Floodplain

The purpose of the Floodplain Study was to determine the precise location of the Vasa Creek floodplain. Updating floodplain maps is important because it provides property owners, lenders, and insurance companies information on flood risk.

The following information applies only to residents who live in the following areas whose properties are located within a regulated floodplain:

- Lower Vasa Creek – Downstream of 163rd Avenue SE to Lake Sammamish, see Attachment A.
- Upper Vasa Creek – 1000 feet upstream of SE 37th Street to the outlet culvert downstream of 152nd Avenue SE (Eastgate Elementary School) and along the East Branch of Vasa Creek from its confluence with the main stem to SE Newport Way. See Attachment B.

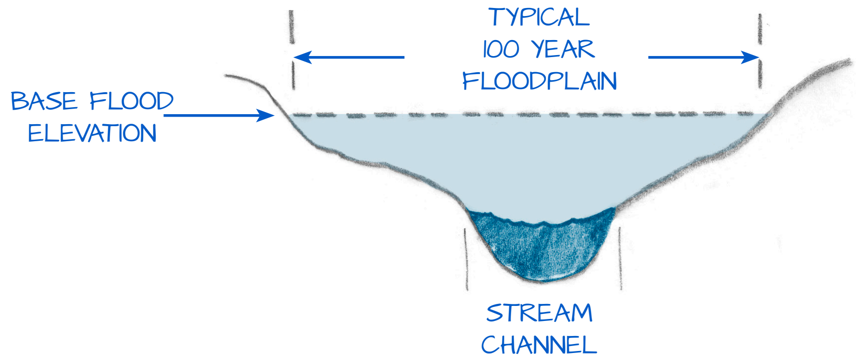
The existing floodplain is based on 1978 FEMA-developed Flood Insurance Maps that only approximated the floodplain. These floodplain maps depict some parts of the floodplain extending to areas far beyond the stream banks where it is actually contained. Attachments A and B show the areas proposed to be added and/or removed from the existing floodplain maps. The areas being added are all contained within the current stream channel.

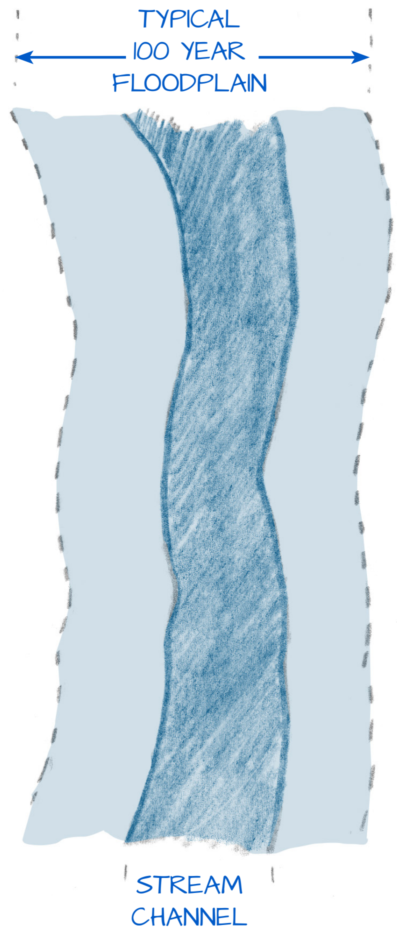
Key Findings

- The hydraulic analysis confirmed that no buildings are located in the floodplain in either upper or lower Vasa Creek.
- The floodplain in both lower and upper Vasa Creek is contained within the stream banks.
- The engineering analysis showed that a high flow bypass pipe diverts approximately 90% of the flows from the 100-year flood from upper Vasa Creek directly to Lake Sammamish. The high flow bypass restricts the flows to lower Vasa Creek to protect the downstream properties. (A high flow bypass is a pipe line that diverts water when it reaches a certain level, like the overflow drain on your bathtub.)
- In upper Vasa Creek the flows are contained within the existing stream banks.

