TECHNICAL MEMORANDUM

Date: June 30, 2017
To: Chehalis Basin Strategy Flood Damage Reduction Technical Committee
From: Larry Karpack, P.E., Watershed Science & Engineering (WSE)
Marissa Karpack, EIT, WSE
Re: Upper Chehalis Basin HEC-HMS Model Development

Overview

An Inflow Design Flood (IDF) is required for the design of a proposed flood retention dam on the Chehalis River near Pe Ell, Washington. A hydrologic model was prepared and calibrated for the upper Chehalis Basin using observed precipitation and river discharge for several large storm events. The Probable Maximum Precipitation (PMP) was determined according to the Washington State Department of Ecology's Dam Safety Guidelines and then routed through the calibrated hydrologic model to produce the Probable Maximum Flood (PMF) that will be used as the IDF for the dam and spillway design.

This memorandum is an update to a draft Memorandum issued November 2, 2016. Comments were received on the draft and are addressed in Appendix A and incorporated into this Memorandum as described in the appendix.

Data Sources

Data for the upper Chehalis Basin were obtained from multiple sources. The digital elevation model used was the U.S. Geological Survey (USGS) National Elevation Dataset at 1/3 arc-second resolution, published in 2013 (USGS 2013). The National Resource Conservation Service Soil Survey Geographic Database (SSURGO) was used for soil information (NRCS 2015). Land cover distribution in the Chehalis Basin was determined using the Multi-Resolution Land Characteristics Consortium National Land Cover Database 2011 spatial dataset (Homer et al. 2015). The areal and temporal characteristics of snow-water equivalent data were obtained using the National Operational Hydrologic Remote Sensing Center (NOHRSC) interactive snow information mapping tool (NOHRSC 2016).

Modeled discharges were evaluated against measured discharge data from two USGS gages in the Chehalis Basin. The first gage, Chehalis River near Doty, Washington (12020000), has observed discharges at 15-minute increments from October 1, 1988, to the present and daily discharges from October 1, 1939, to present. This gage is located downstream of the proposed dam at the downstream end of the modeled drainage basin. The second gage, Chehalis River above Mahaffey Creek near Pe Ell, Washington (12019310), has recorded discharges at 15-minute increments from May 23, 2013, to the present. This gage is near the proposed dam location. Observed precipitation data were obtained from a variety of sources. Spatial variations in long-term average precipitation were assessed using PRISM 30-

year normals for the most recent epoch available (PRISM 2012). Meteorological data, including precipitation observations, were obtained from the Lewis County gage, Chehalis below Thrash Creek (D15080AC). This gage has 15-minute incremental precipitation observations from September 30, 2012, to present. Additional short interval precipitation data were obtained from Weyerhaeuser's meteorological gage near Rock Creek (D15093DA), which has data publicly available from October 1, 2012, to present. Data from Weyerhaeuser's gage were also available for the December 2007 storm event. Additional gridded hourly precipitation data for the December 2007 storm event were obtained from MetStat in 2013. These data were compiled from various sources as described in Parzybok et al. 2009 (see Appendix B).

Model Development Procedure

The U.S. Army Corps of Engineers HEC-HMS hydrologic model was used to simulate runoff from the Chehalis River basin upstream of the USGS streamflow gage near Doty, Washington (USACE 2015). Sub-basins were delineated for each of the major tributaries, with additional sub-basins added for areas draining directly to the mainstem Chehalis River between the tributaries. Sub-basin delineations were checked against the PRISM long-term precipitation averages to assess spatial variations in precipitation within the sub-basins. Additional sub-basins were added as deemed necessary to minimize precipitation gradients in each sub-basin. The resulting final sub-basins with numbering are shown in Figures 1 through 3.

Computational methods used in the HEC-HMS model were selected based on availability of input data and anticipated ease of calibration. The sub-basins used the Green and Ampt loss method, the Clark Unit Hydrograph transform method, and the recession baseflow method. River reaches between sub-basins used the lag routing method. Input parameters for each sub-basin required for the Clark Unit Hydrograph routing method are the time of concentration, T_c, and storage coefficient, *R*. These coefficients were determined using the physical characteristics of each basin (i.e., maximum flow length, average sub-basin slope, and curve number). Flow length and slope were determined by GIS analysis of the digital elevation model and a spatially weighted curve number was determined using SSURGO soils data. The initial time of concentration values were calculated using the Soil Conservation Service Watershed Lag method, shown in Equation 1:

$$T_c = \frac{l^{0.8}(S+1)^{0.7}}{1{,}140Y^{0.5}} \qquad (1)$$

$where$:

$l = flow\ length, ft$

$Y = average\ watershed\ slope, \%$

$S = maximum\ potential\ retention, in \ = \frac{1000}{CN} - 10$

Figure 1
Upper Chehalis Final Sub-basin Delineation

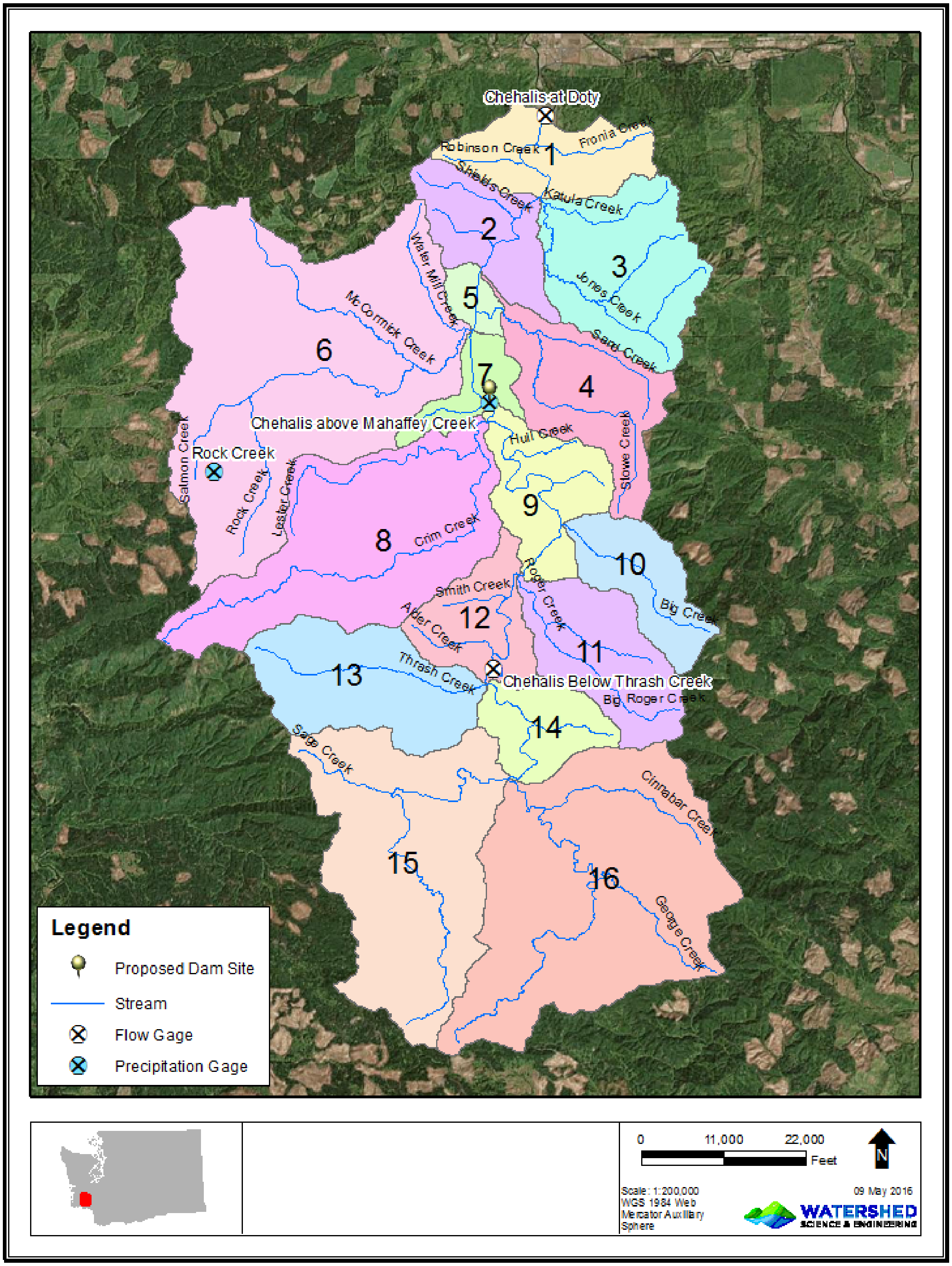


Figure 2
Final Sub-basin Delineation Precipitation Distribution

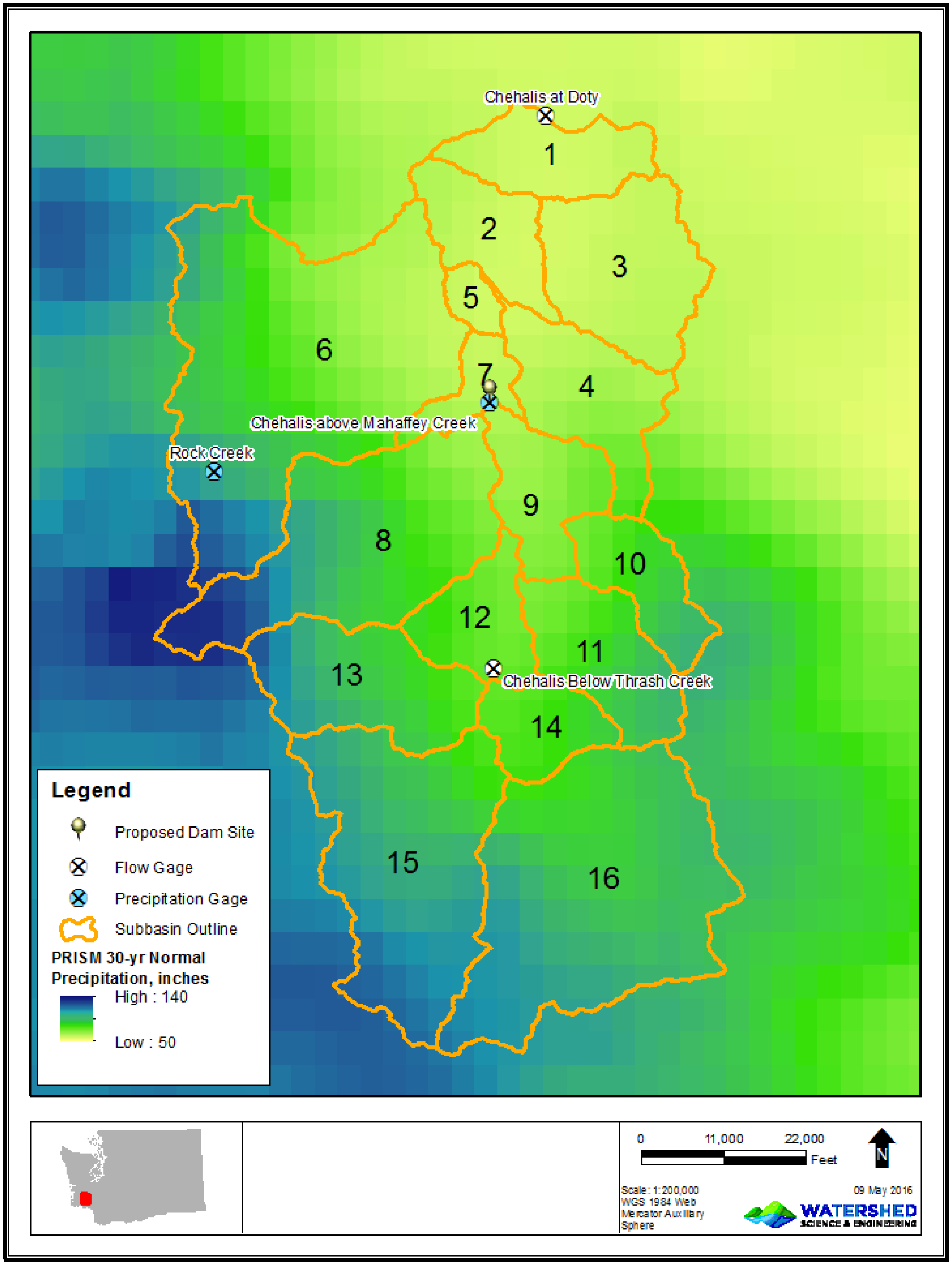
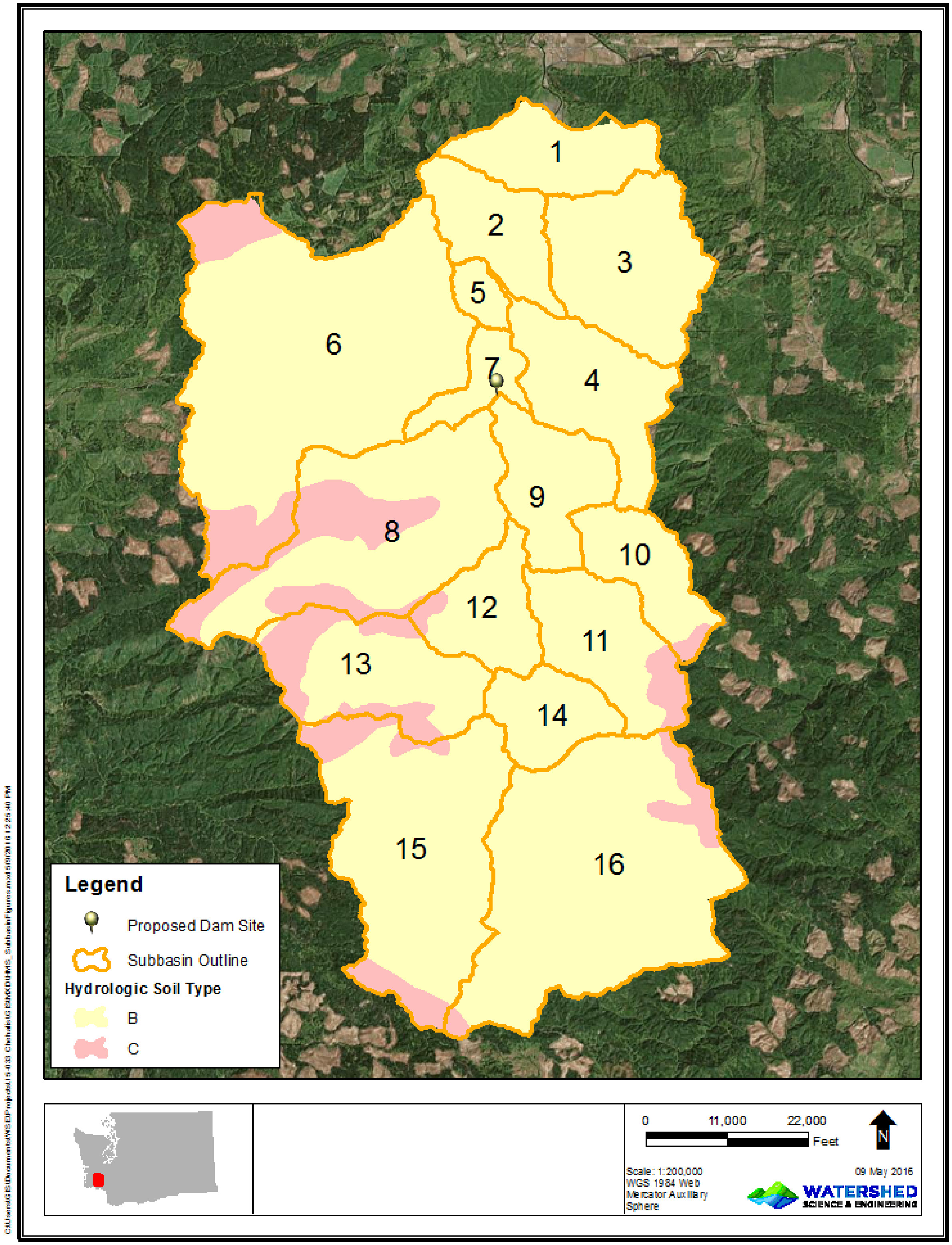


Figure 3
Upper Chehalis Final Sub-basin Delineation Soil Type Distribution



The storage coefficient was calculated by its relationship to the time of concentration, as shown in Equation 2. The value of the constant has been shown to exhibit a regional trend and thus a single constant was used for all sub-basins (FERC 2001). This relationship was maintained throughout the calibration process.

$$\frac{R}{R + T_c} = constant \qquad (2)$$

Initial values for the Green and Ampt loss parameters were estimated based on soil texture classification from SSURGO soils data. The Green-Ampt lookup tables provided initial estimates and feasible ranges for initial water content, saturated water content, suction head, and conductivity. Initial baseflow recession parameters were estimated by analyzing the long-term flow observations to determine initial flow, the ratio-to-peak at which baseflow recession begins, and the recession ratio.

Reach lag times were calculated using the river reach length multiplied by a constant assumed velocity of 7 feet per second. This velocity estimate was found by calculating the average lag time between the peaks flows recorded at the gages below Mahaffey Creek and at Doty for the six largest storms during their overlapping period of record. The lag time was divided by the river length between the two gages to produce a velocity estimate. An existing HEC-RAS model just downstream of the basin corroborated the velocity estimate.

Because precipitation data were only available at specific gage locations, gage weighting in HEC-HMS was used to represent the spatial variation of precipitation within the basin. The weight for each meteorological gage was set as the value at the gage site from the 30-year normal annual precipitation from PRISM. The weight assigned to each sub-basin was the spatial average of the 30-year normal annual precipitation over the sub-basin area. This ensured that precipitation observed at a gage was applied to the sub-basins in the model consistent with the typical precipitation distribution in the basin. The gage weights were also ground truthed by comparison to the MetStat gridded December 2007 observed precipitation, producing no significant difference in model results. The Thrash Creek gage data, scaled to each sub-basin, were used as input for calibration for all events within the gage's period of record. The December 2007 event was calibrated using hourly average precipitation for each sub-basin obtained from the MetStat gridded data as this event occurred prior to installation of the Thrash Creek gage.

