
Outflow = 2.81 cfs @ 8.02 hrs, Volume= 0.955 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 10.83 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 6.34 fps, Avg. Travel Time= 0.1 min

Peak Storage= 11 cf @ 8.02 hrs, Average Depth at Peak Storage= 0.37'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 9.87 cfs

12.0" Diameter Pipe, n= 0.012
Length= 44.0' Slope= 0.0655 '/'
Inlet Invert= 1,308.59', Outlet Invert= 1,305.71'



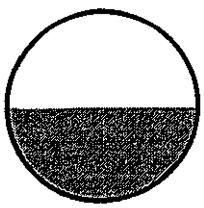
Reach 4R: UPPER 18" CULVERT

Inflow Area = 8.418 ac, Inflow Depth > 5.49"
Inflow = 11.23 cfs @ 8.02 hrs, Volume= 3.850 af
Outflow = 11.22 cfs @ 8.02 hrs, Volume= 3.850 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 12.99 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 7.78 fps, Avg. Travel Time= 0.1 min

Peak Storage= 33 cf @ 8.02 hrs, Average Depth at Peak Storage= 0.74'
Bank-Full Depth= 1.50', Capacity at Bank-Full= 23.13 cfs

18.0" Diameter Pipe, n= 0.012
Length= 38.0' Slope= 0.0413 '/'
Inlet Invert= 1,130.28', Outlet Invert= 1,128.71'



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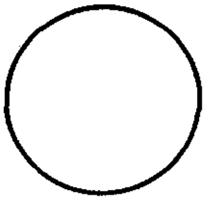
Reach 5R: 2ND UPPER 18" CULVERT

Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 0.00 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.00 fps, Avg. Travel Time= 0.0 min

Peak Storage= 0 cf @ 0.00 hrs, Average Depth at Peak Storage= 0.00'
Bank-Full Depth= 1.50', Capacity at Bank-Full= 35.05 cfs

18.0" Diameter Pipe, n= 0.012
Length= 37.0' Slope= 0.0949 '/'
Inlet Invert= 1,070.42', Outlet Invert= 1,066.91'



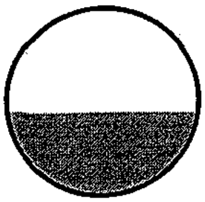
Reach 6R: 18" CULVERT ACROSS ROAD @ BOTTOM

Inflow Area = 10.769 ac, Inflow Depth > 5.25"
Inflow = 13.56 cfs @ 8.03 hrs, Volume= 4.709 af
Outflow = 13.55 cfs @ 8.03 hrs, Volume= 4.709 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 18.10 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 10.85 fps, Avg. Travel Time= 0.1 min

Peak Storage= 57 cf @ 8.03 hrs, Average Depth at Peak Storage= 0.66'
Bank-Full Depth= 1.50', Capacity at Bank-Full= 33.89 cfs

18.0" Diameter Pipe, n= 0.012
Length= 76.0' Slope= 0.0887 '/'
Inlet Invert= 985.67', Outlet Invert= 978.93'



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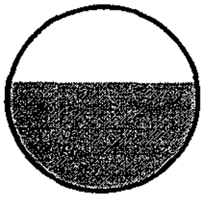
Reach 7R: 18" CULVERT ACROSS ROAD @ BOTTOM

Inflow Area = 10.930 ac, Inflow Depth > 5.26"
Inflow = 13.77 cfs @ 8.03 hrs, Volume= 4.787 af
Outflow = 13.75 cfs @ 8.03 hrs, Volume= 4.787 af, Atten= 0%, Lag= 0.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 12.58 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 7.57 fps, Avg. Travel Time= 0.2 min

Peak Storage= 86 cf @ 8.03 hrs, Average Depth at Peak Storage= 0.89'
Bank-Full Depth= 1.50', *Capacity at Bank-Full= 20.80 cfs*

18.0" Diameter Pipe, n= 0.012
Length= 79.0' Slope= 0.0334 '/'
Inlet Invert= 977.88', Outlet Invert= 975.24'



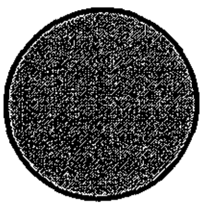
Reach 8R: EXTG CULVERT ACROSS USFS90

Inflow Area = 20.267 ac, Inflow Depth > 5.14"
Inflow = 24.81 cfs @ 8.03 hrs, Volume= 8.689 af
Outflow = 23.31 cfs @ 8.09 hrs, Volume= 8.688 af, Atten= 6%, Lag= 3.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 14.75 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 9.53 fps, Avg. Travel Time= 0.1 min

Peak Storage= 142 cf @ 8.04 hrs, Average Depth at Peak Storage= 1.50'
Bank-Full Depth= 1.50', Capacity at Bank-Full= 22.90 cfs

18.0" Diameter Pipe, n= 0.012
Length= 80.0' Slope= 0.0405 '/'
Inlet Invert= 975.24', Outlet Invert= 972.00'