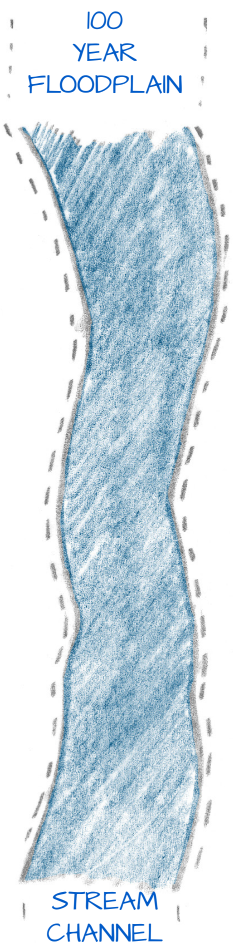
The results of the analysis show the updated 100-year floodplain of lower Vasa Creek (Attachment A) and upper Vasa Creek (Attachment B). Within the 100-year floodplain, also known as the base flood elevation, there is a 1-in-100 chance that a flood that size might happen during any year. This concept is illustrated on the next page.

Floodplain

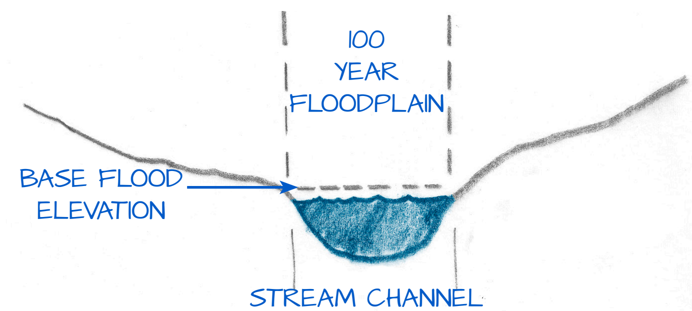




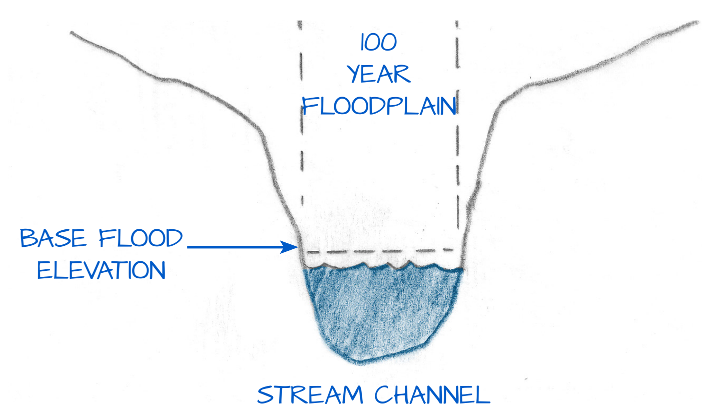
VASA CREEK FLOODPLAIN



Lower Vasa Creek Floodplain



Upper Vasa Creek Floodplain



Floodplain

What will Bellevue Utilities do with this information?

- The city has asked the Federal Emergency Management Agency (FEMA) to remove the current floodplain designation for Vasa Creek as the 100-year flows remain within the stream channel banks. If FEMA removes the current floodplain designation, property owners would not be required to purchase flood insurance if they have a mortgage from a federally regulated, supervised, or insured financial institution. However, if property owners want to purchase flood insurance it would be at the same low rate due to our overall community rating with FEMA.
- If FEMA removes the current floodplain designation, the city will use the updated floodplain map to administer Bellevue's floodplain regulations. Accurate mapping of the floodplain is important because Bellevue's floodplain regulations prevent construction in floodplains.
- If FEMA does not remove the floodplain designation, the city will pursue a formal letter of Map Revision (LOMR) from FEMA, to accurately portray the floodplain area within the stream banks.