After initial parameter values were set, the calibration process consisted of evaluating the similarity of observed and computed discharge based on matching peak flows, peak timing, and overall hygrograph shape. Although long time periods were modeled, only the largest runoff events were analyzed for calibration. The values of input parameters were adjusted iteratively to create a basin model that matched as closely as possible observed discharges using observed precipitation as input. Matching the observed hydrographs required more storage and lower losses in the basin than predicted by basin characteristics. Times of concentration for sub-basins were all increased by the same factor, and the increase in T_c resulted in an increase in R according to Equation 2. The constant in Equation 2 was also used as a calibration parameter. The Green and Ampt parameters were set equal for all sub-basins due to the relative homogeneity of the distribution of soil types across the basin. The difference between initial and saturated soil water content was reduced to replicate the high peak flows observed in the large storm events. Soil conductivity was also found to strongly control model behavior and was thus calibrated to better match observed flows while keeping the parameter within the feasible range from the Green-Ampt lookup table. Baseflow was distributed evenly over the basin, with changes to the ratio-to-peak and recession constant applied uniformly to all sub-basins. Minor adjustments to both parameters were made to better match the observed trailing limbs of the storm hydrographs. The model was insensitive to changes in suction head. The final calibrated parameters and basin characteristics are reported in Table 1 to Table 4.

Table 1
Labels, Areas, and Transform Parameters for Sub-basins in the Final HEC-HMS Model

SUB-BASIN NO.	SUB-BASIN NAME	SUB-BASIN AREA (mi^2)	TIME OF CONCENTRATION (hr), T_C	STORAGE COEFFICIENT, R
1	Jones to Doty Gage	4.09	3.679	3.68
2	Stowe Creek to Jones/Katula Creek	3.72	3.432	3.43
3	Jones Creek	6.97	4.605	4.61
4	Stowe Creek	5.56	4.727	4.73
5	Rock Creek to Stowe Creek	0.89	2.533	2.53
6	Rock Creek	21.64	8.403	8.40
7	Dam Site to Rock Creek	1.79	4.110	4.11
8	Crim Creek	4.14	4.765	4.76
9	Roger Creek to Dam Site	12.43	3.282	3.28
10	Big Creek	3.48	1.489	1.49
11	Roger Creek	5.10	1.923	1.92
12	Thrash Creek to Roger Creek	3.55	1.992	1.99
13	Thrash Creek	6.56	1.881	1.88
14	EF/WF Chehalis to Thrash Creek	2.96	1.311	1.31
15	WF Chehalis	13.13	4.562	4.56
16	EF Chehalis	17.55	3.624	3.62

Notes:
EF = East Fork
hr = hour
mi^2 = square mile
WF = West Fork

Table 2
River Reaches and Lag Times Used in the Final HEC-HMS Model

REACH NO.	DESCRIPTION	LAG TIME (minutes)
16	EF Chehalis	117.05
15	WF Chehalis	108.26
14	EF/WF Chehalis to Thrash Creek	35.67
12	Thrash Creek to Roger Creek	40.22
9a	Roger Creek to Big Creek	14.92
9b	Big Creek to Dam Site	55.17
7	Dam Site to Rock Creek	18.37
5	Rock Creek to Stowe Creek	13.48
2	Stowe Creek to Jones/Katula Creek	23.93
1	Jones Creek to Doty Gage	24.97

Table 3
Green and Ampt Loss Parameters for All Sub-basins in the Final HEC-HMS Model

GREEN AND AMPT PARAMETER	VALUE
Initial Content	0.48
Saturated Content	0.5
Suction Head (inches)	1.9
Conductivity (inches per hour)	0.06

Table 4
Baseflow Recession Parameters Used for All Sub-basins in the Final HEC-HMS Model

BASEFLOW PARAMETER	VALUE
Initial Discharge (cfs/mi^2)	0.23
Recession Constant	0.85
Ratio to Peak	0.10

Note:
cfs/mi^2 = cubic feet per second per square miles

During the calibration process, difficulties arose when attempting to match the model to the observed data from both the December 2007 storm and other large storm events; in particular, the storm event that occurred November 18 to 21, 2012. The November 2012 event was the second largest storm for which precipitation data were available, behind only the December 2007 event and had an observed peak flow greater than 22,000 cubic feet per second (cfs) at the Doty gage. During the December 2007 event, the Doty gage was destroyed and thus a peak flow for this event was estimated by the USGS using indirect methods. The USGS's estimate of the peak was 63,100 cfs. In a peer review of this estimate, WSE suggested that a peak flow of 52,600 cfs was more appropriate (WSE 2014). For calibration of the HEC-HMS model, the flood hydrograph constructed by WSE was used for the December 2007 storm, which is still by far the largest storm on record in the basin.

During calibration, it was found that the model parameters required to match the peak discharge for the December 2007 event resulted in a significant over-prediction of flows for the November 2012 event and most of the other large storms in the recent historical record. Model parameters that performed well for the November 2012 event resulted in a very significant under-prediction of the December 2007 peak (by up to 50%). For model calibration, the precipitation data used for each event was the available source deemed most accurate and representative of the basin, meaning the December 2007 and November 2012 events used different precipitation data sources. To try to eliminate differences in the precipitation data source as the cause of differences in model results for the two events, the models were rerun using precipitation data from the Weyerhaeuser gage at Rock Creek, which was available for both events. Even using the same precipitation data source, the inability of one set of model parameters to closely replicate runoff from both events persisted. Calibrating to the December 2007 event was felt to be more important than any other event because this event is most similar to a PMF. However, the reconstructed discharge data for the December 2007 event introduces significantly more uncertainty than the recorded flows in November 2012 and other later observed events so calibration to the 2007 event is somewhat speculative. Ultimately, parameters were selected that compromised between the two model behaviors. Figures 4 and 5 show the comparison of modeled and observed flows for the final calibration runs for the December 2007 and November 2012 events, respectively.

As seen in Figure 4, the simulated peak for the December 2007 event is still quite a bit lower than the estimated value (even using WSE's estimated peak flow). No parameter set was found that could reproduce the estimated peak for this event, even if rainfall losses were set equal to zero in the model. In fact, it was found that rainfall losses would need to be set to zero and precipitation would need to be increased by 15% above the observed amount to match the estimated peak of that event. However, since there was no indication that the precipitation data used in the analysis was erroneous there was no justification for increasing the rainfall input to the model. As such the results achieved as shown in Figures 4 and 5 were considered to be the best that could be achieved at present, and deemed acceptable with respect to the objective of the current project: to develop an initial estimate of the PMF for preliminary sizing of the spillway.

Figure 4
Final Modeled and Observed Discharges at the Doty Gage for the December 2007 Event

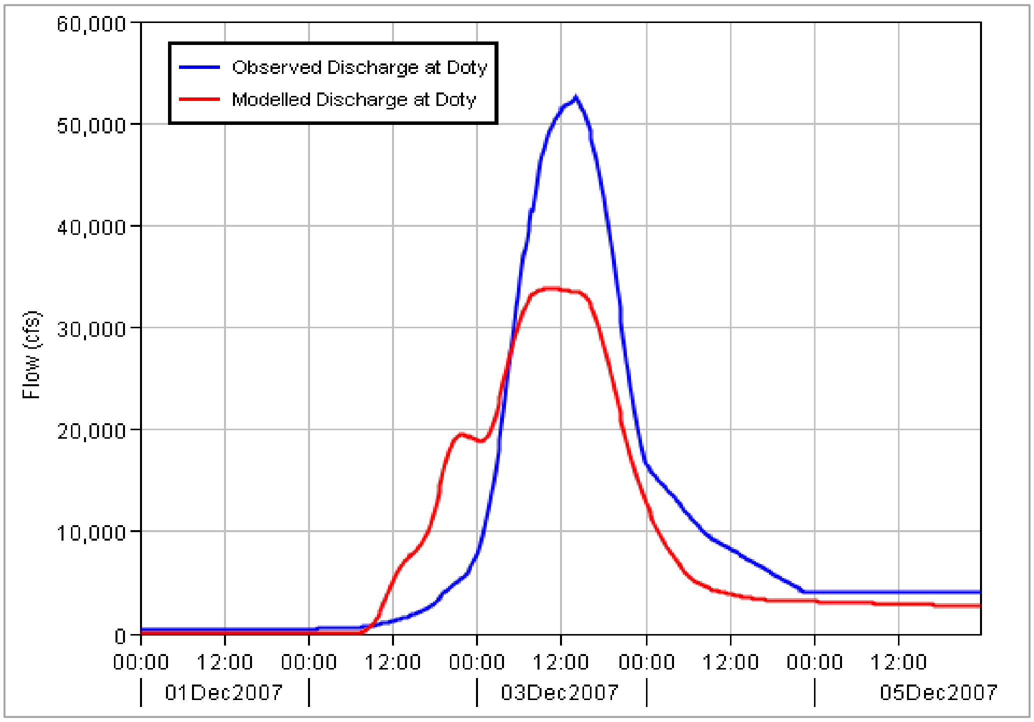
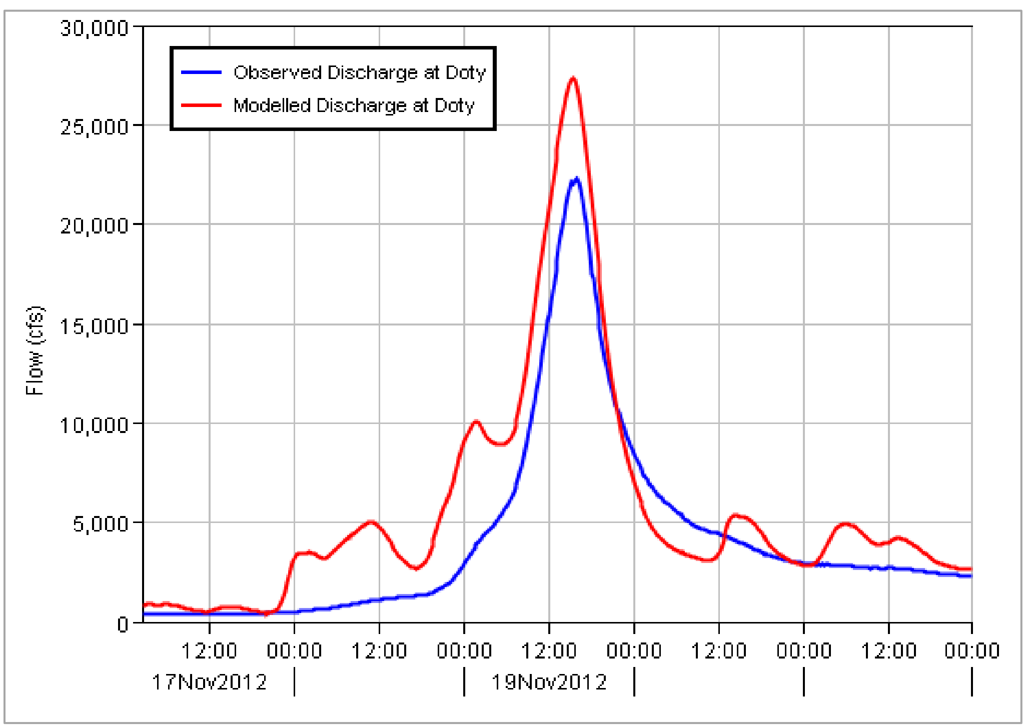


Figure 5
Final Modeled and Observed Discharges at the Doty Gage for the November 2012 Event



Design Storm Development

Once the model parameters were calibrated to observed storms, theoretical design storms were developed and simulated. Washington State Department of Ecology's *Dam Safety Guidelines* were used to develop intermediate and long duration PMP hyetographs. According to Section 2.1 of *Technical Note 3: Design Storm Construction* of the *Dam Safety Guidelines*, the PMP as determined by the National Weather Service's *Hydrometeorological Report No. 57* (HMR-57) is used as the precipitation scaling depth for Design Step 8 dams. Using GIS analysis of the 24-hour 10-square-mile isopluvial maps in HMR-57, the average scaling depth for the basin was determined to be 25.74 inches. This precipitation depth was reduced for the basin area of 68.9 square miles, according to the values in Figure 15.10 of HMR-57. The cumulative precipitation curve up to 72 hours was determined using the temporal adjustments in Table 15.1 of HMR-57. Incremental precipitation values were read from the cumulative precipitation curve for every 15 minutes. These incremental precipitations were rearranged into 18-hour and 72-hour design storms using the process outlined in Section 4.3 of *Technical Note 3*. The temporal distribution was given by dimensionless design hyetographs for Regions 31 – 32 available from the Dam Safety Office. The hyetographs for the intermediate and long duration design storms can be seen in Figures 6 and 7, respectively.

Figure 6
Intermediate Duration (18-hour) Design Hyetograph

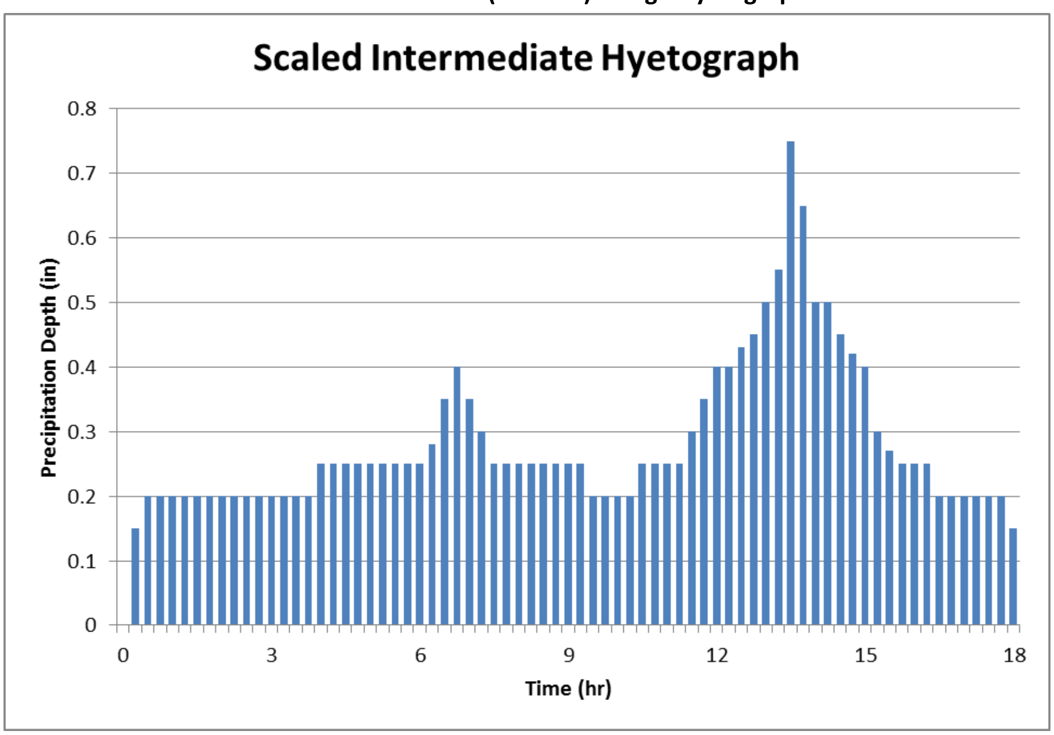
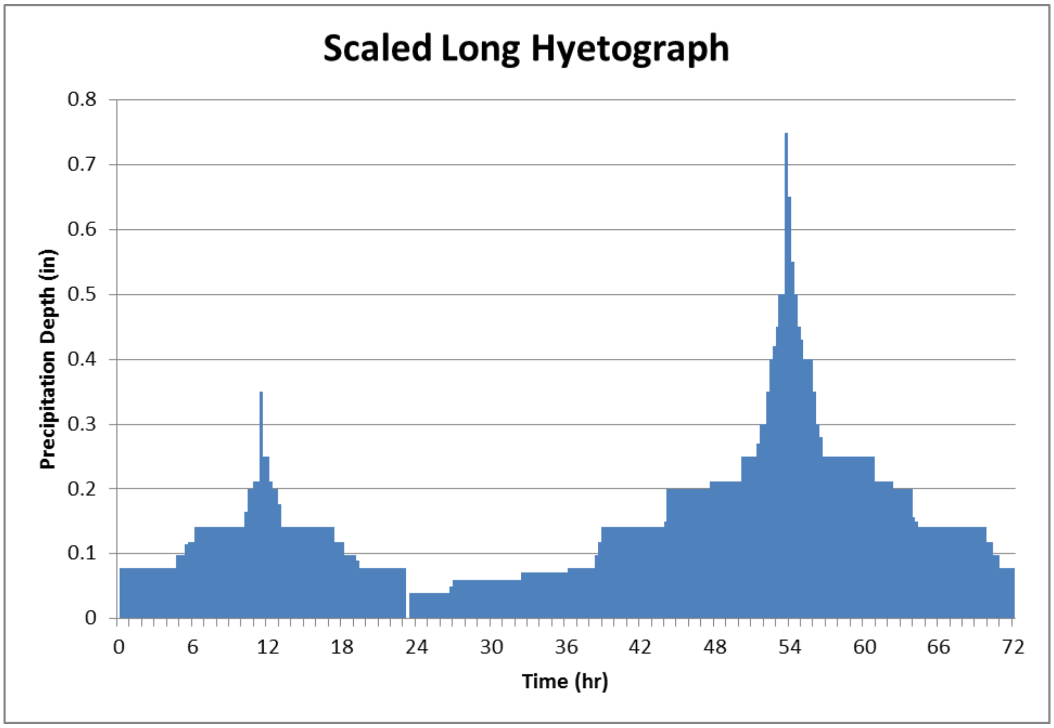


Figure 7
Long Duration (72-hour) Design Hyetograph



Snowmelt Considerations

Although the upper Chehalis Basin typically receives limited snow, the potential for rain-on-snow runoff to augment winter floods made it necessary to consider snowmelt in the HEC-HMS model. Using the NOHRSC satellite data mapping tool, the greatest Snow Water Equivalent (SWE) seen in the basin at any time in any year between 2000 and 2016 was determined to be 4 inches. Potential snowmelt during the design storm was calculated using the Dam Safety Office spreadsheet for rain-on-snow events. Inputs to the spreadsheet included SWE, forest cover percentage, and a conservative temperature assumption of 50°F at the highest point in the basin. The snowmelt was then calculated in elevation bands. It was found that the 4 inches of SWE would be entirely melted during an 18-hour storm. Snowmelt was incorporated into the model by evenly distributing the 4 inches of SWE across the entire storm period for both the intermediate and long duration design storms. The distributed snow water was added to the precipitation hyetograph to create the precipitation input for the HEC-HMS model.