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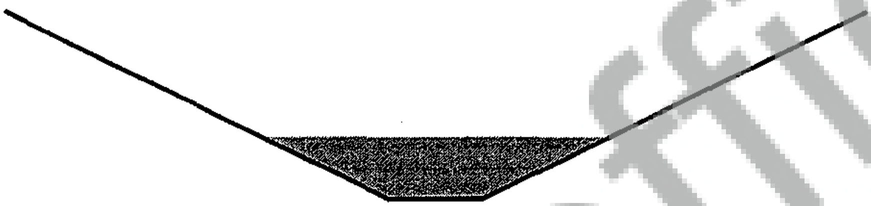
Reach 9R: WORST CASE DITCH

Inflow Area = 10.930 ac, Inflow Depth > 5.26"
Inflow = 13.75 cfs @ 8.03 hrs, Volume= 4.787 af
Outflow = 13.72 cfs @ 8.03 hrs, Volume= 4.785 af, Atten= 0%, Lag= 0.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Max. Velocity= 8.80 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 5.31 fps, Avg. Travel Time= 0.3 min

Peak Storage= 156 cf @ 8.03 hrs, Average Depth at Peak Storage= 0.67'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 165.05 cfs

1.00' x 2.00' deep channel, n= 0.035
Side Slope Z-value= 2.0 '/' Top Width= 9.00'
Length= 100.0' Slope= 0.1500 '/'
Inlet Invert= 0.00', Outlet Invert= -15.00'



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APPENDIX C

LOT INFILTRATION SYSTEM DESIGN
DOCUMENTATION

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Job Name: Wapati Way Short Plat Lots
Job Number: 2018
Date: 2/28/07 8:34 PM
Structure Location: INFILTRATION SYSTEM DESIGN FOR 1,000 SQ FT ROOF

Design Values
Results

Storage and Dissipation System Calculations

Infiltrator High Capacity Chamber

# Units	Perc Rates Horizontal	Perc Rates Vertical
5	4 in/hr	4 in/hr

Elev	Infiltrator High Capacity Units Cumulative Storage	Hor. W. P.	Vert. W. P.	Dissipation
2	78 cf	160 sf	250 sf	0.04 cfs
1.333	76 cf	83 sf	89 sf	0.02 cfs
1	65 cf	63 sf	89 sf	0.01 cfs
0	0 cf	0 sf	89 sf	0.01 cfs

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Job Name: Wapati Way Short Plat Lots
Job Number: 2018
Date: 2/28/07 8:34 PM
Structure Location: INFILTRATION SYSTEM DESIGN FOR 1,800 SQ FT ROOF

Design Values
Results

Storage and Dissipation System Calculations

Infiltrator High Capacity Chamber

# Units	Horizontal (Perc Rates)	Vertical (Perc Rates)
10	4 in/hr	4 in/hr

Elev	Infiltrator High Capacity Units — Cumulative Storage	Hor. W. P.	Vert. W. P.	Dissipation
2	155 cf	320 sf	500 sf	0.08 cfs
1.333	153 cf	167 sf	177 sf	0.03 cfs
1	130 cf	125 sf	177 sf	0.03 cfs
0	0 cf	0 sf	177 sf	0.02 cfs

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Job Name: Wapati Way Short Plat Lots

Job Number: 2018

Date: 2/28/07 8:34 PM

Structure Location: INFILTRATION SYSTEM DESIGN FOR 1,500 SQ FT ROOF

Design Values

Results

Storage and Dissipation System Calculations

Infiltrator High Capacity Chamber

# Units	Perc Rates Horizontal	Perc Rates Vertical
9	4 in/hr	4 in/hr

Elev	Infiltrator High Capacity Units Cumulative Storage	Hor. W. P.	Vert. W. P.	Dissipation
2	140 cf	288 sf	450 sf	0.07 cfs
1.333	138 cf	150 sf	159 sf	0.03 cfs
1	117 cf	113 sf	159 sf	0.03 cfs
0	0 cf	0 sf	159 sf	0.01 cfs