For Additional Information

Website with hydrologic technical memo http://bellevuewa.gov/pdf/Utilities/Vasa_Creek_Hydrologic_Modeling_and_Analysis.pdf

Website with hydraulic technical memo http://bellevuewa.gov/pdf/Utilities/Vasa_Creek_Hydraulic_Modeling_and_Mapping.pdf

Critical areas link Critical Areas (http://bellevuewa.gov/critical-areas.htm)

Questions? Rick Watson 425-452-4896

Memorandum

To: Rick Watson, City of Bellevue

From: Larry Karpack and Erika Ottenbreit, Watershed Science & Engineering

Date: September 18, 2014

Re: Vasa Creek Hydrologic Modeling and Analysis

1.0 INTRODUCTION

Watershed Science & Engineering (WSE) was retained by the City of Bellevue (City) to construct and calibrate a hydrologic model of the Vasa Creek watershed and apply the model to generate flows for use in updating floodplain mapping for portions of Vasa Creek. The Vasa Creek basin is approximately 1,235 acres in size, with headwaters in the Somerset neighborhood of Bellevue. The creek drains generally north northeast until crossing under Interstate 90 and then generally east to its terminus at Lake Sammamish. The creek is generally small (less than 10 feet wide at normal flows) and steep (greater than 4% slope) over most of its length although there are some flatter reaches upstream of road crossings or near the mouth at Lake Sammamish. Land use in the basin consists primarily of residential and commercial development and transportation corridors.

2.0 HYDROLOGIC MODELING AND ANALYSIS

WSE developed and applied a Hydrologic Simulation Program – Fortran (HSPF) model of existing conditions in the Vasa Creek basin. The model development and application included the following steps:

1. Delineating subbasin boundaries upstream of key hydraulic controls (significant road crossings, detention ponds, flow splits) and at each of the newly installed streamflow gages.
2. Developing land-use data for the basin.
3. Obtaining soils data for the basin and importing the data to GIS
4. Generating existing condition SCHEMATIC blocks for HSPF from the subbasin, soils, and land-use information.
5. Creating HSPF FTABLEs for each subbasin in the model based on data obtained from the City and WSDOT, supplemented with field investigations and engineering judgment.
6. Reformatting local precipitation data from the City for use in calibration of the model and for determining an appropriate multiplier for transposition of long term precipitation records.
7. Calibrating the HSPF model using all available streamflow data.
8. Running HSPF model to produce hydrologic analysis. Perform flow frequency analysis to characterize baseline conditions for use in HEC-RAS hydraulic modeling.
9. Running the final HSPF model with the 158-year extended precipitation record developed by MGS Engineers for WSDOT (MGS, 2002) and comparing the results to the long term run

2.1 Hydrologic Input Data

The City provided WSE with topographic data, soils data, parcel data, orthophotos, and hydrometric data for use in the development and calibration of the HSPF model. The City also provided drainage inventory Geographic Information System (GIS) data and survey data. WSE obtained additional drainage infrastructure information from WSDOT as described below.

2.1.1 Drainage Basin Delineation

The City provided WSE with a basin delineation for the Vasa Creek basin in addition to 2-foot contour mapping and drainage system inventory for the basin in GIS format. The City also provided plans and survey data for hydraulic controls and crossings, as available. WSE used these data to prepare preliminary drainage subbasin delineations corresponding to significant tributaries, road crossings, hydraulic controls, and other potential points of interest including three City streamflow gage sites. The subbasins include all areas draining to Vasa Creek as well as areas that drain to a high flow bypass pipe that runs through the basin and outfalls to Lake Sammamish at a location approximately 700 feet south of the Vasa Creek delta. A total of 24 model subbasins were delineated.