Probable Maximum Flood Simulation Results

The results for the intermediate and long duration storms at the proposed dam site and at the Doty gage are reported in Table 5 and Figures 8 through 11. The controlling PMF is produced by the intermediate duration design storm including snowmelt, which results in a peak flow of 69,800 cfs at the dam site.

Table 5
Peak Flow Results at the Dam Site and Doty Gage for PMP Design Storms Using the HEC-HMS Model

	INTERMEDIATE DURATION STORM		LONG DURATION STORM	
	WITHOUT SNOW	WITH SNOW	WITHOUT SNOW	WITH SNOW
Peak Flow at Dam Site (cfs)	60,200	69,800	60,500	62,900
Peak Flow at Doty Gage (cfs)	84,900	99,000	85,600	89,400

Figure 8
Modeled Flow for the Intermediate Duration Design Storm at the Proposed Dam Site

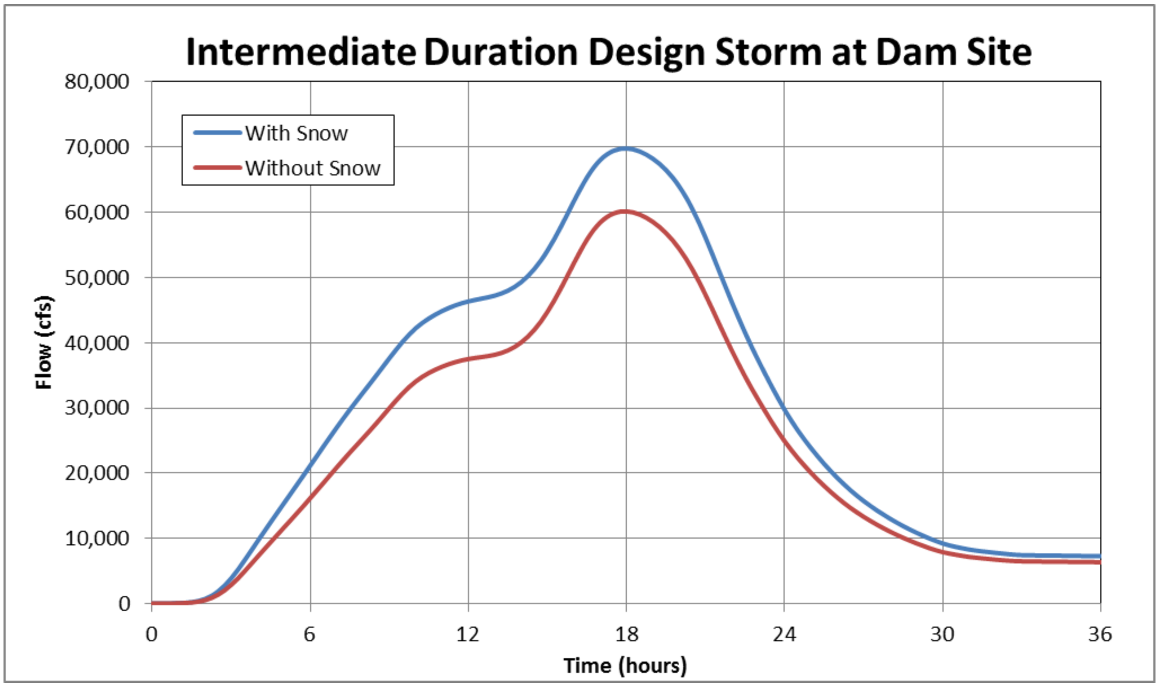


Figure 9

Modeled Flow for the Intermediate Duration Design Storm at the Doty Gage

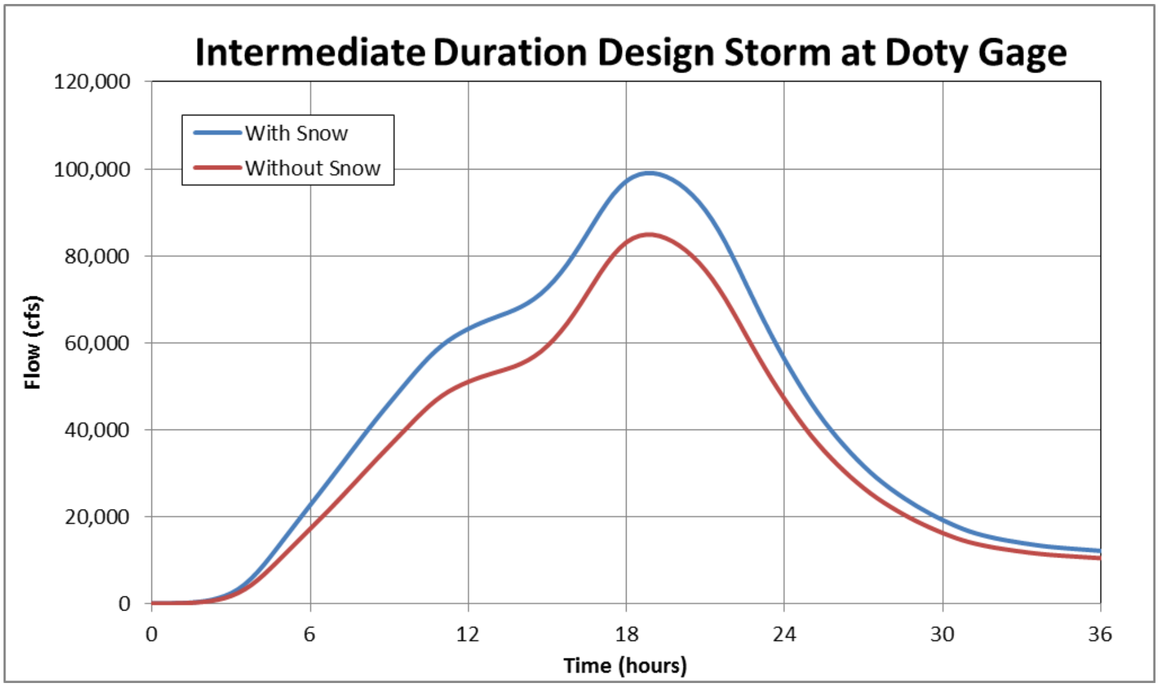


Figure 10

Modeled Flow for the Long Duration Design Storm at the Proposed Dam Site

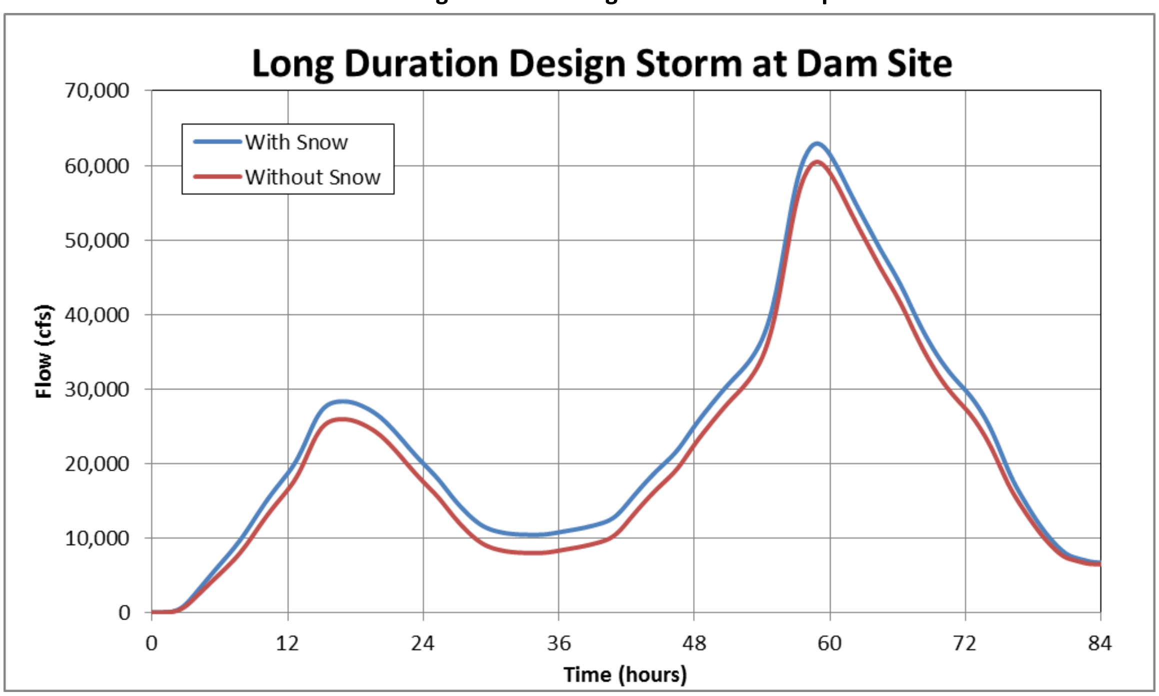
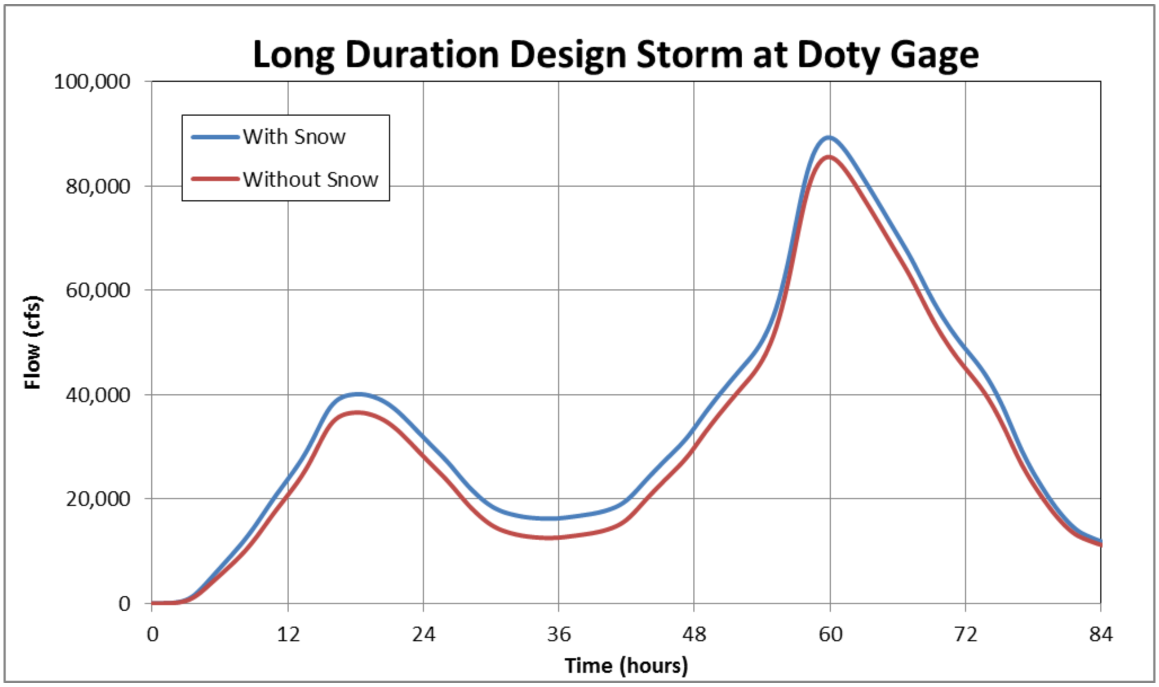


Figure 11
Modeled Flow for the Long Duration Design Storm at the Doty Gage



Frequency Storm Analysis Using HEC-HMS

In addition to the PMP, the 2-, 10-, 25-, 100-, and 500-year precipitation events were also simulated using the HEC-HMS model to obtain flow values at the dam site and at the Doty gage for these events. The precipitation depths for the 10- through 500-year return periods were determined using the *Technical Note 3* precipitation lookup calculator spreadsheet that queries gridded precipitation maps using the basin centroid. This calculator provided precipitation depths for 2-, 6-, and 24-hour storm durations. The 2-year precipitation depths were read from gridded data produced by MGS Engineering Consultants (MGS) and Oregon Climate Service (OCS) for the Washington State Department of Transportation. The 2-year precipitation depths were available for 2- and 24-hour storm durations. The 2-year, 6-hour precipitation was estimated by determining the average ratio of the 2- versus 10-year events for the 2- and 24-hour durations, and then multiplying the 10-year, 6-hour depth by this ratio. For each return period a curve was then fit through the 2-, 6-, and 24-hour precipitation depths, and these curves were used to estimate precipitation depths for the 15-minute, 1-hour, 3-hour, and 12-hour durations.

Within HEC-HMS, the Frequency Storm meteorological model method was used. The storm size parameter in HMS was set to 10 square miles and the storm duration was set to 24 hours. The peak intensity was assumed to occur at the midpoint of the storm and precipitation was applied uniformly over all sub-basins. The precipitation depths as determined above were input into the model to create the design storm hyetograph. The resulting flows at the dam site and at the Doty gage are shown in Table 6.

Table 6
Peak Flow Results for 2-, 10-, 25-, 100-, and 500-year Return Period Storms Using the HEC-HMS Model

RETURN PERIOD	PEAK FLOW AT DAM SITE (cfs)	PEAK FLOW AT DOTY GAGE (cfs)
2-year	7,300	10,900
10-year	10,300	15,500
25-year	12,200	18,200
100-year	15,000	22,400
500-year	18,300	27,400

One notable result from the analysis of the frequency design storms is that the HEC-HMS simulated flows at the Doty gage for a given return period are significantly lower than the corresponding flow quantiles estimated from the USGS gage data. The root cause of this discrepancy is primarily the precipitation frequency data, which appears to be consistently lower than observed rainfall amounts at the basin gages. For example, the December 2007 and November 2012 events experienced a basin average 24-hour precipitation of 11.65 inches and 8.78 inches, respectively. The 500-year, 24-hour precipitation obtained from the MGS and OCS gridded precipitation data queried by the Dam Safety Office Precipitation Lookup spreadsheets was 7.62 inches. Thus, both the December 2007 and November 2012 observed precipitation totals are greater than the estimated 500-year precipitation amount. Although the December 2007 storm is the largest on record for the basin, the November 2012 event is only the fifth largest peak flow recorded at the Doty gage, yet the observed 24-hour precipitation for that event is still 115% of the OCS estimated 500-year total. The observed precipitation data for the December 2007 and November 2012 events were corroborated by multiple gages in the region, as well as the radar precipitation analysis conducted by MetStat. The low precipitation amounts for the frequency design storms relative to the observed storms indicates that the analysis method used to produce the gridded precipitation data queried in the Dam Safety Office spreadsheets may not adequately represent the precipitation patterns in the upper Chehalis Basin, and flows produced by the HEC-HMS model for the frequency design storms would not be reliable.

Summary and Conclusion

A HEC-HMS hydrologic model of the upper Chehalis Basin, upstream of Doty, Washington, was developed and calibrated to observed discharges at the USGS gage on the Chehalis River at Doty. The model was then used, together with precipitation data derived from various sources, to simulate the PMF and a range of other design storm events. Simulated flows were analyzed for the gage site near Doty and at the site of a proposed flood retention dam on the Chehalis River upstream of Pe Ell. The

PMF, with a peak discharge at the dam site of 69,800 cfs, will be used as the IDF for evaluation and design of the dam and spillway.

Design storms for the 2- through 500-year recurrence interval were also simulated. However, because the precipitation frequency data used as input to these simulations does not appear to be reasonable for the upper Chehalis watershed, frequency design flows simulated with the hydrologic model are not considered to be reliable. For reservoir routing analyses performed for the Operations Plan (Anchor QEA 2016) streamflow data from the Chehalis River at Doty gage and the Chehalis River at Mahaffey Creek gage were used to develop inflows and design storms for a HEC-ResSim model of the proposed reservoirs. That methodology is more reliable and provides the data required to analyze reservoir operations.

References

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WSE (Watershed Science and Engineering), 2014. *Peer Review of December 2007 Peak and Hydrograph at Doty Gaging Station*. Technical memorandum prepared for the Hydrologic and Hydraulic Technical Committee. January 31.

Appendix A: Response to Comments on Draft Memorandum

MEMORANDUM

Date: June 30, 2017

To: Guy Hoyle-Dodson and Martin Walther, Chrissy Bailey, Jessica Hausman (Washington State Department of Ecology)

From: Larry Karpack, Marissa Karpack, (Watershed Science & Engineering [WSE])

Re: Comments on Upper Chehalis Basin HEC-HMS Model Development - WSE Responses

The purpose of this memorandum is to respond to comments provided by Guy Hoyle-Dodson and Martin Walther on November 28, 2016 on a draft Technical Memorandum titled "Upper Chehalis Basin HEC-HMS Model Development."

A. Data Sources

1. **On page 1-2**: "…gridded hourly precipitation data for the December 2007 storm event were obtained from MetStat in 2013." How the gridded hourly precipitation data derived from the SPAS model was used in the HEC-HMS model is not completely clear. Was this gridded data used solely to verify sub-basin gauge weights? Please provide some additional explanation.

On pages 1 and 2, we are simply listing the different data sources that were used. The use of the data is discussed in subsequent sections. For example, on page 3 we describe using the MetStat data to verify the gage weights derived from PRISM data. Additional information regarding the precipitation data used as input to the model calibration has been added to the memorandum, including a description of the use of the MetStat data.

Various tests were run on the December 2007 flood event using different approaches to rainfall estimation. These included using the gridded data directly, using the PRISM data for gage weighting with precipitation totals in each subbasin based on the nearest available gage, using the PRISM data for gage weighting with precipitation totals taken from only the Rock Creek gage. None of these proved to provide better results and therefore we did not provide much detail on the tests. Additional explanation of these tests was added on page 9.