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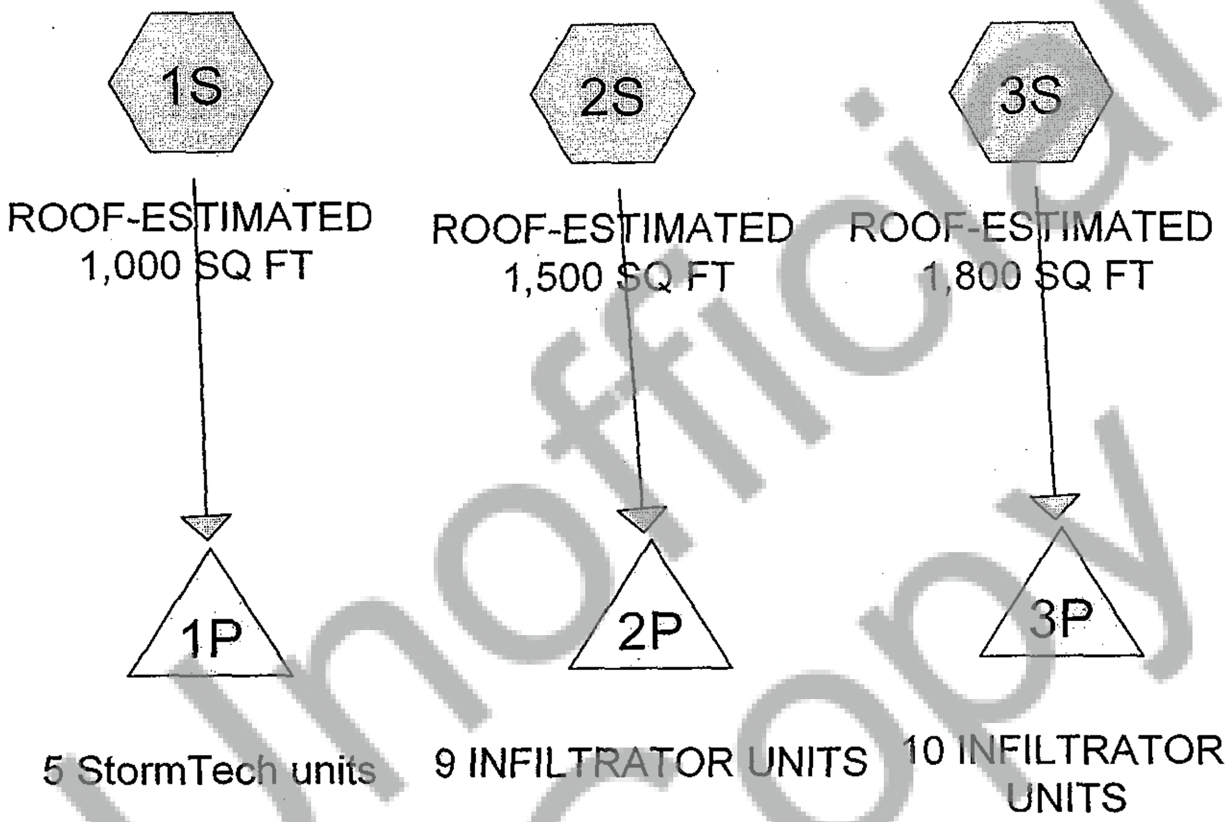

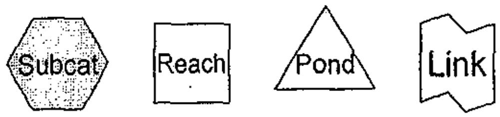

Drainage Diagram for *typical roof infiltration units*[1]
Prepared by Hopper Dennis Jellison, PLLC 2/28/2007
HydroCAD® 8.00 s/n 000668 © 2006 HydroCAD Software Solutions LLC

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Time span=0.00-24.00 hrs, dt=0.25 hrs, 97 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: ROOF-ESTIMATED 1,000 SQ FT Runoff Area=1,000 sf Runoff Depth>8.01"
Tc=6.0 min CN=98 Runoff=0.05 cfs 0.015 af

Subcatchment 2S: ROOF-ESTIMATED 1,500 SQ FT Runoff Area=1,500 sf Runoff Depth>8.01"
Tc=6.0 min CN=98 Runoff=0.07 cfs 0.023 af

Subcatchment 3S: ROOF-ESTIMATED 1,800 SQ FT Runoff Area=1,800 sf Runoff Depth>8.01"
Tc=6.0 min CN=98 Runoff=0.08 cfs 0.028 af

Pond 1P: 5 StormTech units Peak Elev=2.01' Storage=78 cf Inflow=0.05 cfs 0.015 af
Discarded=0.02 cfs 0.015 af Primary=0.01 cfs 0.000 af Outflow=0.03 cfs 0.015 af

Pond 2P: 9 INFILTRATOR UNITS Peak Elev=1.20' Storage=130 cf Inflow=0.07 cfs 0.023 af
Discarded=0.03 cfs 0.023 af Primary=0.00 cfs 0.000 af Outflow=0.03 cfs 0.023 af

Pond 3P: 10 INFILTRATOR UNITS Peak Elev=1.15' Storage=140 cf Inflow=0.08 cfs 0.028 af
Discarded=0.03 cfs 0.027 af Primary=0.00 cfs 0.000 af Outflow=0.03 cfs 0.027 af

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Subcatchment 1S: ROOF-ESTIMATED 1,000 SQ FT

Runoff = 0.05 cfs @ 7.86 hrs, Volume= 0.015 af, Depth> 8.01"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
1,000	98	ROOF
1,000		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, ESTIMATED TRAVEL TIME**

Subcatchment 2S: ROOF-ESTIMATED 1,500 SQ FT

Runoff = 0.07 cfs @ 7.86 hrs, Volume= 0.023 af, Depth> 8.01"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
1,500	98	ROOF
1,500		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, ESTIMATED TRAVEL TIME**

Subcatchment 3S: ROOF-ESTIMATED 1,800 SQ FT

Runoff = 0.08 cfs @ 7.86 hrs, Volume= 0.028 af, Depth> 8.01"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Type IA 24-hr Rainfall=8.25"

Area (sf)	CN	Description
1,800	98	ROOF
1,800		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, ESTIMATED TRAVEL TIME**

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Pond 1P: 5 StormTech units

Inflow Area =	0.023 ac,	Inflow Depth > 8.01"		
Inflow =	0.05 cfs @	7.86 hrs, Volume=	0.015 af	
Outflow =	0.03 cfs @	8.26 hrs, Volume=	0.015 af,	Atten= 28%, Lag= 24.3 min
Discarded =	0.02 cfs @	8.31 hrs, Volume=	0.015 af	
Primary =	0.01 cfs @	8.25 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, *Time Span= 0.00-24.00 hrs, dt= 0.25 hrs*
Peak Elev= 2.01' @ 8.26 hrs Surf.Area= 0 sf Storage= 78 cf