The initial subbasin delineations were reviewed to identify areas that required a more detailed review. WSE requested design and as-built drawings from WSDOT for any areas in question and spoke with WSDOT field staff to verify several components of the drainage system. WSE staff also field verified questionable areas and discussed the findings of these investigations with the City. WSE refined or redelineated the basin and subbasin boundaries to match field observations, City drainage inventory data, and WSDOT as-built drawings. Figure 1 shows the final subbasin delineations. Vasa Creek subbasins which drain to the high flow bypass pipe and those draining directly to Lake Sammamish are shown on Figure 1. WSE provided the revised subbasin delineations to the City in GIS format.

2.1.2 Land-Use and Soils Data

The City provided GIS data for parcels and tax assessor data for the Vasa Creek basin. In addition to the parcel data, the City provided 2012 orthophotos of the study area. WSE defined land-use classes that would be used for hydrologic modeling and using the 2012 orthophotos and parcel data, created a GIS land-use layer to match the current conditions in the basin. Existing land use was grouped into the following categories:

- open water (generally open water bodies larger than 1 acre)
- forest
- pasture
- grass
- rural single family residential (less than or equal to 1 unit per 5 acres)
- low density single family residential (1 unit per 5 acres to 2 units per acre)
- medium density single family residential (2 to 6 units per acre)
- high density single family residential (greater than 6 units per acre)
- multi-family residential
- commercial/industrial
- streets (residential streets)
- transportation (major arterials and highways)

For each land-use category a percentage (ranging from 0 to 95%) is assumed to be impervious while the remainder is assumed to be pervious. The impervious portion is further adjusted to account for areas that are impervious but not well connected to the drainage system. This is referred to as the percent connectedness and the resulting value (imperviousness times connectedness) yields the effective impervious area as a percentage of the area in each land use category. The pervious portion is further subdivided between forest, pasture, and grass reflecting the distribution of pervious land as observed from aerial photos and field reconnaissance. The final effective impervious area (EIA) percentage and breakdown of pervious area for each land-use type is shown in Table 1. Note that the calibration analysis, described below, indicated that different EIA values were needed in the upper and lower portions of the basin (e.g. upstream and downstream of the WSDOT I-90 detention pond). The analysis determined that adjusting HSPF PERLND parameters alone could not reasonably match observed peak flows so a reduction in EIA values in the upper basin (subbasins 115-170) was made. This is discussed further in Section 2.2.1.

Table 1- Effective Impervious Area and Forest/Grass Distribution for Land-use Analysis

Land Use	Pervious Cover (with default split)	Effective Impervious Area (EIA)		
		Gross Imp (%)	Connected Imp (%)	Effective Imp (%)
Subbasins 115-170				
Open Water	n/a	0	0	0
Forest	F	0	0	0
Pasture	P	0	0	0
Grass	G	0	0	0
Rural Density SFR	F(50%)/P(40%)/G(10%)	1	0	0
Low Density SFR	F(30%)/ P(54%)/G(13%)	15	10	1.5
Medium Density SFR	G	25	20	5
High Density SFR	G	50	30	15
Multifamily Residential	G	60	40	24
Commercial	G	90	47.5	42.8
Streets	G	55	45	24.8
Trans	G	70	45	31.5
All Other Subbasins				
Open Water	n/a	0	0	0
Forest	F	0	0	0
Pasture	P	0	0	0
Grass	G	0	0	0
Rural Density SFR	F(50%)/P(40%)/G(10%)	1	0	0
Low Density SFR	F(30%)/ P(54%)/G(13%)	15	20	3
Medium Density SFR	G	25	40	10
High Density SFR	G	50	60	30
Multifamily Residential	G	60	80	48
Commercial	G	90	95	85.5
Streets	G	55	90	49.5
Trans	G	70	90	63
Note: For Rural and Low Density SFR, WSE estimated the percentage of forest, pasture, and grass based on aerial photos and field reconnaissance and past practice.				

Soils data were obtained from the City. These soils were generally grouped by WSE into three categories (Till, Outwash, and Wetland). Table 2 shows a list of soils found in the basin and the category they were assigned to for purposes of the hydrologic modeling. Figure 2 shows the soils as used in HSPF modeling.