B. Model Development

1. **On page 2**: It would be useful to understand more clearly the criteria for creating sub-basins to minimize the spatial variations in precipitation gradients in each sub-basin. What is the "…significant" variation that triggers creating smaller sub-basins? Please discuss.

We did not define a threshold for "significance" in precipitation gradients. We simply checked to be sure that in our engineering judgment it was not necessary to add more sub-basins. The sentence has been edited for clarity.

2. **From Table 3 on page 8**: The Green-Ampt loss method used a suction head and a conductivity that appears to be inconsistent (contradictory) with known soil types. Is this intentional? An artifact of the calibration process? Please discuss.

The value of conductivity was arrived at through calibration (see page 6). The results are insensitive to suction head so the noted inconsistency is not a problem (i.e., we could change the suction head to a higher value without affecting the results). This has now been noted in the memorandum (see page 7).

3. Conceptually, the runoff volume should be less than the precipitation volume falling on the watershed. Please provide a calculation of the precipitation volume on the watershed for the observed December 2007 72-hour flows at Doty. Rainfall volumes may be calculated as the product of rainfall depth on each sub-basin times the sub-basin area, then sum for all sub-basins to get the rain volume for the overall watershed. This data should be available from the input data to the HEC-HMS model. Preliminary calculations (below) suggest that the accumulative precipitation for the observed 72-hour storm would have to equal or exceed 15.1 inches to produce the total volume of flow observed at the December 2007 Doty gauge. This suggests that calibration to the 2007 event at the Doty gauge would be difficult, if one assumes a 72-hour cumulative precipitation less than 15.1 inches.

Agreed. The spatially weighted total precipitation for the December 2007 event was 15.96 inches, slightly higher than the U.S. Geological Survey (USGS) reported runoff but not significantly so. Recall, of course, that the USGS gage failed during the rising limb of this event so the reported hydrograph is subject to great uncertainty.

Table 1
December Reported Hydrograph

				M. Walther, 11/28/16
Doty gage, observed discharge		December 2007 event		
Drainage area =	113.56 square miles	Conversion:	1,000 cfs =	60,000 cu.ft/min.
	72,678 acres			3,600,000 cu.ft/hr.
				82.6446 ac-ft/hr.
Hydrograph ordinates:	72 hrs. cumulative core =	15.1 inches	24 hrs. cumulative core =	11.8 inches

DATE	TIME, HRS.	FLOW, CFS	AC-FT/ HRS.	ELAPSED TIME, HRS.	INCR. TIME, HRS.	AVERAGE AC-FT/HR.	CUMULATIVE VOL, AC-FT	CUMULATIVE RUNOFF (IN.)
2	0.00	0	0					
2	12.00	1200	99.2	12.00	12.00	49.6	595	0.1
2	18.00	2800	231.4	18.00	6.00	165.3	1586	0.3
3	0.00	7600	628.1	24.00	6.00	429.8	4165.289256	0.7
3	3.25	20000	1652.9	27.25	3.25	1140.5	7871.900826	1.3
3	5.00	30000	2479.3	29.00	1.75	2066.1	11487.60331	1.9
3	7.25	40000	3305.8	31.25	2.25	2892.6	17995.86777	3.0
3	11.00	50000	4132.2	35.00	3.75	3719.0	31942.14876	5.3
3	14.00	52400	4330.6	38.00	3.00	4231.4	44636.36364	7.4
3	16.00	50000	4132.2	40.00	2.00	4231.4	53099.17355	8.8
3	18.50	40000	3305.8	42.50	2.50	3719.0	62396.69421	10.3
3	20.25	30000	2479.3	44.25	1.75	2892.6	67458.67769	11.1
3	22.50	20000	1652.9	46.50	2.25	2066.1	72107.43802	11.9
4	0.00	16000	1322.3	48.00	1.50	1487.6	74338.84298	12.3
4	8.00	10000	826.4	56.00	8.00	1074.4	82933.8843	13.7
4	12.00	8000	661.2	60.00	4.00	743.8	85909.09091	14.2
4	22.00	4000	330.6	70.00	10.00	495.9	90867.7686	15.0
5	0.00	4000	330.6	72.00	2.00	330.6	91528.92562	15.1
5	12.00	4000	330.6	84.00	12.00	330.6	95495.86777	15.8

Notes:
ac-ft = acre foot
cfs = cubic feet per second
cu. ft = cubic foot
hr. = hour
in. = inch

4. **On page 2**: Values for R and TC were computed for input into HEC-HMS. As outlined in the WSDOT Hydraulics Manual M 23-03.03, a check can be made for calculating the time of concentration: TC using hydraulic theory. A procedure for determining the time of concentration for overland flow was developed by the USDA Natural Resources Conservation Service. The time of concentration can be calculated as in Equations 2-2 and 2-3:

$$T_t = \frac{L}{K\sqrt{S}} = \frac{L^{1.5}}{K\sqrt{\Delta H}} \quad (2\text{-}2)$$

$$T_c = T_{t1} + T_{t2} + \cdots\ T_{tnz} \quad (2\text{-}3)$$

Where:

Tt	=	the travel time of flow segment in minutes
Tc	=	time of concentration in minutes
L	=	length of segment in feet (meters)
ΔH	=	elevation change across segment in feet (meters)
K	=	ground cover coefficient in feet (meters)
S	=	slope of segment ΔH L in feet per feet (meter per meter)

Please explain or discuss the preference for the NRCS lag equation used in the report rather than the time-of-travel calculations.

The watershed lag method used in the current analysis is simple to calculate in GIS and uses available data rather than requiring the estimation of new data (i.e., ground cover coefficients) as needed in the above formula. Given the intended purpose of this work, initial estimation of Probable Maximum Flood (PMF) flows for preliminary spillway sizing, the techniques used in the analysis were felt to be adequate. The above formula and approach may be evaluated in the future when a more detailed and accurate estimate of the PMF inflow is required to design or analyze the spillway.

5. **On page 2**: Calculation of the linear Storage: R = (constant*TC) / (1- constant) should be made more explicit, with an explanation of how the constant was derived. Is this based on watershed characteristics? Please provide more description.

   Note: One approach suggested by previous studies is the use of multiple-regression analysis, that can be applied to determine relations among (TC+R), R / (TC+R), and watershed characteristics. Methods and equations have been developed that relate TC and R to watershed characteristics for watersheds in Illinois (Graf and others, 1982a, b; Melching and Marquardt, 1996 - Cited in USGS: Water-Resources Investigations Report 00–4184).

We are aware of the Illinois study, but not aware of a similar study in the Pacific Northwest. The scope of this project did not allow for the evaluation of runoff from multiple flood events in multiple gaged watersheds as would be needed to conduct the multiple regression analysis. The constant R/(Tc+R) was initially estimated in previous work by Anchor QEA and was refined here through calibration to the available flow data.

6. **From the map in Figure 3 on page 6 (now 5)**: Hydrologic Soil Group B suggests soils with rather high surface infiltration rates. How was interflow considered in the HEC-HMS model? Is this implicit in the Clark Unit Hydrograph? Please discuss.

Note, If it is determined that interflow should be considered, the Dam Safety office (DSO) has found that one method of incorporating interflow, is to use the Horton's Infiltration Model to produce surficial and deep soil infiltration rates. The former can be combined with a regional synthetic unit hyetograph to produce a truncated user-specified interflow hyetograph (with peak limited to soil infiltration rate). This can then be applied to an Interflow sub-basin, in conjunction with a Surface Run-off sub-basin. The final hydrograph produced is a superposition of the contribution from the two sub-basins' hyetographs, with appropriate losses and transforms. Other methods of incorporating interflow are also available.

Interflow is not explicitly modeled in the HEC-HMS model but rather is implicit in the Clark Unit hydrograph. In future phases of the project, as more data are available and as the work to more accurately define the PMF becomes more critical, alternative modeling approaches will be considered. As noted in the reviewers' previous comment, the observed runoff during the December 2007 flood event (USGS data as adjusted by WSE) was nearly equal to the observed rainfall in that event (MetStat data). Thus, to achieve any semblance of calibration in this event infiltration rates were required to be set very low (clearly somewhat inconsistent with Type B soils).

7. It is unclear if the antecedent moisture conditions were different at the start of each storm (2007 and 2012 storms). Different values might explain, in part, the model's failure to approach the observed 2007 peak. Was this considered? Please discuss.

Different antecedent conditions were used in each of the modeled events. However, no adjustments to antecedent conditions could alter the simulations to match both the December 2007 and November 2012 observed flood events. Furthermore, conditions prior to the December 2007 flood event (which is being under simulated) were not particularly wet and therefore even the assumption made in the current model (of saturated ground at the start of this event) is problematic.

8. **On page 15-16**: The discrepancy between the calculator precipitation and the observed precipitation is striking. We'd like more information on this. Could you please provide a copy of your calculations, (i.e. Basin (sub-basin) centroids used, storms considered (i.e. long, intermediate, short?), etc.). I will note that the selection of a representative point in the basin (sub-basin?) is important to ensure acceptable estimates of projected precipitation depth from the calculator.

The centroid of the entire basin was used in the calculator (46.5041, -123.308). The precipitation depth-duration values determined from this point were applied uniformly across the entire basin. A storm duration of 24 hours was the only duration considered (see page 15). Note, however, that the design storm data do not affect the simulated PMF, as the precipitation totals used in the PMF were derived using HMR57. The focus of the current modeling effort was to develop a preliminary estimate of the PMF to allow preliminary sizing of the reservoir spillway as needed for cost estimating purposes.

Appendix A

1. There is an uncertainty range associated with the Storm Precipitation Analysis System (SPAS) precipitation estimates (see below):

In real storm cases, the SPAS DAD results were generally within +/-5% of the published Weather Bureau results for the Westfield, MA, storm of 1955 and Ritter, IA, storm of 1953 (see table 2). (U.S. Army Corps of Engineers, 1953; U.S. Army Corps of Engineers. 1955). These results confirm the reproducibility of not only the storm centered DAD results, but also the spatial and temporal characteristics of the storm precipitation.

Table 2. *The comparison of DAD results from SPAS and the Weather Bureau published results for the Westfield, MA, storm of August 15-23, 1955.*

SPAS

SQ-MILES	6-HOUR	12-HOUR	24-HOUR	36-HOUR	48-HOUR	60-HOUR	TOTAL
10	7.96	11.48	16.40	19.10	19.11	19.47	19.70
100	7.22	10.72	15.20	17.77	17.76	18.23	18.47
200	6.99	10.27	14.28	16.91	16.84	17.39	17.54
1000	5.97	9.06	12.55	14.97	15.08	15.40	15.95
5000	4.14	6.45	9.25	11.70	12.02	12.35	13.05
10000	3.23	5.46	7.63	9.60	9.91	10.26	10.86
20000	2.24	4.03	5.91	7.66	7.97	8.22	8.77

Weather Bureau

SQ-MILES	6-HOUR	12-HOUR	24-HOUR	36-HOUR	48-HOUR	60-HOUR	TOTAL
10	7.80	11.10	16.40	18.90	19.40	19.40	19.40
100	7.60	10.50	14.60	18.10	18.80	19.00	19.00
200	7.40	10.20	14.20	17.60	18.20	18.40	18.40
1000	6.20	9.20	12.40	15.90	16.20	16.40	16.40
5000	4.00	6.30	9.50	12.10	12.60	13.00	13.00
10000	3.10	5.00	8.00	10.00	10.60	10.80	10.80
20000	2.10	3.60	6.30	7.90	8.30	8.50	8.50

Percent Difference

SQ-MILES	6-HOUR	12-HOUR	24-HOUR	36-HOUR	48-HOUR	60-HOUR	TOTAL
10	2.1%	3.4%	0.0%	1.1%	-1.5%	0.4%	1.5%
100	-5.0%	2.1%	4.1%	-1.8%	-5.5%	-4.1%	-2.8%
200	-5.5%	0.7%	0.6%	-3.9%	-7.5%	-5.5%	-4.7%
1000	-3.7%	-1.5%	1.2%	-5.8%	-6.9%	-6.1%	-2.7%
5000	3.5%	2.4%	-2.6%	-3.3%	-4.6%	-5.0%	0.4%
10000	4.2%	9.2%	-4.6%	-4.0%	-6.5%	-5.0%	0.6%
20000	6.7%	11.9%	-6.2%	-3.0%	-4.0%	-3.3%	3.2%

> In the memorandum it is unclear how this uncertainty has been applied to the Willapa Hills gridded precipitation data set.
>
> Additional uncertainty is associated with the radar-derived precipitation techniques that rely on a relationship between radar reflectivity and precipitation rate. This non-linear relationship is described by the Z-R equation. Other uncertainty is associated with the precipitation gauge.
>
> It is unclear from the memorandum how this uncertainty will be factored into the model. Please discuss.

It is not clear to us where the data shown above came from, what its purpose is, or what is being requested by the reviewer. The MetStat gridded precipitation data for the December 2007 flood event (derived using SPAS) would clearly have associated uncertainties, as would any data. However, as documented in our analysis, the only use made of the MetStat data was to simulate the December 2007 calibration event (calibration was also attempted using all other available precipitation data sets) and to cross check the sub-basin gage weights derived from PRISM data. Given the overall poor quality of model calibration to the December 2007 and November 2012 flood events, we do not envision making any adjustments to the data or conducting additional tests at this time to address precipitation data uncertainty.

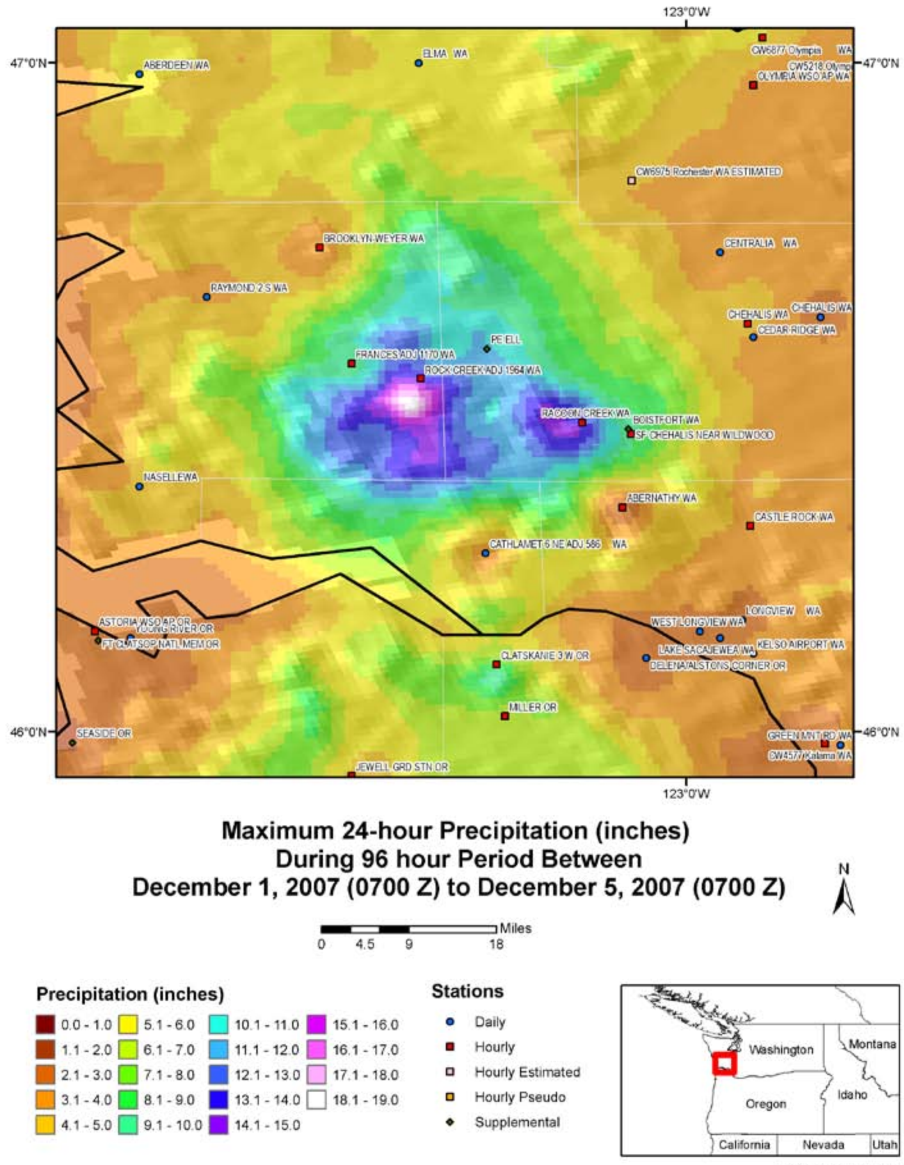
2. The actual number of precipitation gauges used in the SPAS model to develop the gridded precipitation profile is unclear. Please identify which gauges were used in the Chehalis model.

The gridded rainfall data development for the December 2007 event was done by MetStat for an earlier project. Detailed questions about the SPAS data would need to be discussed with MetStat. However, it is our understanding that all gages listed in the MetStat document (496 gages as reported on page 4 of the MetStat summary) were used in the SPAS analysis. Once again it should be noted that the MetStat data for the December 2007 flood event were used for two purposes, for input to the calibration model (calibration was also attempted using all other available precipitation data sets) and for validating the sub-basin gage weights determined from PRISM data. The MetStat data were not used for the PMF modeling, the primary objective of WSE's analysis.