Plug-Flow detention time= 43.0 min calculated for 0.015 af (99% of inflow)
Center-of-Mass det. time= 40.2 min (686.8 - 646.6)

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	78 cf	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (cubic-feet)
0.00	0
1.00	65
1.33	76
2.00	78

Device	Routing	Invert	Outlet Devices
#1	Discarded	0.00'	**Special & User-Defined** Elev. (feet) 0.00 0.10 1.00 1.33 Disch. (cfs) 0.000 0.010 0.010 0.020
#2	Primary	2.00'	**Special & User-Defined** Head (feet) 0.00 0.67 Disch. (cfs) 0.000 2.000

Discarded OutFlow Max=0.02 cfs @ 8.31 hrs HW=1.83' (Free Discharge)
↑—**1=Special & User-Defined** (Custom Controls 0.02 cfs)

Primary OutFlow Max=0.01 cfs @ 8.25 hrs HW=2.00' (Free Discharge)
↑—**2=Special & User-Defined** (Custom Controls 0.01 cfs)

Pond 2P: 9 INFILTRATOR UNITS

Inflow Area =	0.034 ac,	Inflow Depth > 8.01"		
Inflow =	0.07 cfs @	7.86 hrs, Volume=	0.023 af	
Outflow =	0.03 cfs @	8.25 hrs, Volume=	0.023 af,	Atten= 56%, Lag= 23.5 min
Discarded =	0.03 cfs @	8.25 hrs, Volume=	0.023 af	
Primary =	0.00 cfs @	0.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, *Time Span= 0.00-24.00 hrs, dt= 0.25 hrs*
Peak Elev= 1.20' @ 8.41 hrs Surf.Area= 0 sf Storage= 130 cf

Plug-Flow detention time= 38.5 min calculated for 0.023 af (99% of inflow)
Center-of-Mass det. time= 33.9 min (680.5 - 646.6)

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Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	140 cf	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (cubic-feet)
0.00	0
1.00	117
1.33	138
3.00	140

Device	Routing	Invert	Outlet Devices
#1	Discarded	0.00'	**Special & User-Defined** Elev. (feet) 0.00 0.10 1.00 1.33 Disch. (cfs) 0.000 0.010 0.030 0.030
#2	Primary	2.00'	**Special & User-Defined** Head (feet) 0.00 1.00 Disch. (cfs) 0.000 2.000

Discarded OutFlow Max=0.03 cfs @ 8.25 hrs HW=1.18' (Free Discharge)
↑—**1=Special & User-Defined** (Custom Controls 0.03 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=0.00' (Free Discharge)
↑—**2=Special & User-Defined** (Controls 0.00 cfs)

Pond 3P: 10 INFILTRATOR UNITS

Inflow Area = 0.041 ac, Inflow Depth > 8.01"
Inflow = 0.08 cfs @ 7.86 hrs, Volume= 0.028 af
Outflow = 0.03 cfs @ 8.25 hrs, Volume= 0.027 af, Atten= 63%, Lag= 23.5 min
Discarded = 0.03 cfs @ 8.25 hrs, Volume= 0.027 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.25 hrs
Peak Elev= 1.15' @ 8.62 hrs Surf.Area= 0 sf Storage= 140 cf

Plug-Flow detention time= 28.8 min calculated for 0.027 af (100% of inflow)
Center-of-Mass det. time= 26.4 min (673.0 - 646.6)

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	160 cf	**Custom Stage Data**Listed below

Elevation (feet)	Cum.Store (cubic-feet)
0.00	0
1.00	130
1.33	153
3.00	160

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Device	Routing	Invert	Outlet Devices
#1	Discarded	0.00'	**Special & User-Defined** Elev. (feet) 0.00 0.10 1.00 1.33 Disch. (cfs) 0.000 0.020 0.030 0.030
#2	Primary	2.00'	**Special & User-Defined** Head (feet) 0.00 1.00 Disch. (cfs) 0.000 2.000

Discarded OutFlow Max=0.03 cfs @ 8.25 hrs HW=1.05' (Free Discharge)
↑—**1=Special & User-Defined** (Custom Controls 0.03 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=0.00' (Free Discharge)
↑—**2=Special & User-Defined** (Controls 0.00 cfs)

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APPENDIX D

STILLING WELL DESIGN
DOCUMENTATION

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Wapati Way Stilling Well Sizing Calculations:

Base Assumptions:
-Use FHWA HEC 14 sizing procedures (see attached documentation)
-Diameter of pipe leaving site (D) = 18" (1.5')
-Outgoing 18" culvert invert = 975.24'
-Maximum estimated 25-year storm flow rate in approach culvert, Q=14 cfs±

Sizing Procedure:

1. Using Figure X-B-1, select minimum well diameter
   For Q=14 cfs, culvert diameter = 1.5', D_w = 3D±
   Use 54" min. diameter for stilling well. 60" diameter selected as more readily available size.

2. Set depth of well above culvert inlet (h_2) equal to 2D and calculate elevation of pipe invert to stilling well.

   2D = 3'

   Set top of riser installed on end of existing 18" culvert running under 90 Road at 3' above the invert of the incoming culvert.