Table 2- Soils Classification

Soil Name	HSPF Classification
Alderwood and Kitsap soils, very steep	Outwash
Alderwood gravelly sandy loam, 6 to 15 percent slopes	Outwash
Alderwood gravelly sandy loam, 15 to 30 percent slopes	Outwash
Arents, Alderwood material, 6 to 15 percent slopes	Till
Arents, Everett material	Outwash
Beausite gravelly sandy loam, 6 to 15 percent slopes	Till
Beausite gravelly sandy loam, 15 to 30 percent slopes	Till
Everett-Alderwood gravelly sandy loams, 6 to 15 percent slopes	Outwash
Everett gravelly sandy loam, 0 to 5 percent slopes	Outwash
Everett gravelly sandy loam, 5 to 15 percent slopes	Outwash
Everett gravelly sandy loam, 15 to 30 percent slopes	Outwash
Kitsap silt loam, 15 to 30 percent slopes	Till
Norma sandy loam	Wetland
Pits	Outwash

2.1.3 Drainage Network and FTABLEs

The City provided drainage inventory GIS including pipes and catch basin structures. WSE also obtained design and as-built drawings from WSDOT for drainage features associated with Interstate 90. These data were used to refine subbasin delineations and to delineate drainage pathways for the HSPF model network. Figure 3 shows the model network diagram.

WSE created stage-storage-discharge tables (FTABLES) for each HSPF subbasin based on the hydraulic characteristics of the sub-basin outlet or downstream-most reach in the subbasin. Stage-discharge values were based on hand calculations, hydraulic modeling, and engineering judgment as appropriate. Stage-storage data were based on the topographic data at each basin outlet. Two subbasins, 115 and 225, drain to WSDOT sedimentation/detention facilities. FTABLEs for these basins were based on WSDOT as-built plans, limited field surveys, and available topographic data. The FTABLE for the pond in subbasin 115 is well defined as the outlet structures were recently surveyed by the City of Bellevue. The outlet control structure in the pond in subbasin 225 was based on WSDOT as-built information for the outlet control structure which consists of a weir, orifice, and culvert in series.

A significant hydraulic control on flows in Vasa Creek is a flow splitter located in the drainage system downstream of I-90. The flow splitter receives inflow from the WSDOT detention pond located in subbasin 115 and splits this to Vasa Creek via a 12 inch concrete pipe or via a 48 inch concrete pipe to the high flow bypass pipe running down 35th Place SE. Hydraulic analysis of the flow splitter was conducted using SWMM to evaluate the flow split under various hydraulic conditions. Geometric data for the SWMM model was taken from City surveys and WSDOT as-built drawings and hydrologic inputs to the model were developed using HSPF. The SWMM modeling showed that under low flow conditions

(< 4 cfs) the flow splitter would send all outflows to Vasa Creek, then at moderate and high flow conditions the splitter would direct most of the flow to the high flow bypass. At the estimated 100-year flow the splitter would send 15 cfs to Vasa Creek and 145 cfs to the high flow bypass. Table 3 lists the approach used to develop FTABLEs for each model subbasin.