Appendix B: 2009 Storm Precipitation Analysis System Report: Atmospheric River Storm of December 1 to 4, 2007

STORM PRECIPITATION ANALYSIS SYSTEM (SPAS) FINAL REPORT

Atmospheric River Storm of December 1-4, 2007
Willapa Hills, Washington
SPAS Storm #1172



Maximum 24-hour Precipitation (inches)

Report date: December 10, 2009

Metstat, Inc. **Applied Weather Associates, LLC**

STORM PRECIPITATION ANALYSIS SYSTEM (SPAS) FINAL REPORT

Atmospheric River Storm of December 1-4, 2007
Willapa Hills, Washington
SPAS Storm #1172

By:

Tye W. Parzybok	**Metstat, Inc.**
Doug M. Hultstrand	**Metstat, Inc.**
Ed Tomlinson, Ph.D	**Applied Weather Associates, LLC**
Bill Kappel	**Applied Weather Associates, LLC**

Report date: December 10, 2009

STORM PRECIPITATION ANALYSIS SYSTEM (SPAS) FINAL REPORT

Atmospheric River Storm of December 1-4, 2007 Willapa Hills, Washington SPAS Storm #1172

PROJECT AREA

The study area for SPAS (see Appendix C) storm #1172 encompasses western Oregon and western Washington. It runs from 49°N to 42°N and 125°West to 121°West. Although larger than necessary for the Willapa Hills region of southwestern Washington, the SPAS #1172 domain is consistent with SPAS #1053 which was conducted for a probable maximum precipitation (PMP) study earlier in 2009. The rainfall event occurred during the period December 1, 2007 and December 4, 2007 during a classic Pineapple Express (a.k.a. Atmospheric River) synoptic event.

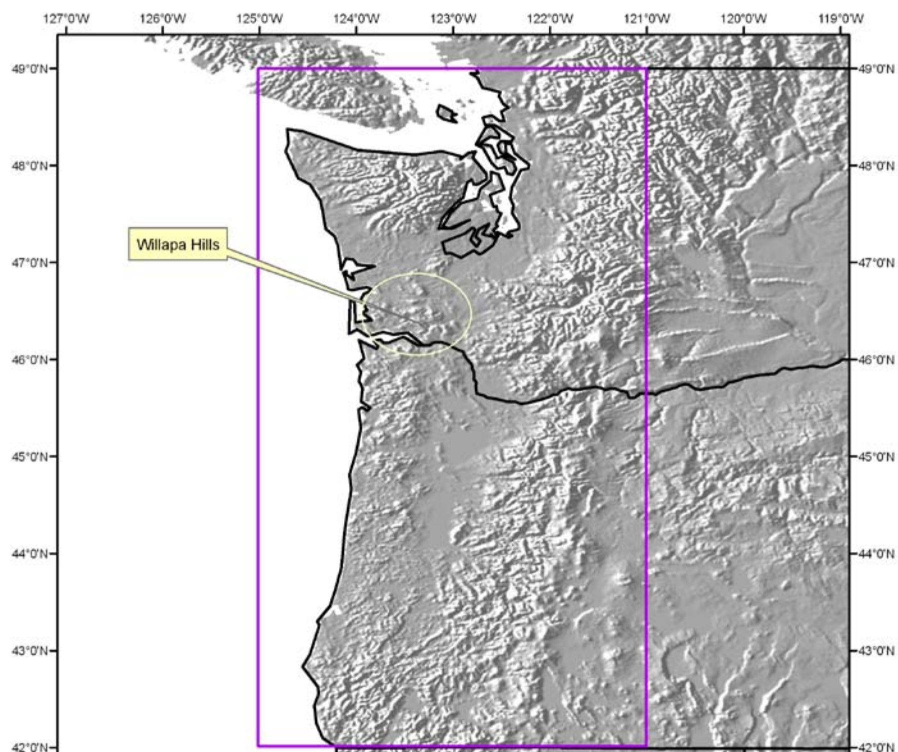


Figure 1.0 SPAS #1172 Storm analysis domain and general location of Willapa Hills, WA.

STORM ANALYSIS DETAILS

General Storm Location: Western Washington and Western Oregon, including the Willapa Hills area of southwestern Washington

Storm Dates: December 1, 2007 (0700 Z) – December 5, 2007 (0700 Z)

Type of Event: Atmospheric River

Maximum SPAS Rainfall Amount: 20.33"(Grid/Pixel Point)

Latitude: 46.4950 °N

Longitude: 123.4050 °W

Maximum Rain Gauge Amount: 19.64" at Rock Creek, WA

Number of Stations: 496

SPAS Version: 7.0

Base Map Used: PRISM Mean (1971-2000) December Precipitation

Spatial resolution: 0.53 sq-mi

METEOROLOGIC DATA

Surface precipitation observations measured on an hourly and 24-hour basis within the project area were obtained from multiple sources. Although some of these sources are considered unofficial, they were only used if they passed quality control checks. Regardless, only official data was used in/around the Willapa Hills. Data was acquired from the following sources:

- National Weather Service offices (NOAA)
- U.S. Department of the Interior's U.S. Geological Survey (USGS)
- NOAA's National Climatic Data Center (NCDC/COOP)
- Weyerhaeuser (WEYER)
- NRCS SNOwpack TELemetry (SNOTEL)
- The WeatherUnderground (WXUNDER)
- MesoWest
- Remote Automated Weather Stations (RAWS)
- Community Collaborative Rain, Hail, and Snow Network (COCORAHS)
- Pacific Northwest Cooperative Agricultural Network (AGRIMET)
- Other:
  - MesoWest
  - Citizen reports
  - Federal Aviation Administration (FAA)

Number of stations: 496 (see Appendix A)

- 236 - Hourly

- 37 - Estimated hourly
- 17 - Hourly pseudo (unreliable magnitude, but worthy timing)
- 178 - Daily
- 28 - Supplemental (no observation time)

RADAR DATA

Mosaicked Doppler radar Level II data was obtained from Weather Decision Technologies, Inc. (WDT) The base reflectivity data was provided at a temporal resolution of 5 minutes and a spatial resolution of 0.01 x 0.01 decimal degrees, which is approximately 1 km x 1 km. The radar data was subjected to Radar Data Quality Control (RDQC) algorithm developed by WDT and the National Severe Storms Laboratory. The RDQC algorithm removes non-precipitation radar artifacts from Level-II radar data such as Ground Clutter, Sea Clutter, Anomalous Propagation (AP), sun strobes, clear air returns, chaff, biological targets such as birds, insects or wind-borne particles, electronic interference and hardware test patterns. This algorithm uses sophisticated image and data processing and a Quality Control Neural Network (QCNN) to delineate precipitation echoes from echoes caused by radar artifacts. All 3 Doppler moments (Reflectivity, Radial Velocity, and Spectrum Width) are used where available to determine which echoes correspond to precipitation versus which do not. Although the RDQC algorithm is very effective in “cleaning up” the radar data, SPAS conducted further QC and infilling of suspicious radar data in completely blocked regions. The radar was partially blocked in the Willapa Hills, particularly along a line from Rock Creek to the Portland, Oregon radar site and along the southwestern side of the Willapa Hills. The radar data in these areas was filled in by adjacent, reliable radar data. Although the radar data in the Willapa Hills did not accurately capture the magnitude of heavy rainfall in the Willapa Hills, its spatial pattern combined with the gauge data produced a reliable depiction of precipitation in this area.

STORM ANALYSIS DETAILS

The Storm Precipitation Analysis System (SPAS) was used to analyze the precipitation associated with this storm event. SPAS utilized observed (ground truth) precipitation data, in conjunction with Doppler radar data to produce grids of incremental hourly precipitation totals for a 96-hour period. The 96 hourly grids where when added up to produce a total storm grid (Figure 1). Similarly, a moving 24-hour window was used to identify the maximum 24-hour precipitation depth (intensity) at each pixel. (Figure 2) The maximum intensity was also determined for 6-, 12-, 36-, 48- and 72-hours. The maximum 24-hour intensity grid was subsequently converted to an 24-hour average recurrence interval (ARI) using the recently developed precipitation frequency grids for Washington and Oregon (Schaefer 2002, 2008). (Figure 3)

We used the hourly precipitation at Frances, Oregon that was reported in NOAA’s Hourly Precipitation Data document; the storm total from this source was 11.4”. Radar data and hourly precipitation at surrounding gauges suggested light rain occurred for approximately 8 hours before the first 0.20” tip occurred at 12 noon December 2, 2007. In fact, a National Weather Service Public Information Statement, issued by the Seattle NWS office at 230 PM PST FRI DEC 7 2007 (see Appendix D) indicated a storm total of 14.1”. The maximum 24-hour precipitation via a moving window through NOAA’s Hourly Precipitation Data was 9.6”, but the Monthly Precipitation Maxima table (in the back of the document) only indicates 9.5”. The same 24-hour period totaled 9.5” via SPAS at Frances, WA, but an adjacent grid cell is 9.8”, which equate to average recurrence intervals of 376 and 463 years respectively. The National Weather Service Public Information Statement, issued by the Seattle NWS office at 230 PM PST FRI DEC 7 2007 indicated a maximum 24-hour value of 9.7". The Public Service Information Statement does say the values are "ROUGH ESTIMATES" and that "SOME OF THE LOCATIONS DID NOT RECORD THE BEGINNING OF THE RAINFALL BECAUSE COLD AIR AND SNOW AFFECTED THE GAGE READINGS FOR A TIME." Regardless of what the total storm value was at Frances, the maximum 24-hour intensity appears to be somewhat consistent among the different sources.

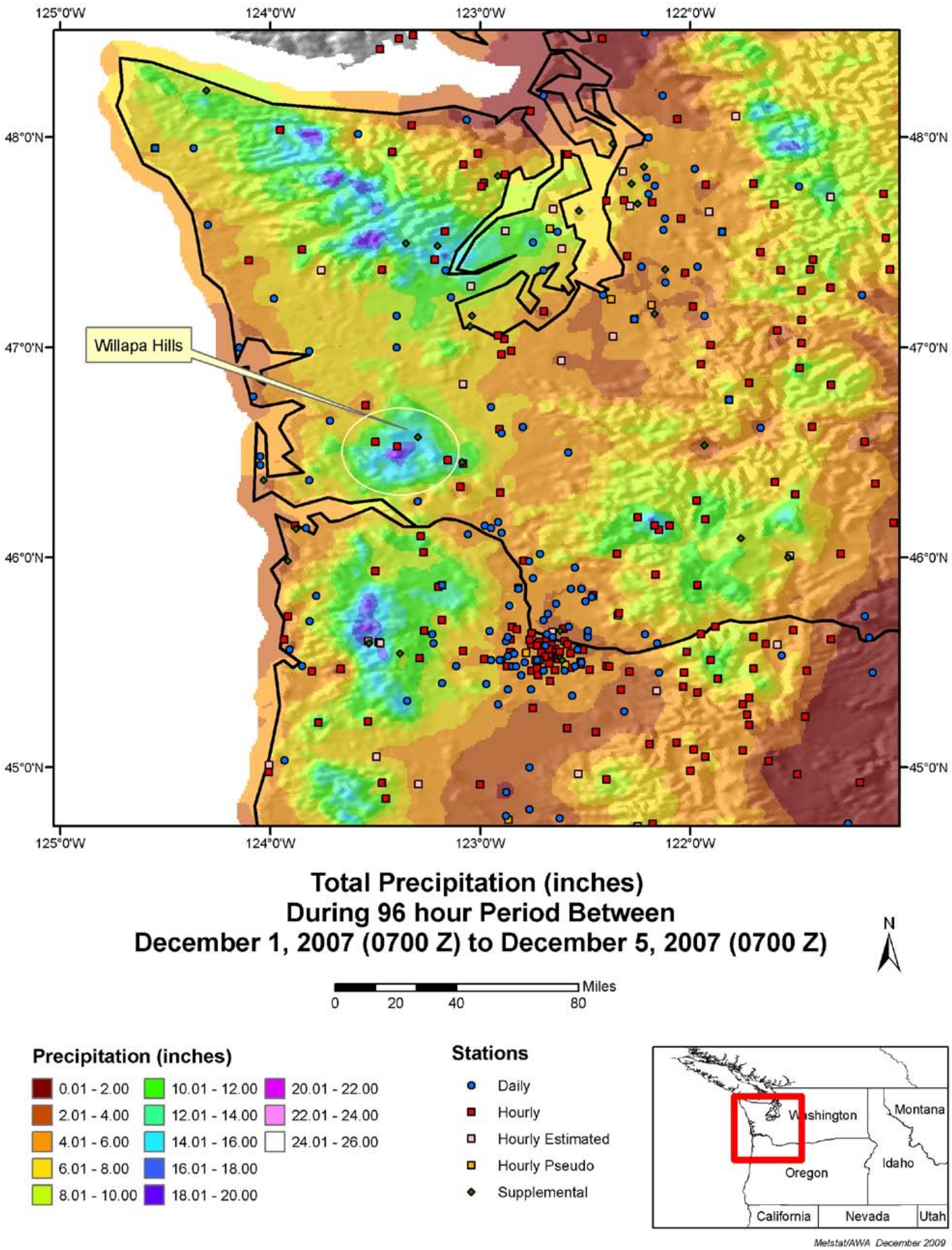


Figure 1. Total SPAS storm rainfall map.

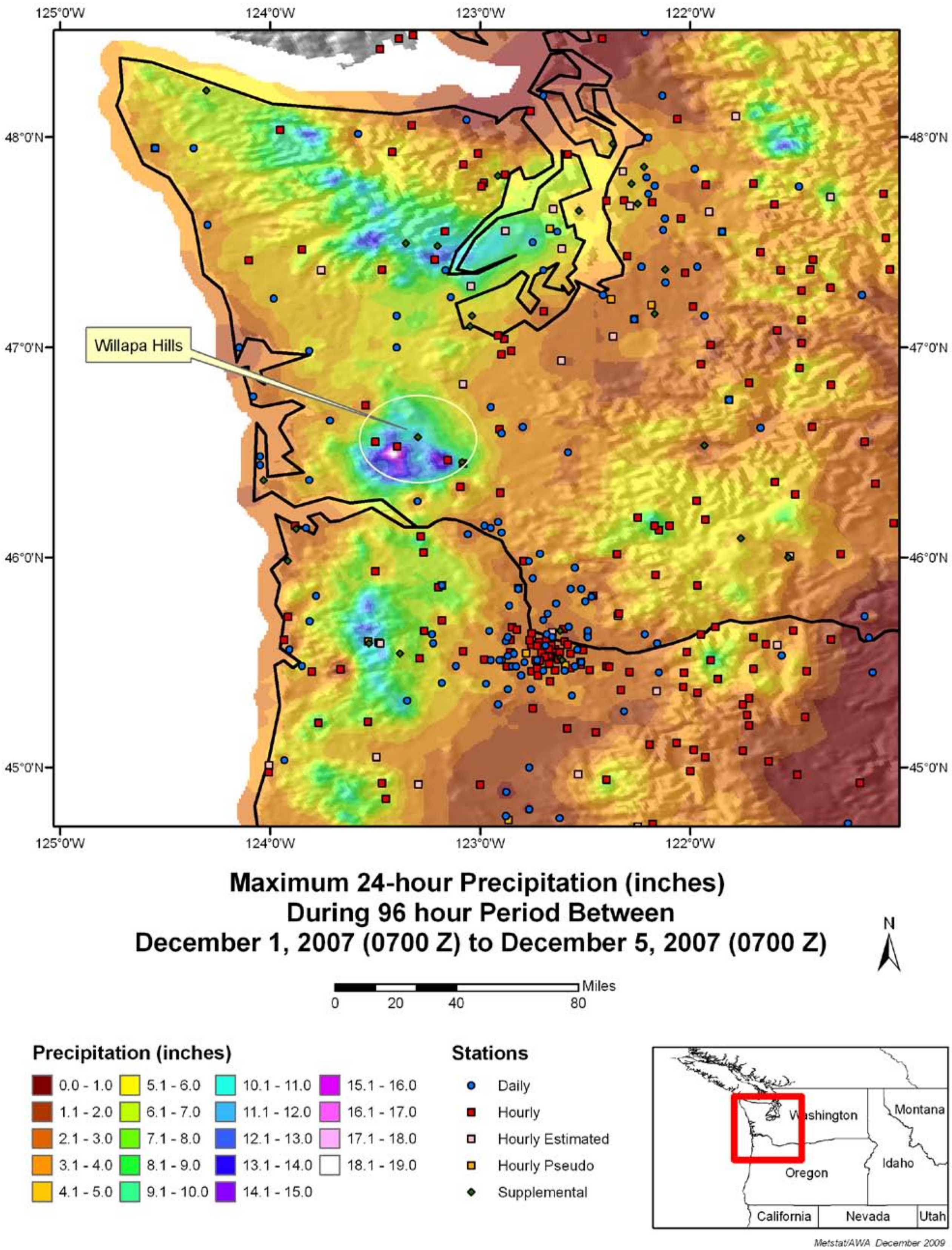


Figure 2. Maximum 24-hour precipitation.