3. Calculate slope of approach culvert (3.34%). Based on the slope, use Figure X-B-2, determine the resulting depth of the well below the culvert inlet.

   As shown on the Stormwater Plan, the approach culvert (culvert 7) has a slope of 3.34%. Using Figure X-B-2, $h1/D_w$ is less than 0.1. For D_w of 5', the resulting h_1 (depth of well below culvert inlet) is equal to or less than 1'. The depth has been increased to 1' to improve the stilling well's performance.

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X-B. CORPS OF ENGINEERS STILLING WELL

The design of this type of stilling well energy dissipator is based on model tests conducted by the Corps of Engineers. (X-B-1 and 2)

The dissipator has application where debris is not a serious problem. It will operate with moderate to high concentrations of sand and silt but is not recommended for areas where quantities of large floating or rolling debris is expected unless suitable debris-control structures are utilized. Its greatest potential, as far as highways are concerned, is at the outfalls of storm drains, median, and pipe down drains where little debris is expected. It may also be useful as a temporary erosion control device during construction.

Design Recommendations

The design is straightforward. Once the size and discharge of the incoming pipe are determined, figure X-B-1 is used to select the stilling well diameter (D_W). The model tests indicated that satisfactory performance can be maintained for $Q/D^{5/2}$ ratios as large as 10.0, with stilling well diameters of one, two, three, and five times that of the incoming conduits. These ratios were used to define the curves shown in figure X-B-1.

The tests also indicated that there is an optimum depth of stilling well below the invert of the incoming pipe. This depth is determined by entering figure X-B-2 with the slope of the incoming pipe and using the stilling well diameter (D_W) previously obtained from figure X-B-1.

The height of the stilling well above the invert is fixed at twice the diameter of the incoming pipe (2D). This dimension results in satisfactory operation and is practical from a cost standpoint; however, if increased, greater efficiency will result.

Tailwater also increases the efficiency of the stilling well. Whenever possible, it should be located in a sump or depressed area.

It is recommended that riprap or other types of channel protection be provided around the stilling well outlet and for a distance of at least $3D_W$ downstream.

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The outlet may also be covered with a screen or grate for safety. However, the screen or grate should have a clear opening area of at least 75 percent of the total stilling well area and be capable of passing small floating debris such as cans and bottles.

Design Procedures

(1) Select approach pipe diameter (D) and discharge (Q).

(2) Obtain well diameter (D_W) from figure X-B-1.

(3) Calculate the culvert slope = (Vertical/horizontal distance). The depth of the well below the culvert invert (h_1) is determined from figure X-B-2.

(4) The depth of the well above the culvert invert (h_2) is equal to 2(D) as a minimum but may be greater if the site permits.

(5) The total height of the well (h_W) = h_1+h_2.

Example Problem

Given: 24" CMP downdrain on a 2:1 slope carrying a Q = 15 cfs

Find: Stilling well dimensions

Solution:

(1) D=2 ft., Q=15 cfs
(2) From figure X-B-1 D_W=1.5D=3 ft.
(3) Slope=1/2=.5, h_1/D_W=.42 from figure X-B-2
h_1=.42(3.0)=1.26 ft., Use h_1=1.3 ft.
(4) h_2=2(D)=2(2)=4 ft.
(5) h_W= h_1+h_2=1.3+4=5.3 ft.

X-B-1. IMPACT-TYPE ENERGY DISSIPATOR FOR STORM-DRAINAGE OUTFALLS STILLING WELL DESIGN, U. S. Army Corps of Engineers, Technical Report No. 2-620 March 1963, WES, Vicksburg, Mississippi.

X-B-2. Grace, J. L., Pickering, G. A., EVALUATION OF THREE ENERGY DISSIPATORS FOR STORM DRAIN OUTLETS, U.S. Army WES, HRB 1971, Washington, D.C.