Table 3- Methods Utilized for FTABLE Development

FTABLE ID (Reach No.)	Methodology	Notes
100	Free outfall	Vasa Creek Outfall
103	HEC-RAS Model	
105	HEC-RAS Model	
110	HEC-RAS Model	
113	SWMM Model	Flow split to bypass pipe and Vasa Creek. WSDOT as-builts & City measurements utilized
117	HEC-RAS Model	
115	WSDOT Pond Rating table	Rating table developed by WSE. Storage estimates provided by the City
120	HEC-RAS Model	
125	HEC-RAS Model	
130	HEC-RAS Model	
133	Normal depth & channel dimensions	Eastgate Elementary School Gage Site
135	HY-8 & channel dimensions [a]	
140	HY-8 & channel dimensions	
145	HY-8 & channel dimensions	
150	Normal depth & channel dimensions	
160	HY-8 & channel dimensions	
165	HY-8 & channel dimensions	
170	HY-8 & channel dimensions	
200	HY-8 & pipe dimensions	Based on WSDOT as-builts for the bypass system
205	HY-8 & pipe dimensions	Based on WSDOT as-builts for the bypass system
207	HY-8 & pipe dimensions	Based on WSDOT as-builts for the bypass system
210	HY-8 & pipe dimensions	Based on WSDOT as-builts
215	HY-8 & pipe dimensions	Based on WSDOT as-builts for the bypass system
220	HY-8 & pipe dimensions	Based on WSDOT as-builts for the bypass system
225	Hydraulic analysis of outlet structure	Based on WSDOT as-builts
230	Free outfall	High flow bypass outlet to Lake Sammamish
235	Free outfall	Direct discharge to Lake Sammamish

Note: [a] For many subbasins the stage discharge values were computed using HY-8 while the stage-volume values were based on estimated channel or pipe properties (width, side slope, gradient).

2.1.4 Meteorological Data

The City provided recent precipitation data for 4 gages located near the Vasa Creek basin; Cougar Mt., Forest Hills, Parksite, and Phantom Lake. Data included 15-minute precipitation generally covering the last 2 years and hourly precipitation covering the period January 2007 through May 2014. Precipitation data was provided in Excel format. WSE processed the data and imported it into EPA's Watershed Data Management (WDM) format. After reviewing the precipitation data and QA/QC records, the locations of the gages, and the mean annual precipitation for the basin from PRISM mapping[1], WSE concluded that the Parksite gage provided the best data for use in the current modeling effort. 15-minute precipitation data from this gage were therefore used in the model calibration and the hourly record from this gage was used to establish a multiplier for transposing SeaTac precipitation data to the basin.

The basin was subdivided into 3 precipitation zones as shown in Figure 4 based on PRISM mapping of the average annual rainfall for the years 1981 – 2010. Multipliers for each of these zones were determined by dividing the PRISM precipitation at the Parksite rain gage (45.37 inches) by the average PRISM precipitation in the corresponding zone. Based on this analysis the multipliers were determined to be 0.94, 1.00, and 1.08 respectively in Zones 1, 2, and 3.

To allow long-term simulations, precipitation data from SeaTac for the period October 1948 – September 2010 were transposed to the basin based on a comparison of the SeaTac and Parksite data. Cumulative hourly precipitation data for the Parksite gage for the period January 2007 through September 2010 were compared to the SeaTac data in a double mass analysis as shown in Figure 5. The slope of the line in Figure 5 indicates that the Parksite gage gets, on average, approximately 22% more rain than SeaTac. SeaTac data were therefore transposed to the Vasa Creek basin using the local basin multipliers noted above (0.94, 1.00, 1.08) times 1.22 resulting in transposition multipliers of 1.15, 1.22, and 1.32 for Zones 1, 2, and 3 respectively. All data during the period of record were scaled uniformly by these scaling factors. Evaporation data for all HSPF modeling was taken as the observed or estimated daily pan evaporation data at the Puyallup Experimental station with a pan coefficient of 0.70.

2.2 HSPF Model Development

Subbasin, soils, and land-use data developed as described above were overlain in GIS and then aggregated in Excel to generate HSPF land surface runoff routing inputs (PERLND and IMPLND information for HSPF SCHEMATIC block). Unique HSPF PERLNDs were created for each soil/cover combination and for each of the three precipitation zones. Precipitation data from the Parksite gage with the multipliers described above were used in the model.