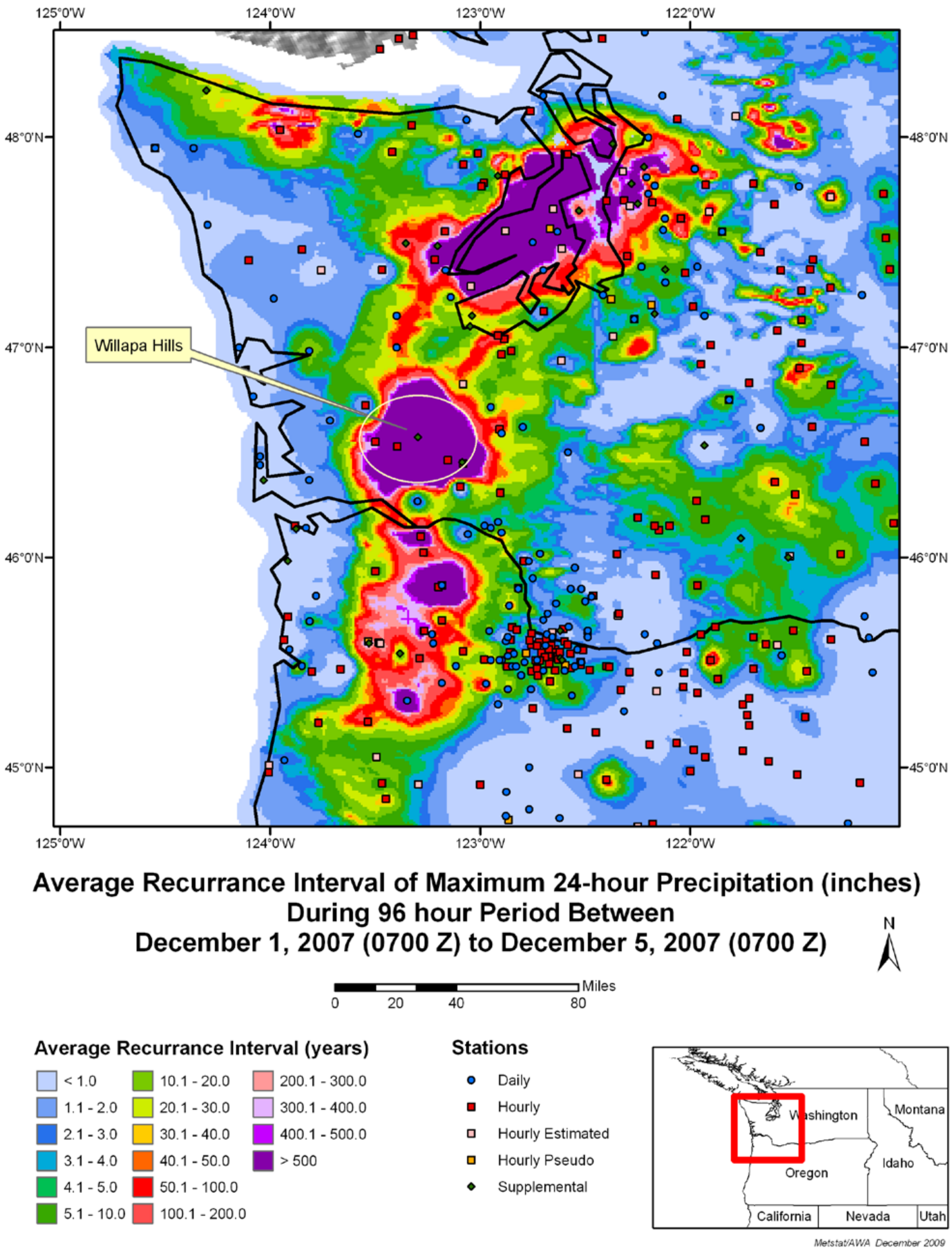


Figure 3. Average Recurrence Interval (ARI) of maximum 24-hour precipitation.

APPENDIX A. Station list

Type: D=daily, H=hourly, S=daily supplemental, HE = Hourly estimated, HP = Hourly Pseudo. See "METEOROLOGIC DATA" section for Source descriptions.

Stid	Name	Source	Type	Lat	Lon	Elev(ft)	OBSppt
450008	ABERDEEN WA	COOP	D	46.9833	-123.8167	10	7.56
451209	ABERNATHY WA	RAWS	H	46.3354	-123.0954	2526	2.63
USGS111	AIRPORT WAY 2OR	USGS	H	45.5595	-122.5124	24	3.78
USGS117	ALBINAOR	USGS	H	45.5366	-122.6745	63	4.18
350126	ALLEGANY OR	NCDC	H	43.4167	-124.0333	49	3.90
350145	ALSEA FISH HATCHERY OR	COOP	D	44.4000	-123.7500	230	7.80
450176	ANACORTES WA	COOP	D	48.5167	-122.6167	30	0.77
APSW1	APLINE MEADOWS WA	NCDC	H	47.7800	-121.7000	3500	9.49
USGS174	ARLETA SCHOOL PSEUDOOR	USGS	HP	45.4860	-122.5960	233	4.36
450257	ARLINGTON WA	COOP	D	48.2000	-122.1333	102	2.20
350304	ASHLAND 1 N OR	COOP	D	42.2167	-122.7167	1781	0.22
USGS193	ASTOR ELEMENTARYOR	USGS	H	45.5790	-122.7295	154	3.81
350328	ASTORIA WSO AP OR	NCDC	H	46.1500	-123.8833	10	3.93
ORMN4	AUMSVILLE 5.4 S OR	COCORAHS	D	44.8814	-122.8775	464	1.52
ARAO	AURORAOR	AGRIMET	H	45.2819	-122.7503	140	2.45
BKFO3	BALD KNOB LOOKOUT OR ESTIMATED	RAWS	HE	42.6936	-124.0394	3630	2.45
350471	BANDON 2 E OR	COOP	D	43.1167	-124.3667	249	2.90
450456	BARING ADJ 899 WA	COOP	D	47.7667	-121.4833	771	7.28
BATTL5	BATTLE GROUND LAKE WA	WXUNDER	D	45.8100	-122.4700	541	3.25
GARIB1	BAY VIEW PACIFIC COAST OR	WXUNDER	D	45.5600	-123.9100	50	3.08
USGS152	BEAUMONT sCHOOLOR	USGS	H	45.5490	-122.6216	250	3.67
BEAVE28	BEAVERTON OR	WXUNDER	D	45.4800	-122.8500	240	5.70
ORWS3	BEAVERTON 1.6 S OR	COCORAHS	D	44.7672	-122.8786	358	3.00
BEAVE25	BEAVERTON OR	WXUNDER	D	45.5000	-122.7900	200	6.73
450587	BELLINGHAM 3 SSW WA	COOP	D	48.7167	-122.5167	30	1.89
350699	BEND 7 NE OR	COOP	D	44.1167	-121.2167	3358	0.16
327000	BEND WATERSHED OR	RAWS	H	44.0300	-121.5683	5330	3.38
BEWO	BENDOR	AGRIMET	H	44.0475	-121.3203	3620	0.55
450321	BLACK KNOB WA	RAWS	H	47.4136	-124.1031	588	6.28
450729	BLAINE WA	NCDC	H	48.9833	-122.7500	39	4.00
BLAO3	BLAZED ALDEROR	SNOTEL	H	45.4200	-121.8700	3650	11.60
BOIS1	BOISTFORT WA	SEATTLETIMES	S	46.4527	-123.0867	640	12.53
350897	BONNEVILLE DAM OR	NCDC	H	45.6333	-121.9500	89	6.40
BOONE8	BONNEY LAKE MANOR WA	WXUNDER	S	47.1600	-122.1700	512	3.54
USGS058	BONNY SLOPE PSEUDOOR	USGS	HP	45.5444	-122.7831	623	4.44
351909	BOULDER CREEK OR	RAWS	H	44.9833	-122.0000	3570	4.63

BOFO3	BOULDER CREEK OR ESTIMATED	RAWS	HE	44.7022	-122.0031	3570	4.62
KPWT	BREMERTON AIRP WA	NWS	D	47.5000	-122.7500	440	13.18
450872	BREMERTON NAVY YARDWA	COOP	D	47.5500	-122.6333	10	10.57
351033	BRIGHTWOOD 1 WNW OR	NCDC	H	45.3833	-122.0333	981	4.80
351058	BROOKINGS OR	COOP	D	42.0667	-124.2794	410	3.56
351058	BROOKINGS PSEUDO ESTIMATEOR	NCDC	HE	42.0667	-124.2794	410	2.74
BROOKW1	BROOKLYN-WEYER WA	WEYER	H	46.7240	-123.5480	1020	5.04
BMPW1	BUMPING RIDGE WA	SNOTEL	H	46.8200	-121.3300	4600	9.20
351149	BUNCOM 2 SE OR	COOP	D	42.1500	-122.9667	1932	0.73
351149	BUNCOM 2 SE PSEUDO OR	NCDC	HP	42.1500	-122.9667	1932	0.60
450986	BURLINGTON 5 N WA	NCDC	H	48.5500	-122.3333	49	0.50
BUSW1	BURNT MOUNTAIN WA	SNOTEL	H	47.0112	-121.9030	4514	5.20
324A21	BUSH CREEK OR	RAWS	H	44.2844	-122.8494	2300	2.18
3510207	BUTTE FALLS 1 SE OR	NCDC	H	42.5333	-122.5500	2500	0.60
351222	BUXTON OR	NCDC	H	45.7000	-123.1833	371	5.70
CLFO3	CALIMUS ESTIMATED OR	RAWS	HE	42.6314	-121.5597	6629	0.15
ORCC3	CANBY 0.2 S OR	COCORAHS	D	44.4170	-123.0248	449	1.97
451921	CANYON CREEK WA	RAWS	H	45.9167	-122.1667	2500	6.15
351354	CANYONVILLE 2S OR	COOP	D	42.9419	-123.2800	700	1.89
451160	CARSON FISH HATCHERY WA	NCDC	H	45.8667	-121.9667	1132	11.90
USGS153	CASCADE CAMPUSOR	USGS	H	45.5627	-122.6742	206	4.21
351433	CASCADIA RS OR	NCDC	H	44.3833	-122.5000	801	2.90
4510207	CASTLE ROCK WA	RAWS	H	46.3075	-122.9047	213	6.20
451205	CATHLAMET 6 NE ADJ 586 WA	COOP	D	46.2667	-123.3000	180	5.43
351448	CAVE JUNCTION OR	COOP	D	42.1667	-123.6500	1332	2.67
350215	CEDAR OR	RAWS	H	45.2117	-123.7719	2240	12.61
NAPAV1	CEDAR RIDGE WA	WXUNDER	D	46.5900	-122.9000	444	6.64
451276	CENTRALIA WA	COOP	D	46.7167	-122.9500	190	5.84
AVANC12	CHARTER OAK WA	WXUNDER	D	45.8500	-122.5700	344	4.44
451103	CHEHALIS WA	RAWS	H	46.6100	-122.9083	262	8.68
CHEHA4	CHEHALIS WA	WXUNDER	D	46.6200	-122.8000	316	3.20
351546	CHEMULT 2 N OR	COOP	D	43.2500	-121.7833	4754	0.74
USGS192	CHILDRENS MUSEUMOR	USGS	H	45.5087	-122.7166	663	5.23
CLLO3	CLACKAMAS LAKEOR	SNOTEL	H	45.0800	-121.7500	3400	4.68
CLACK3	CLACKAMAS OR	WXUNDER	D	45.4800	-122.8300	349	3.95
351643	CLATSKANIE 3 W OR	NCDC	H	46.1000	-123.2833	79	10.30
352560	CLAY CREEK 1 OR ESTIMATED	RAWS	HE	43.8989	-123.5583	1128	5.96
CLKO3	CLEAR LAKEOR	SNOTEL	H	45.2000	-121.7200	3500	4.60
451484	CLEARBROOK WA	COOP	D	48.9667	-122.3333	59	2.61
451496	CLEARWATER WA	COOP	D	47.5833	-124.3000	80	4.71
351735	COLTON OR	NCDC	H	45.1667	-122.4500	620	2.70
USGS0107	COLUMBIA IPSOR	USGS	H	45.5971	-122.7199	34	4.14
451679	CONCRETE WA	COOP	D	48.5333	-121.7500	269	4.04
351836	COQUILLE KWRO OR	COOP	D	43.1833	-124.2000	69	1.82

ALOHA6	CORNELIUS PASS OR	WXUNDER	D	45.5100	-122.9000	205	5.89
COPW1	CORRAL PASS WA	SNOTEL	H	47.0200	-121.4700	6000	4.40
ORBN5	CORVALIS 2 NW OR	COCORAHS	D	44.5936	-123.3055	395	5.54
ORBN1	CORVALIS 2 SSW OR	COCORAHS	D	44.5390	-123.2930	362	3.75
351877	CORVALLIS WATER BUREAU OR	COOP	D	44.5000	-123.4500	512	8.67
CRVO	CORVALLISOR	AGRIMET	H	44.6342	-123.1900	230	3.50
351902	COTTAGE GROVE DAM OR	NCDC	H	43.7167	-123.0500	820	1.40
USGS146	COTTREL SCHOOLOR	USGS	H	45.4548	-122.2898	718	3.56
451759	COUGAR 4 SW WA	NCDC	H	46.0167	-122.3500	520	7.20
351914	COUGAR DAM OR	NCDC	H	44.1333	-122.2500	1260	1.70
450117	COUGAR MTN WA	RAWS	H	47.9230	-123.0119	3826	3.31
451783	COUPEVILLE 1 S WA	COOP	D	48.2000	-122.7000	49	1.40
COVIN6	COVINGTON WA	WXUNDER	S	47.3700	-122.1200	351	4.11
351946	CRATER LAKE NP HQ OR	COOP	D	42.9000	-122.1333	6475	2.56
CSHW1	CUSHMAN DAM WA	NWS	H	47.4167	-123.2167	760	14.20
CPHW1	CUSHMAN PWRHSE NO2 ADJ 1177 WA	COOP	D	47.3667	-123.1667	403	10.84
C0672	CW0672 Bonney Lake PSEUDO WA	APRSWXNET	HP	47.2006	-122.1844	636	4.68
C0870	CW0870 Victoria	APRSWXNET	H	48.4692	-123.3894	184	4.02
C1035	CW1035 Port Townsend WA	APRSWXNET	H	48.1250	-122.7619	233	1.02
C1043	CW1043 La Pine OR	APRSWXNET	H	43.6458	-121.5694	4203	0.40
C1855	CW1855 Liberal OR	APRSWXNET	H	45.1861	-122.5872	268	2.70
C1943	CW1943 Seattle WA ESTIMATED	APRSWXNET	HE	47.6739	-122.2883	230	6.04
C2512	CW2512 Bremerton PSEUDO WA	APRSWXNET	HP	47.5650	-122.6692	210	9.30
C2936	CW2936 Portland OR	APRSWXNET	H	45.5031	-122.5233	121	4.21
C3067	CW3067 Eugene OR	APRSWXNET	H	44.0678	-123.0594	427	1.40
C3132	CW3132 Sammamish WA	APRSWXNET	H	47.6136	-122.0458	355	5.20
C3453	CW3453 Beaverton OR	APRSWXNET	H	45.5453	-122.8528	253	5.31
C3683	CW3683 Seattle WA	APRSWXNET	H	47.6994	-122.3158	423	6.18
C3812	CW3812 Lake Oswego OR	APRSWXNET	H	45.4097	-122.6689	176	6.83
C4176	CW4176 AlohaOR	APRSWXNET	H	45.4806	-122.8728	210	4.66
C4577	CW4577 Kalama WA	APRSWXNET	H	45.9822	-122.7931	840	3.55
C4635	CW4635 Victoria	APRSWXNET	H	48.4200	-123.4789	171	2.71
C4887	CW4887 Trout Lake WA ESTIMATED	APRSWXNET	HE	46.0064	-121.5272	1929	6.23
C4896	CW4896 Walterville OR	APRSWXNET	H	44.0700	-122.8322	574	0.99
C5022	CW5022 Kirkland WA	APRSWXNET	H	47.6900	-122.1808	262	5.72
C5053	CW5053 Heisson WA	APRSWXNET	H	45.8181	-122.4639	751	3.60
C5088	CW5088 Bethany OR	APRSWXNET	H	45.5478	-122.8581	250	6.04
C5218	CW5218 Olympia WA	APRSWXNET	H	46.9817	-122.8533	205	4.90
C5404	CW5404 Dallas OR ESTIMATED	APRSWXNET	HE	44.9181	-123.2958	282	5.12
C5456	CW5456 Hansville WA	APRSWXNET	H	47.9200	-122.5850	49	4.96
C5474	CW5474 Grants Pass OR	APRSWXNET	H	42.4286	-123.3864	915	2.31
C5579	CW5579 O'Brien OR	APRSWXNET	H	42.0444	-123.7136	1550	4.15
C6318	CW6318 Welches OR	APRSWXNET	H	45.3558	-121.9678	1283	4.22

C6780	CW6780 Victoria	APRSWXNET	H	48.4856	-123.3206	213	2.20
C6829	CW6829 Yelm WA ESTIMATED	APRSWXNET	HE	46.9361	-122.6139	348	3.63
C6873	CW6873 Vancouver WA ESTIMATED	APRSWXNET	HE	45.6425	-122.6572	213	3.44
C6877	CW6877 Olympia WA	APRSWXNET	H	47.0378	-122.8861	164	7.73
C6930	CW6930 Portland OR	APRSWXNET	H	45.4589	-122.7561	236	5.48
C6975	CW6975 Rochester WA ESTIMATED	APRSWXNET	HE	46.8239	-123.0819	160	6.29
C6976	CW6976 Bend OR	APRSWXNET	H	44.0392	-121.1525	3550	0.12
C7027	CW7027 Olympia WA	APRSWXNET	H	47.0558	-122.9175	144	7.73
C7091	CW7091 Carnation WA ESTIMATED	APRSWXNET	HE	47.6444	-121.9106	75	4.38
C7211	CW7211 Duvall WA	APRSWXNET	H	47.7736	-121.9283	951	2.53
C7275	CW7275 Maple Valley WA	APRSWXNET	H	47.3539	-122.0242	587	4.16
C7286	CW7286 Tacoma PSEUDO WA	APRSWXNET	HP	47.2289	-122.3767	26	4.31
C7354	CW7354 Seattle WA	APRSWXNET	H	47.6967	-122.4006	148	6.41
C7357	CW7357 Anderson Isla WA	APRSWXNET	H	47.1719	-122.6981	259	3.71
C7518	CW7518 Snoqualmie PSEUDO WA	APRSWXNET	HP	47.5500	-121.8500	955	4.13
C8562	CW8562 Sandy OR ESTIMATED	APRSWXNET	HE	45.3636	-122.1614	1360	3.98
C8910	CW8910 Ferndale WA	APRSWXNET	H	48.7889	-122.7097	10	1.38
C9083	CW9083 Lynnwood WA ESTIMATED	APRSWXNET	HE	47.8372	-122.3222	453	5.65
C9111	CW9111 Elk Plain WA ESTIMATED	APRSWXNET	HE	47.0511	-122.3681	440	4.17
451968	DALLESPORT FAA AP WA	COOP	D	45.6167	-121.1500	236	1.11
DALO3	DALY LAKEOR	SNOTEL	H	44.6200	-122.0500	3600	3.80
DEFO	DEE FLATOR	AGRIMET	H	45.5864	-121.6406	1150	5.81
RAINI1	DELENA/ALSTONS CORNER OR	WXUNDER	D	46.1100	-123.0600	600	4.06
352292	DETROIT DAM PWR HOUSE OR ESTIMATED	NCDC	HE	44.7167	-122.2500	1299	6.90
DTRO	DETROIT LAKEOR	AGRIMET	H	44.7300	-122.1792	1675	7.44
352295	DEVILS FLAT OR	NCDC	H	42.8167	-123.0500	2030	2.40
452157	DIABLO DAM PSEUDO WA	NCDC	HP	48.7167	-121.1500	889	5.80
452157	DIABLO DAM WA	COOP	D	48.7167	-121.1500	889	6.66
352325	DILLEY 1 S OR	COOP	D	45.4833	-123.1167	171	4.79
352345	DISSTON 5 NE LAYING CK OR	NCDC	H	43.7000	-122.7333	1211	1.30
352374	DORENA DAM OR	COOP	D	43.7833	-122.9667	758	1.11
352408	DRAIN 10 NNW OR	NCDC	H	43.7833	-123.4333	751	4.70
352440	DUFUR OR	COOP	D	45.4500	-121.1333	1332	1.12
352559	DUNES OR	RAWS	H	43.9578	-124.1197	20	3.02
DGSW1	DUNGENESS WA	NCDC	H	47.8700	-123.0800	4100	7.80
350728	EAGLE CREEK OR	RAWS	H	45.3686	-122.3311	744	3.52
VANCO22	EAST VANCOUVER WA	WXUNDER	D	45.6400	-122.4900	285	4.48
452384	EASTON WA	COOP	D	47.2500	-121.1833	2172	2.84
SHERW9	EDY ROAD OR	WXUNDER	D	45.3700	-122.8700	200	5.91
352633	ELKTON 2 W OR	COOP	D	43.6500	-123.6000	131	4.73
452531	ELMA WA	COOP	D	47.0000	-123.4000	69	7.45
452548	ELWHA RS ADJ 619 WA	COOP	D	48.0167	-123.5833	361	5.30
352693	ESTACADA 2 SEOR	COOP	D	45.2667	-122.3167	410	2.74