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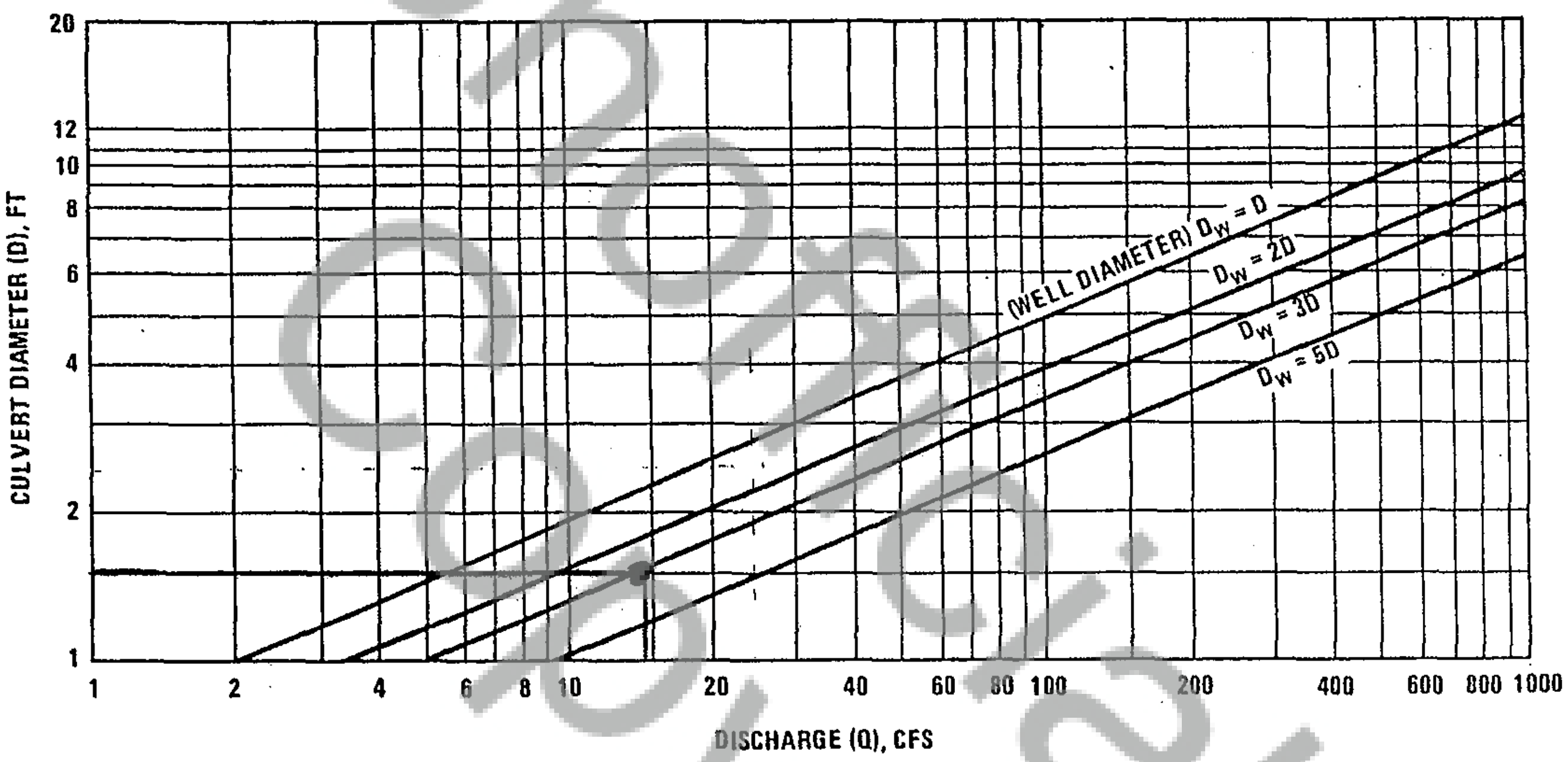

FIGURE X-B-1. STILLING WELL DIAMETER (D_W) FROM REFERENCE X-B-1

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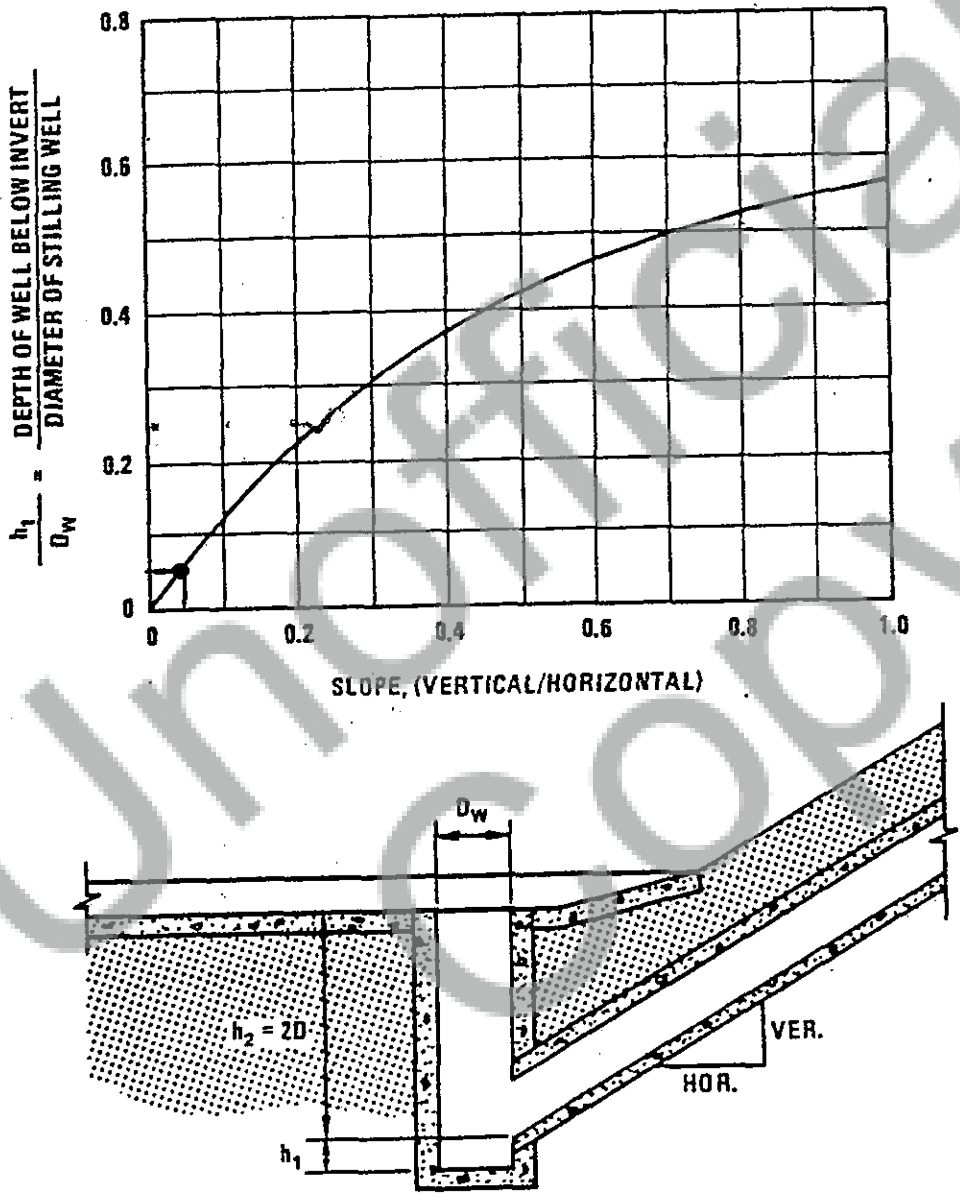