352697	ESTACADA 24 SE INTAKEOR	NCDC	H	45.0833	-121.9833	2201	5.20
352709	EUGENE WSO APOR	NCDC	H	44.1167	-123.2167	367	2.23
452675	EVERETTWA	COOP	D	48.0000	-122.2000	120	3.92
352800	FALLS CITY OR	NCDC	H	44.8500	-123.4500	551	10.50
VANCO27	FELIDA WA	WXUNDER	D	45.7000	-122.7000	200	3.59
PORTL76	FELONY FLATS OR	WXUNDER	D	45.4600	-122.6000	238	6.91
USGS012	FERNWOOD SCHOOLOR	USGS	H	45.5370	-122.6320	159	4.08
837507	FINELY NWR OR	RAWS	H	44.4183	-123.3253	308	5.02
451721	FIRE TRAINING ACADEMY WA	RAWS	H	47.4536	-121.6658	1570	5.62
FISW1	FISH LAKE WA	SNOTEL	H	47.5200	-121.0700	3371	7.99
352972	FLORENCE 3 NWOR	NCDC	H	44.0167	-124.1167	59	4.40
ORLA1	FLORENCE 5.9 NNE OR	COCORAHS	D	44.0612	-124.0475	200	6.71
FPRO3	FLYNN PRAIRIE OR ESTIMATED	RAWS	HE	42.3956	-124.3786	1543	3.23
ORWS9	FOREST GROVE 9.8 NW OR	COCORAHS	D	45.6343	-123.2293	576	10.29
FOGO	FOREST GROVEOR	AGRIMET	H	45.5531	-123.0836	180	6.41
452914	FORKS 1 E WA	COOP	D	47.9500	-124.3667	351	7.40
452914	FORKS 1E WA	COOP	D	47.9500	-124.3667	351	7.40
353047	FOSTER DAM OR	NCDC	H	44.4167	-122.6667	550	2.40
FRAW1	FRANCES ADJ 1170 WA	NOAA	H	46.5500	-123.5000	231	11.27
USGS072	FREMONTOR	USGS	H	45.5424	-122.5715	189	4.02
353014	FT CLATSOP NATL MEM OR	NCDC	S	46.1358	-123.8783	42	4.35
353029	FT ROCK 4 NW OR	NCDC	S	43.3633	-121.1333	4300	0.22
ORYM1	GASTON 3.2 SW OR	COCORAHS	D	45.4000	-123.1830	740	8.69
GRBO3	GERBER RESERVOIR OR ESTIMATED	RAWS	HE	42.2058	-121.1381	4920	0.17
353305	GLENDALE 2 NEOR	NCDC	H	42.7667	-123.4000	1503	3.40
353318	GLENWOOD OR	NCDC	H	45.6500	-123.2667	479	11.60
453183	GLENWOOD WA	NCDC	H	46.0167	-121.2833	1903	5.70
352545	GOODWIN PEAK OR	RAWS	H	43.9281	-123.8903	1826	5.78
353402	GOVERNMENT CAMP OR	NCDC	H	45.3000	-121.7500	3983	4.50
353445	GRANTS PASS OR	COOP	D	42.4333	-123.3167	932	1.90
453320	GRAYLAND 2 S WA	COOP	D	46.7667	-124.0833	15	3.32
GRLW1	GREEN LAKE WA	SNOTEL	H	46.5500	-121.1700	6000	3.72
KALAM4	GREEN MNT RD WA	WXUNDER	D	45.9800	-122.7700	1350	5.08
353509	GREEN SPRINGS PWR PLT OR	COOP	D	42.1167	-122.5667	2441	1.44
GRPO3	GREENPOINTOR	SNOTEL	H	45.6200	-121.7000	3200	8.21
353521	GRESHAM 2 SE OR	NCDC	H	45.4833	-122.4000	449	4.40
USGS064	HARNEYOR	USGS	H	45.4622	-122.6433	58	4.53
353705	HASKINS DAM OR	COOP	D	45.3167	-123.3500	722	13.51
USGS007	HAYDEN ISLANDOR	USGS	H	45.6132	-122.6868	24	3.91
3520107	HAYSTACK OR	RAWS	H	44.4503	-121.1300	3240	0.01
353770	HEADWORKS PORTLAND WTR OR	COOP	D	45.4500	-122.1500	748	4.05
UUBR6	HEATHER HIGHLANDS WA	WXUNDER	D	47.3100	-122.1200	400	3.13
350920	HEHE 1 OR	RAWS	H	44.9661	-121.4908	2640	0.97

HILLS22	HELVETIA OR	WXUNDER	D	45.6000	-122.8800	355	3.57
352550	HIGH POINT OR	RAWS	H	43.9064	-123.3794	1935	5.00
LYLE4	HIGH PRARIE WA	WXUNDER	D	45.7200	-121.1700	2020	1.29
353915	HILLS CREEK DAM OR	NCDC	H	43.7500	-122.5000	1280	1.20
HILLS15	HILLSBORO OR	WXUNDER	D	45.5100	-122.9100	180	5.76
PORTL46	HILLSBORO OR	WXUNDER	D	45.6200	-122.8700	470	3.55
CLINT3	HILLTOP TERRACE WA	WXUNDER	S	47.9700	-122.3700	450	6.28
HOPO3	HOGG PASSOR	SNOTEL	H	44.4200	-121.8700	4760	6.50
USGS021	HOLGATEOR	USGS	H	45.4886	-122.5236	211	5.12
353971	HOLLEY OR	COOP	D	44.3500	-122.7833	541	3.10
BOTHE7	HOLLYHILLS WA	WXUNDER	D	47.7700	-122.1700	248	4.77
BELLE15	HORIZON CREST WA	WXUNDER	D	47.5600	-122.1300	920	5.22
350727	HORSE CREEK OR	RAWS	H	44.9406	-122.4003	2000	9.49
354060	HOWARD PRAIRIE DAM OR	COOP	D	42.2167	-122.3667	4573	0.10
HKSW1	HUCKLEBERRY CREEK WA	SNOTEL	H	47.0790	-121.5860	2083	3.00
453826	HUMPTULIPS SALMON HTCH WA	COOP	D	47.2333	-123.9833	140	6.30
HUFW1	HUMPTULLIPS ESTIMATED	RAWS	HE	47.3672	-123.7583	2400	7.36
450312	HUMPTULLIPS WA	RAWS	H	47.3680	-123.4680	2572	7.28
354126	IDLEYLD PARK 4 NE OR	COOP	D	43.3667	-122.9667	1080	0.75
450911	JEFFERSON CREEK WA	RAWS	H	47.5510	-123.1690	1950	14.89
SUP2	JEFFERSON RIDGE WA	NWS	S	47.4832	-123.2038	-9999	14.92
354276	JEWELL GRD STN OR	NCDC	H	45.9333	-123.5000	489	7.40
JOJO3	JUMP OFF JOEOR	SNOTEL	H	44.3800	-122.1700	3500	7.00
MRBW1	JUNE LAKE WA	SNOTEL	H	46.1300	-122.1500	3340	15.41
AS628	K9SCH Enumclaw WA	APRSWXNET	H	47.1944	-121.9872	741	3.85
AR754	KA8ZGM Corvallis OR	APRSWXNET	H	44.5969	-123.2539	250	6.64
454084	KALAMA FALLS HATCHERY WA	COOP	D	46.0167	-122.7167	312	6.83
SHELT8	KAMILCHE PT WA	WXUNDER	S	47.1500	-123.0400	180	6.89
AS504	KB7IVK Hillsboro OR	APRSWXNET	H	45.5142	-122.9817	164	5.18
AR969	KB7PGV Gresham OR	APRSWXNET	H	45.4786	-122.3867	449	5.19
AP685	KD7CTY Vancouver WA	APRSWXNET	H	45.6606	-122.6042	302	3.19
AS405	KD7MPG-2 Sheridan OR ESTIMATED	APRSWXNET	HE	45.0494	-123.4947	440	6.82
AP795	KD7TTL Lake Stevens WA	APRSWXNET	H	48.0872	-122.0628	492	3.11
USGS014	KELLY SCHOOLOR	USGS	H	45.4727	-122.5718	210	4.58
KKLS	KELSO AIRPORT WA	NWS	D	46.1167	-122.9000	20	5.35
454169	KENT WA	COOP	D	47.3833	-122.2333	30	3.43
PORTL73	KENTON NEIGHBORHOOD OR	WXUNDER	D	45.5800	-122.6900	104	4.58
354606	LACOMB 3 NNE OR	NCDC	H	44.6167	-122.7167	520	1.60
BELLE5	LAKE HILL WA	WXUNDER	D	47.6134	-122.1215	436	4.95
LONGV9	LAKE SACAJEWEA WA	WXUNDER	D	46.1400	-122.9500	21	4.33
454486	LANDSBURG WA	COOP	D	47.3833	-121.9667	541	4.26
TR951	LARCH MT ESTIMATED	RAWS	HE	45.7231	-122.3453	1150	7.09
4510301	LARCH MT WA	RAWS	H	45.7322	-122.3408	1150	7.32
PORTL22	LAURELHURST OR	WXUNDER	S	45.5200	-122.6200	171	3.73

352618	LAVA BUTTE OR	RAWS	H	43.9300	-121.3300	4655	0.23
354811	LEABURG 1 SW OR	COOP	D	44.1000	-122.6833	679	1.21
ORLN1	LEBANON 4.8 E OR	COCORAHS	D	44.5440	-122.8070	428	1.47
54824	LEES CAMP PSEUDO OR	NCDC	HP	45.6000	-123.5333	600	15.40
354835	LEMOLO LAKE OR	COOP	D	43.3333	-122.1667	4163	0.54
PORTL52	LENTS NEIGHBORHOOD OR	WXUNDER	D	45.4800	-122.5500	235	5.07
AR659	LINCON Lincoln City OR	APRSWXNET	H	44.9769	-124.0089	187	4.45
LMDO3	LITTLE MEADOWSOR	SNOTEL	H	44.6200	-122.2200	4000	11.01
350605	LOCKS OR	RAWS	H	45.6694	-121.8817	128	7.50
350604	LOG CREEK OR	RAWS	H	45.5100	-121.9031	2500	12.79
LPSW1	LONE PINE WA	SNOTEL	H	46.2700	-121.9700	3800	10.48
454748	LONG BEACH EXP STN WA	NCDC	S	46.3667	-124.0333	30	3.43
454764	LONGMIRE RAINIER NPS PSEUDO WA	NCDC	HP	46.7500	-121.8167	2762	5.70
454764	LONGMIRE RAINIER NPS WA	COOP	D	46.7500	-121.8167	2762	6.85
454769	LONGVIEW WA	COOP	D	46.1667	-122.9167	10	4.30
355026	LOOKINGGLASS 2 NE OR	COOP	D	43.1833	-123.5000	630	1.52
355050	LOOKOUT POINT DAM OR	COOP	D	43.9167	-122.7667	712	1.31
355050	LOOKOUT POINT DAM PSEUDO OR	NCDC	HP	43.9167	-122.7667	712	1.10
355055	LOST CREEK DAM OR	NCDC	H	42.6667	-122.6833	1552	0.90
LOHW1	LOST HORSE WA	SNOTEL	H	46.3500	-121.1200	5000	5.22
ORLN12	LYONS 1.6 SSW OR	COCORAHS	D	44.7571	-122.6245	1670	2.36
MRSO	MADRASOR	AGRIMET	H	44.6800	-121.1486	2440	0.36
USGS115	MALLORYOR	USGS	H	45.5813	-122.6633	48	4.45
355206	MAPLETON 2 NNW OR	NCDC	H	44.0667	-123.8833	39	6.40
USGS172	MAPLEWOOD SCHOOLOR	USGS	H	45.4714	-122.7298	392	4.12
454999	MARBLEMOUNT RS WA	NCDC	H	48.5333	-121.4500	331	4.40
3550213	MARCOLA OR	NCDC	H	44.1667	-122.8500	531	1.10
USGS137	MARINE DROR	USGS	H	45.6367	-122.7568	23	3.81
355221	MARION FORKS HATCHERY OR	COOP	D	44.6167	-121.9500	2451	5.83
355221	MARION FORKS HATCHERY PSEUDO OR	NCDC	HP	44.6167	-121.9500	2451	5.70
MRFO3	MARION FORKSOR	SNOTEL	H	44.5800	-121.9700	2600	5.80
455086	MATLOCK 8 S WA	COOP	D	47.1500	-123.4000	110	7.98
455110	MAYFIELD PWR PLT WA	COOP	D	46.5000	-122.5833	279	4.68
355362	MC KENZIE BRG RS OR	COOP	D	44.1667	-122.1667	1381	2.70
455224	MC MILLIN RSVR WA	COOP	D	47.1333	-122.2667	581	3.51
455224	MC MILLIN RSVR WA ESTIMATED	NCDC	HE	47.1333	-122.2667	581	3.90
MPSW1	MEADOWS PASS WA	SNOTEL	H	47.2700	-121.4700	3500	7.29
355429	MEDFORD WB APOR	NCDC	H	42.3667	-122.8667	1329	0.46
TIGAR6	MERESTONE POND OR	WXUNDER	D	45.4374	-122.8062	173	4.41
455305	MERWIN DAM WA	COOP	D	45.9500	-122.5500	224	5.50
352110	METOLUIS ARM OR	RAWS	H	44.6275	-121.6147	3440	3.53
USGS173	METRO LEARNING CENTEROR	USGS	H	45.5263	-122.6932	113	4.66

350812	MIDDLE MNT OR ESTIMATED	RAWS	HE	45.5833	-121.5856	2600	6.43
BOTHE10	MILL CREEK WA	WXUNDER	S	47.8600	-122.2200	350	6.86
350308	MILLER OR	RAWS	H	46.0228	-123.2711	1090	8.99
455525	MONROE WA	COOP	D	47.8500	-121.9800	180	5.45
MRSW1	MORSE LAKE WA	SNOTEL	H	46.9000	-121.4800	5400	11.70
BAK42	Mount Baker ESTIMATED	MESOWEST	HE	48.8650	-121.6781	4219	10.46
PORTL31	MOUNTAIN PARK OR	WXUNDER	D	45.4600	-122.7000	540	4.83
MHSW1	MOWICH WA	SNOTEL	H	46.9200	-121.9500	3150	5.98
455659	MT ADAMS RS WA	NCDC	S	46.0000	-121.5333	1962	6.32
MTCW1	MT CRAG WA	NCDC	H	47.7656	-122.9957	4314	8.40
MGSW1	MT GARDNER WA	SNOTEL	H	47.3679	-121.5695	4413	8.21
MTHO3	MT HOOD TEST SITEOR	SNOTEL	H	45.3300	-121.7200	5400	5.60
PORTL71	MT TABOR OR	WXUNDER	S	45.5100	-122.6100	285	4.68
350916	MT WILSON OR	RAWS	H	45.0300	-121.6278	3780	1.62
455704	MUD MTN DAM WA	COOP	D	47.1500	-121.9333	1312	3.58
MUD03	MUD RIDGEOR	SNOTEL	H	45.2500	-121.7300	3800	6.00
350917	MUTTON MOUNTAIN OR	RAWS	H	44.9258	-121.1917	4100	0.83
RIDGE2	MYSTIQUE WA	WXUNDER	D	45.7800	-122.6400	289	4.22
AP035	N7GME Seattle WA ESTIMATED	APRSWXNET	HE	47.4694	-122.6122	456	7.58
AS558	N7NVP Silverdale WA ESTIMATED	APRSWXNET	HE	47.6572	-122.6544	171	6.40
AP036	N7YT Bremerton WA ESTIMATED	APRSWXNET	HE	47.5533	-122.8814	591	11.10
455774	NASELLEWA	COOP	D	46.3667	-123.8167	30	7.10
GALES3	NEAR HWY 6-8 JUNCTION	WXUNDER	D	45.5909	-123.2250	338	9.28
STHEL2	NEAR MCCORMICK PARK OR	WXUNDER	D	45.8500	-122.8200	79	5.41
355969	NEHALEM OR	NCDC	H	45.7167	-123.9167	79	3.70
ORTL1	NEHALEM 4.1 ESE OR	COCORAHS	D	45.6950	-123.8140	69	8.73
355971	NEHALEM 9 NE OR	COOP	D	45.8167	-123.7833	141	5.88
1429980	NEHALEM NR VERNONIA	USGS	H	45.8600	-123.2000	-999	11.35
ORWS4	NEWBERG 6.2 N OR	COCORAHS	D	45.3962	-122.9728	174	8.77
455840	NEWHALEM WA	COOP	D	48.6833	-121.2500	531	6.26
ORLC1	NEWPORT 5.1 N OR	COCORAHS	D	44.6898	-124.0655	20	3.82
356032	NEWPORTOR	COOP	D	44.6333	-124.0667	157	3.61
356073	NORTH BEND FAA AP OR	COOP	D	43.4167	-124.2500	30	2.57
NFRO3	NORTH FORKOR	SNOTEL	H	45.5500	-122.0167	3120	9.10
ORWS2	NORTH PLAINS 4.1 NNE OR	COCORAHS	D	45.6480	-122.9580	883	6.41
BOTHE6	NORWAY VISTA WA	WXUNDER	D	47.7300	-122.2000	213	5.78
356213	OAKRIDGE RS OR	COOP	D	43.7500	-122.4333	1312	1.12
OCEAN17	OCEAN SHORES WA	WXUNDER	D	47.0000	-124.1500	26	2.07
OMWW1	OLALLIE MEADOWS WA	SNOTEL	H	47.3700	-121.4300	3700	10.19
456096	OLGA 2 SE WA	COOP	D	48.6167	-122.8000	79	2.03
SUP6	OLSONS RESORT WA	NWS	S	48.2242	-124.3055	-9999	10.10
456114	OLYMPIA WSO AP WA	NCDC	H	46.9667	-122.9000	217	6.07
ORCC2	OREGON CITY 1.0 NNW OR	COCORAHS	D	45.3411	-122.5631	390	4.97
451919	ORR CREEK WA	RAWS	H	46.3583	-121.5967	2550	6.51

356366	OTIS OR	COOP	D	45.0333	-123.9333	151	5.94
OLYMP11	OYSTER BAY WA	WXUNDER	S	47.1000	-123.0500	70	6.89
456262	PACKWOOD WA	COOP	D	46.6167	-121.6667	1060	3.32
AFSW1	PARADISE WA	SNOTEL	H	46.8300	-121.7200	5120	7.98
356466	PARKDALE 2 NEOR	COOP	D	45.5333	-121.5667	1519	4.35
PEELL1	PE ELL	CITIZEN	S	46.5725	-123.2977	461	15.18
PVRO3	PEAVINE RIDGEOR	SNOTEL	H	45.0500	-121.9300	3500	6.59
352554	PEBBLE OR	RAWS	H	44.2333	-121.9833	3560	3.85
356532	PELTON DAM OR	COOP	D	44.7333	-121.2500	1410	0.45
PGPW1	PIGTAIL PEAK WA	SNOTEL	H	46.6200	-121.4200	5900	5.40
PNGO	PINE GROVEOR	AGRIMET	H	45.6522	-121.5092	620	4.90
USGS0145	PLEASANT VALLEYOR	USGS	H	45.4645	-122.4792	352	4.86
350912	POLLYWOG OR	RAWS	H	45.4586	-121.4464	3320	3.62
356784	PORT ORFORD 2 OR	COOP	D	42.7500	-124.5000	49	3.90
356795	PORT ORFORD 5 E OR	COOP	D	42.7333	-124.4000	151	5.66
USGS001	PORTLAND FIREOR	USGS	H	45.5216	-122.6710	27	4.15
356750	PORTLAND NWSFO OR	COOP	D	45.5611	-122.5381	21	4.12
PORTL27	PORTLAND OR	WXUNDER	D	45.5000	-122.5200	262	4.14
356751	PORTLAND WB AP OR	NCDC	H	45.6000	-122.6000	39	3.42
USGS159	POST OFFICEOR	USGS	H	45.5851	-122.5844	19	3.51
PTHW1	POTATO HILL WA	SNOTEL	H	46.3000	-121.5000	4500	10.50
356822	POWERS TELEMETERING OR	NCDC	H	42.9000	-124.0667	220	5.70
QPFO3	QUAIL PRAIRIE LOOKOU OR ESTIMATED	RAWS	HE	42.2422	-124.0453	3183	7.46
456846	QUILCENE 2 SW	COOP	S	47.8167	-122.9167	515	6.99
456851	QUILCENE 5 SW DAM WA	NCDC	H	47.7833	-122.9833	1030	7.90
4500207	QUILCENE WA	RAWS	H	47.8231	-122.8831	60	6.90
456858	QUILLAYUTE WSO AP WA	COOP	D	47.9500	-124.5500	180	6.48
456858	QUILLAYUTE WSO AP PSEUDO WA	NCDC	HP	47.9500	-124.5500	180	3.80
456864	QUINAULT RS WA	NCDC	H	47.4667	-123.8500	220	9.50
VANCO39	RABBIT HOLE WA	WXUNDER	S	45.6500	-122.6200	252	3.73
RACOW1	RACOON CREEK WA	WEYER	H	46.4622	-123.1558	1086	15.81
456909	RANDLE 1 E	COOP	S	46.5333	-121.9333	872	3.02
456914	RAYMOND 2 S WA	COOP	D	46.6500	-123.7167	30	6.04
REDO3	RED HILLOR	SNOTEL	H	45.4700	-121.7000	4400	8.58
357062	REDMOND FAA AP OR	NCDC	H	44.2667	-121.1500	3084	0.01
357127	REX 1 SOR	COOP	D	45.3000	-122.9167	489	3.51
357171	RIDDLE 4 SW OR	NCDC	H	42.9167	-123.4333	723	2.20
357169	RIDDLE OR	COOP	D	42.9667	-123.3500	659	1.63
ROCKW1	ROCK CREEK ADJ 1964 WA	WEYER	H	46.5281	-123.3964	1424	19.16
HILLS6	ROCK CREEK AREA WA	WXUNDER	D	45.8500	-122.5200	530	3.44
351710	ROCKHOUSE 1 OR	RAWS	H	44.9250	-123.4694	2000	9.74
AS469	ROCKWY Rockaway Beac OR	APRSWXNET	H	45.6069	-123.9350	450	3.47
357331	ROSEBURG KQENOR	COOP	D	43.2000	-123.3500	469	0.83

457185	ROSS DAM WA	COOP	D	48.7333	-121.0667	1236	6.15
357391	RUCH OR	COOP	D	42.2333	-123.0333	1552	0.40
350505	RYE MOUNTAIN OR	RAWS	H	45.2172	-123.5356	2000	9.95
SUP5	SADDLE MOUNTAIN OR	NWS	S	45.5427	-123.3823	-9999	9.90
357500	SALEM WSO AP OR	NCDC	H	44.9167	-123.0000	210	2.69
VANCO42	SALMON CREEK WA	WXUNDER	D	45.7300	-122.6800	200	4.13
SAJO3	SANTIAM JUNCTIONOR	SNOTEL	H	44.4300	-121.9300	3750	6.87
SASW1	SASSE RIDGE WA	SNOTEL	H	47.3700	-121.0500	4200	8.00
USGS003	SAUVIE ISLANDOR	USGS	H	45.6553	-122.8265	33	4.37
357572	SAUVIES ISLAND OR	NCDC	H	45.6667	-122.8500	40	5.50
KSPB	SCAPPOOSE AIRP OR	NWS	D	45.7690	-122.8620	52	6.07
357631	SCOTTS MILLS 9 SE OR ESTIMATED	NCDC	HE	44.9667	-122.5333	2221	6.30
BATTLE11	SE OF BATTLE GROUND LAKE WA	WXUNDER	D	45.7900	-122.5000	550	4.77
357641	SEASIDE OR	NCDC	S	45.9833	-123.9167	10	2.82
457470	SEATTLE SAND PT WSFO WA	COOP	S	47.6833	-122.2500	60	6.25
457473	SEATTLE TACOMA AP WBAS WA	NCDC	H	47.4333	-122.3000	384	5.66
457507	SEDRO WOOLLEY 1 E WA	COOP	D	48.5000	-122.2167	59	0.86
23D02S	SEINE CREEKOR	SNOTEL	H	45.5200	-123.2900	2060	12.10
457544	SEQUIM 2 E WA	COOP	D	48.0833	-123.0667	50	1.46
SFCHEH	SF CHEHALIS NEAR WILDWOOD	USGS	H	46.4450	-123.0825	220	12.53
22C10S	SHEEP CANYON WA	SNOTEL	H	46.1900	-122.2500	4030	13.21
457585	SHELTON AP WA	COOP	D	47.2381	-123.1408	271	9.17
357817	SILVER LAKE RS OR	COOP	D	43.1333	-121.0667	4382	0.09
357817	SILVER LAKE RS PSEUDO OR	NCDC	HP	43.1333	-121.0667	4382	0.10
357823	SILVERTON OR	COOP	D	45.0000	-122.7667	408	3.00
357857	SISTERSOR	COOP	D	44.2833	-121.5333	3182	1.39
KBVS	SKAGIT BURLINGTO MTR WA	NWS_FAA	H	48.4700	-122.4200	144	0.03
457696	SKAMANIA FISH HATCHERY WA	COOP	D	45.6333	-122.2167	440	3.97
KSUW1	SKOOKUM CREEK WA	NCDC	H	47.6800	-121.6000	3920	7.69
457709	SKYKOMISH 1 ENE WA ESTIMATED	NCDC	HE	47.7167	-121.3333	1030	14.00
USGS002	SKYLINE SCHOOLOR	USGS	H	45.6075	-122.8569	717	3.58
BEAVE31	SKYVIEW OR	WXUNDER	D	45.5400	-122.8400	270	6.12
457773	SNOQUALMIE FALLS WA	COOP	D	47.5500	-121.8500	430	5.39
457781	SNOQUALMIE PASS WA	NCDC	H	47.4167	-121.4167	3022	9.20
357940	SOUTH DEER CREEK OR	COOP	D	43.1667	-123.2167	702	1.10
SFBO3	SOUTH FORK BULL RUNOR	SNOTEL	H	45.4500	-122.0300	2630	6.90
SFKO3	SOUTH FORK ESTIMATED	RAWS	HE	45.5953	-123.4836	2257	13.98
350216	SOUTH FORK OR ESTIMATED	RAWS	HE	45.5906	-123.4761	2240	14.15
BRIER3	SOUTHWEST BRIER WA	WXUNDER	S	47.7800	-122.2800	320	6.55
SPMW1	SPENCER MEADOW WA	SNOTEL	H	46.1800	-121.9300	3400	12.30
22C12S	SPIRIT LAKE WA	SNOTEL	H	46.1500	-122.1000	3120	12.19
SUP1	STAIRCASE WA	NWS	S	47.4949	-123.3551	-9999	15.33
458009	STAMPEDE PASS WB WA	NCDC	H	47.2833	-121.3333	3958	6.37

351911	STAYTON PSEUDOOR	RAWS	HP	44.7500	-122.8667	507	1.74
358095	STAYTONOR	COOP	D	44.8000	-122.7667	469	1.82
358102	STEAMBOAT RS OR	NCDC	H	43.3500	-122.7333	1240	0.50
SVNW1	STEVENS PASS WA	NCDC	H	47.7300	-121.0800	4070	9.19
358182	SUMMIT OR ESTIMATED	NCDC	HE	44.6333	-123.5833	722	7.50
USGS171	SUNNYSIDE SCHOOLOR	USGS	H	45.5150	-122.6289	153	4.14
358246	SUNRIVER OR	COOP	D	43.8933	-121.4117	4180	0.36
SPLW1	SURPRISE LAKES WA	SNOTEL	S	46.0900	-121.7600	4250	9.11
358263	SUTHERLIN CAMP WEYERHA OR	NCDC	H	43.4667	-123.0500	1070	1.20
SWCW1	SWIFT CREEK WA	SNOTEL	H	46.1500	-122.1700	3770	15.41
PORTL19	SYLVAN AND HWY 26 OR	WXUNDER	D	45.5100	-122.7300	790	4.06
USGS161	SYLVAN SCHOOLOR	USGS	H	45.5106	-122.7373	824	4.62
USGS004	SYLVANIA PCCOR	USGS	H	45.4375	-122.7269	748	5.17
458278	TACOMA 1 WA	COOP	D	47.2500	-122.4167	25	4.44
452317	TEPEE CREEK WA	RAWS	H	46.1631	-121.0322	2980	3.29
352622	TEPEE DRAW OR	RAWS	H	43.8353	-121.0833	4740	0.23
USGS167	TERMINAL 4 NEOR	USGS	H	45.6061	-122.7661	66	3.94
USGS120	THOMASOR	USGS	H	45.4939	-122.6728	47	4.87
BOTHE11	THRASHERS CORNER WA	WXUNDER	D	47.8100	-122.2100	168	4.17
TCMO3	THREE CREEKS MEADOWOR	SNOTEL	H	44.1500	-121.6300	5650	5.20
358466	THREE LYNX OR	NCDC	H	45.1167	-122.0667	1122	5.30
LONGB1	TIDES WEST WA	WXUNDER	D	46.4400	-124.0500	32	5.07
358494	TILLAMOOK OR	COOP	D	45.4833	-123.8500	39	7.26
358504	TILLAMOOK 9 EOR	NCDC	H	45.4667	-123.6667	249	2.40
350208	TILLAMOOK OR	RAWS	H	45.4569	-123.8031	22	3.84
LEESC1	TILLAMOOK STATE FOREST OR	WXUNDER	S	45.5900	-123.5300	700	17.54
358512	TILLER 15 ENEOR	NCDC	H	43.0000	-122.7000	2500	0.40
TKSW1	TINKHAM CREEK WA	SNOTEL	H	47.1300	-121.4700	3070	8.31
358536	TOKETEE FALLSOR	COOP	D	43.2833	-122.4500	2060	0.83
450121	TOMS CREEK WA	RAWS	H	48.0348	-123.9535	1175	14.18
352552	TROUT CREEK OR	RAWS	H	44.1111	-122.5750	2400	1.69
TUALA2	TUALATIN OR	WXUNDER	D	45.3700	-122.7600	241	4.59
352621	TUMALO RIDGE OR	RAWS	H	44.0494	-121.4003	4000	1.61
458715	UPPER BAKER DAM WA	COOP	D	48.6500	-121.6833	689	4.96
358788	UPPER OLALLA OR	COOP	D	43.0333	-123.5500	760	1.69
358790	UPPER STEAMBOAT CREEKOR	NCDC	H	43.4833	-122.6000	1855	1.30
458773	VANCOUVER WA	COOP	D	45.6333	-122.6833	102	4.87
KVUO	VANCOUVER AIRP WA	NWS	D	45.6202	-122.6564	26	3.79
VANCO16	VANCOUVER WA	WXUNDER	D	45.6700	-122.5800	230	3.10
VANCO24	VANCOUVER WA	WXUNDER	D	45.6200	-122.4900	280	3.36
VANCO47	VANCOUVER WA	WXUNDER	D	45.6500	-122.4900	260	3.74
458838	VERLOT WA ESTIMATED	NCDC	HE	48.1000	-121.7833	981	5.70
USGS041	VERNON SCHOOLOR	USGS	H	45.5621	-122.6438	212	3.46
358884	VERNONIA 2 OR	NCDC	D	45.8667	-123.1833	630	12.84

358884	VERNONIA 2 PSEUDO OR	NCDC	HP	45.8667	-123.1833	630	8.20
352547	VILLAGE CREEK OR ESTIMATED	RAWS	HE	44.2525	-123.4639	1500	7.77
AP682	W7KKE-3 Road's End ESTIMATED OR	APRSWXNET	HE	45.0108	-124.0061	89	5.18
AS234	WA7EBH-15 Port Angel WA	APRSWXNET	H	48.0567	-123.3264	807	3.54
350913	WAMIC MILL OR	RAWS	H	45.2406	-121.4531	3320	2.35
350726	WANDERERS PEAKOR	RAWS	H	45.1094	-122.1953	4350	4.31
350919	WASCO BUTTE OR	RAWS	H	45.6100	-121.3300	2345	2.03
WHSW1	WATERHOLE WA	NCDC	H	47.9300	-123.4200	5000	12.10
359083	WATERLOO OR	NCDC	S	44.5000	-122.8167	410	2.11
459021	WAUNA 3 SW MINTER CK WA	COOP	D	47.3667	-122.7000	20	7.09
AP886	WB7OXJ Shelton WA ESTIMATED	APRSWXNET	HE	47.2908	-123.0453	271	12.66
LONGV5	WEST LONGVIEW WA	WXUNDER	D	46.1500	-122.9800	23	5.37
WASH08	WESTERN COLUMBIA RIVER GORGE WA	WXUNDER	D	45.5900	-122.1600	250	4.06
AS192	WH6KO St Helens OR	APRSWXNET	H	45.8544	-122.8189	79	5.46
359316	WICKIUP DAM OR	COOP	D	43.6833	-121.7000	4334	0.58
359390	WILLIAMS OR	COOP	D	42.2333	-123.2667	1352	1.13
359390	WILLIAMS PSEUDO OR	NCDC	HP	42.2333	-123.2667	1352	1.10
HILL25	WITCH HAZEL OR	WXUNDER	D	45.5100	-122.9500	166	7.72
WOODL2	WOODLAND WA	WXUNDER	D	45.9000	-122.7500	35	4.97
BAINB4	WOODWARD ELEM SCHOOL WA	WXUNDER	S	47.6500	-122.5300	180	6.34
USGS160	WPCLOR	USGS	H	45.5849	-122.7585	33	4.40
359588	YACHATSOR	COOP	D	44.3192	-124.1131	61	5.30
352024	YELLOWSTONE MT OR	RAWS	H	44.5922	-122.4278	3080	6.85
USGS121	YEONOR	USGS	H	45.5464	-122.7103	36	4.90
ASTOR18	YOUNG RIVER OR	WXUNDER	D	46.1400	-123.8300	23	4.53
HILLS14	185TH AND WALKER OR	WXUNDER	D	45.5300	-122.8700	61	5.12
OCEAN2	1MI S OCEAN PARK WA	WXUNDER	D	46.4800	-124.0500	1	5.35