FIGURE X-B-2. STILLING WELL HEIGHT FROM REFERENCE X-B-1

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APPENDIX E

DESIGN REFERENCE DATA

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Table III-1.3 SCS Western Washington Runoff Curve Numbers
(Published by SCS in 1982) Runoff curve numbers for selected agricultural, suburban and urban land use for Type 1A rainfall distribution, 24-hour storm duration.

LAND USE DESCRIPTION		CURVE NUMBERS BY HYDROLOGIC SOIL GROUP A	B	C	D
Cultivated land(1):	winter condition	86	91	94	95
Mountain open areas:	low growing brush & grasslands	74	82	89	92
Meadow or pasture:		65	78	85	89
Wood or forest land:	undisturbed	42	64	76	81
Wood or forest land:	young second growth or brush	55	72	81	86
Orchard:	with cover crop	81	88	92	94
Open spaces, lawns, parks, golf courses, cemeteries, landscaping.					
Good condition:	grass cover on ≥75% of the area	68	80	86	90
Fair condition:	grass cover on 50-75% of the area	77	85	90	92
Gravel roads & parking lots:		76	85	89	91
Dirt roads & parking lots:		72	82	87	89
Impervious surfaces, pavement, roofs etc.		98	98	98	98
Open water bodies:	lakes, wetlands, ponds etc.	100	100	100	100
Single-family residential(2):		Separate curve number shall be selected for pervious & impervious portions of the site or basin			
Dwelling Unit/Gross Acre	%Impervious(3)				
1.0 DU/GA	15				
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				
PUD's, condos, apartments, commercial businesses & industrial areas	%impervious must be computed				

(1) For a more detailed description of agricultural land use curve numbers refer to National Engineering Handbook, Sec. 4, Hydrology, Chapter 9, August 1972.
(2) Assumes roof and driveway runoff is directed into street/storm system.
(3) The remaining pervious areas (lawn) are considered to be in good condition for these curve numbers.

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Table III-1.4 "n" AND "k" Values Used in Time Calculations for Hydrographs

"n_s" Sheet Flow Equation Manning's Values (for the initial 300 ft. of travel)	n_s
Smooth surfaces (concrete, asphalt, gravel, or bare hand packed soil)	0.011
Fallow fields or loose soil surface (no residue)	0.05
Cultivated soil with residue cover ($s \leq 0.20$ ft/ft)	0.06
Cultivated soil with residue cover ($s > 0.20$ ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grasses	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods or forest with light underbrush	0.40
Woods or forest with dense underbrush	0.80

*Manning values for sheet flow only, from Overton and Meadows 1976 (See TR-55, 1986)

"k" Values Used in Travel Time/Time of Concentration Calculations

Shallow Concentrated Flow (After the initial 300 ft. of sheet flow, R = 0.1)	k_s
1. Forest with heavy ground litter and meadows (n = 0.10)	3
2. Brushy ground with some trees (n = 0.060)	5
3. Fallow or minimum tillage cultivation (n = 0.040)	8
4. High grass (n = 0.035)	9
5. Short grass, pasture and lawns (n = 0.030)	11
6. Nearly bare ground (n = 0.25)	13
7. Paved and gravel areas (n = 0.012)	27

Channel Flow (intermittent) (At the beginning of visible channels R = 0.2)	k_c
1. Forested swale with heavy ground litter (n = 0.10)	5
2. Forested drainage course/ravine with defined channel bed (n = 0.050)	10
3. Rock-lined waterway (n = 0.035)	15
4. Grassed waterway (n = 0.030)	17
5. Earth-lined waterway (n = 0.025)	20
6. CMP pipe (n = 0.024)	21
7. Concrete pipe (0.012)	42
8. Other waterways and pipe 0.508/n	

Channel Flow (Continuous stream, R = 0.4)	k_c
9. Meandering stream with some pools (n = 0.040)	20
10. Rock-lined stream (n = 0.035)	23
11. Grass-lined stream (n = 0.030)	27
12. Other streams, man-made channels and pipe 0.807/n**	

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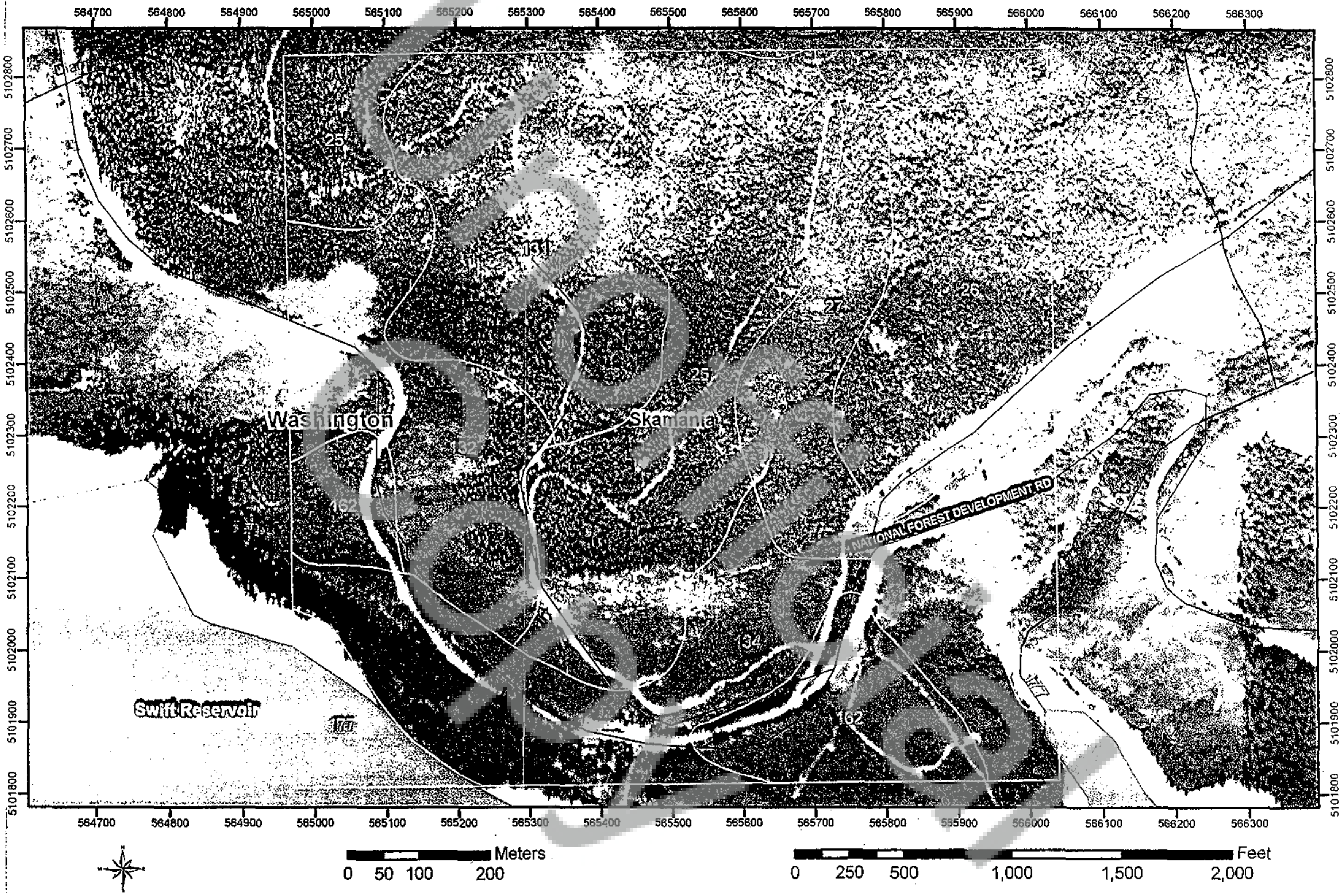
SOIL SURVEY OF SKAMANIA COUNTY AREA, WASHINGTON



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MAP LEGEND

- Soil Map Units
- Cities
- Detailed Counties
- Detailed States
- Interstate Highways
- Roads
- Rails
- Water
- Hydrography
- Oceans
- Escarpment, bedrock
- Escarpment, non-bedrock
- Gulley
- Levee
- Slope
- Blowout
- Borrow Pit
- Clay Spot
- Depression, closed
- Eroded Spot
- Gravel Pit
- Gravelly Spot
- Gulley
- Lava Flow
- Landfill
- Marsh or Swamp
- Miscellaneous Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Slide or Slip
- Sinkhole
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Perennial Water
- Wet Spot

MAP INFORMATION

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov

Coordinate System: UTM Zone 10

Soil Survey Area: Skamania County Area, Washington
Spatial Version of Data: 2
Soil Map Compilation Scale: 1:24000

Map comprised of aerial images photographed on these dates:
7/30/1994

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

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Map Unit Legend Summary

Skamania County Area, Washington

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
25	Cinnamon sandy loam, 2 to 30 percent slopes	57.0	20.9
26	Cinnamon sandy loam, 30 to 65 percent slopes	34.9	12.8
27	Cinnamon sandy loam, 65 to 90 percent slopes	22.1	8.1
131	Swift cindery sandy loam, 30 to 65 percent slopes	43.0	15.8
132	Swift cindery sandy loam, 65 to 90 percent slopes	29.4	10.8
134	Swift-Rock outcrop complex, 65 to 90 percent slopes	55.8	20.5
162	Yalelake sandy loam, 2 to 30 percent slopes	21.2	7.8
177	Water	9.0	3.3

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