2.2.1 HSPF Model Calibration

The existing conditions HSPF model was then calibrated against available streamflow data for the City's gage at W. Lake Sammamish Parkway and the newly installed gage near Eastgate Elementary School. In addition, anecdotal information on flooding (i.e., road overtopping, pond water levels, etc.) was considered in the model calibration. Initial HSPF PERLND parameters developed by the City for the Kelsey Creek basin were used as a starting point for the calibration. The model calibration focused primarily on peak streamflows for storm events but also considered mean monthly flows and storm runoff volumes. HSPF PERLND parameters were adjusted as necessary to obtain the best fit to the observed data. Also, in the upper Vasa Creek basin (above the WSDOT Detention Pond) an adjustment was made to reduce the effective impervious area. This adjustment was necessary since solely adjusting PERLND parameters was ineffective at reducing peak discharges to reasonably match observed values.

Figure 6 shows calibration comparison plots for the two gages for the period of record. Table 4 provides a comparison of simulated versus observed mean monthly flows for all periods when the gages were operational and Table 5 provides a summary of the highest peak flows recorded at the gages and the

[1] Parameter-elevation Regressions on Independent Slopes Model, PRISM Climate Group, Oregon State University, 2014

corresponding modeled discharges. From Table 4 it can be seen that the average discharges at the Eastgate school gage are simulated quite well while Table 5 indicates that the high flow discharges at this gage are generally over-simulated. For the West Lake Sammamish Gage Table 5 shows a mix of under- and over-simulated peaks with the average being about right while Table 4 indicates that the flow volumes at this gage are somewhat over-simulated. One issue of note for the West Lake Sammamish gage was that the gage was damaged by debris in February 2014 and was inoperable for several weeks. Data for the period prior to the gage failure compared more favorably with the simulations than data collected after the gage was brought back online (see Figure 6). This issue can be investigated further as additional data become available in future years. Also, questions about annual runoff volumes, which could not be evaluated in this study due to the lack of observed data, can be reviewed as more data become available.

The model calibration was discussed with the City at a meeting at WSE's office on June 27, 2014. It was agreed at that meeting that the calibration was reasonable and adequate for proceeding with the existing conditions analysis. In particular since peak flows (the primary interest of the current project) are being simulated well or somewhat over-simulated the use of the modeled results will be conservative, if anything, from a floodplain mapping perspective. When more data are available the model calibration can be reviewed and refined as necessary in keeping with the objectives of any future study. Final HSPF PERLND parameters used in this study are shown in Table 6.

Table 4 - Comparison between Observed and Simulated Discharge Volumes

At Eastgate School gage:

	Mean Monthly Discharge (cfs)		**Difference**	
	Observed	**Simulated**	**(cfs)**	**Percent**
October	N.A.	0.83	N.A.	N.A.
November	N.A.	0.90	N.A.	N.A.
December	N.A.	0.66	N.A.	N.A.
January	1.38	1.12	-0.25	-18%
February	1.98	1.58	-0.40	-20%
March	2.46	2.40	-0.06	-2%
April	1.46	1.43	-0.03	-2%
May	1.09	1.27	0.18	17%
June	0.42	0.72	0.30	72%
Total	**1.67**	**1.56**	**-0.11**	**-7%**

At West Lake Sammamish Parkway gage:

	Mean Monthly Discharge (cfs)		**Difference**	
	Observed	**Simulated**	**(cfs)**	**Percent**
October	1.67	2.04	0.37	22%
November	1.38	2.25	0.87	63%
December	1.47	1.75	0.28	19%
January	2.03	2.59	0.56	28%
February	N.A.	3.40	N.A.	N.A.
March	3.29	4.60	1.31	40%
April	2.61	3.56	0.95	36%
May	2.27	3.02	0.75	33%
June	1.72	1.98	0.25	15%
Total	**2.06**	**2.72**	**0.67**	**32%**

Table 5 - Comparison between Observed and Simulated Peak Discharges (for all flows exceeding 9.5 cfs)

At Eastgate School gage:

Observed		Simulated			
Event Start Date	**Peak (cfs)**	**Event Start Date**	**Peak (cfs)**	**Difference (cfs)**	**Difference (%)**
01/02/2014	8.2	01/02/2014	13.8	5.6	68%
01/11/2014	7.6	01/11/2014	18.7	11.1	146%
02/16/2014	10.1	02/16/2014	11.3	1.1	11%
03/04/2014	9.6	03/05/2014	18.2	8.6	90%
03/10/2014	6.2	03/10/2014	10.0	3.8	62%
03/16/2014	8.8	03/16/2014	9.6	0.8	9%
03/28/2014	7.7	03/28/2014	16.5	8.8	115%
03/29/2014	7.5	03/29/2014	12.6	5.1	68%
04/17/2014	7.4	04/17/2014	14.0	6.6	89%
04/24/2014	7.9	04/24/2014	9.6	1.6	21%
05/03/2014	9.2	05/03/2014	11.5	2.3	25%
05/04/2014	8.5	05/04/2014	22.4	14.0	164%
08/13/2014	37.4	08/13/2014	33.7	-3.6	-10%

At West Lake Sammamish Parkway gage:

Observed		Simulated			
Event Start Date	**Peak (cfs)**	**Event Start Date**	**Peak (cfs)**	**Difference (cfs)**	**Difference (%)**
01/02/2014	11.8	01/02/2014	15.6	3.8	32%
01/11/2014	13.1	01/11/2014	16.2	3.1	24%
01/29/2014	9.2	01/29/2014	9.7	0.5	5%
02/11/2014	13.3	02/11/2014	9.1	-4.2	-32%
02/16/2014	19.6	02/16/2014	13.9	-5.7	-29%
03/05/2014	25.1	03/04/2014	17.0	-8.1	-32%
03/08/2014	12.1	03/08/2014	11.5	-0.6	-5%
03/10/2014	16.5	03/10/2014	11.4	-5.1	-31%
03/16/2014	14.2	03/15/2014	12.0	-2.2	-15%
03/29/2014	11.6	03/28/2014	13.6	2.0	17%
04/08/2014	7.4	04/08/2014	10.2	2.8	38%
04/17/2014	13.7	04/16/2014	15.4	1.7	12%
04/24/2014	11.5	04/23/2014	11.7	0.2	2%
05/03/2014	17.4	05/03/2014	17.7	0.3	2%
05/08/2014	7.4	05/08/2014	11.4	4.0	55%
07/23/2014	N.A.	07/23/2014	11.9	N.A.	N.A.
08/13/2014	37.6	08/13/2014	28.3	-9.3	-25%

Table 6: Calibrated HSPF Model Parameters

PERLND ID	Description	FOREST	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC	INFEXP	INFILD
110, 310, 510	TF MILD	0.75	10.500	0.0800	800.00	0.0500	0.0000	0.9900	2.0000	2.0000
120, 320, 520	TF MODERATE	0.75	10.500	0.0800	800.00	0.1000	0.0000	0.9900	2.0000	2.0000
130, 330, 530	TF STEEP	0.75	10.500	0.0800	400.00	0.2000	0.0000	0.9900	2.0000	2.0000
140, 340, 540	TP MILD	0.05	10.500	0.0600	800.00	0.0500	0.0000	0.9900	2.0000	2.0000
150, 350, 550	TP MODERATE	0.05	10.500	0.0600	800.00	0.1000	0.0000	0.9900	2.0000	2.0000
160, 360, 560	TP STEEP	0.05	10.500	0.0600	400.00	0.2000	0.0000	0.9900	2.0000	2.0000
170, 370, 570	TG MILD	0.05	10.500	0.0300	800.00	0.0500	0.0000	0.9900	2.0000	2.0000
180, 380, 580	TG MODERATE	0.05	10.500	0.0300	800.00	0.1000	0.0000	0.9900	2.0000	2.0000
190, 390, 590	TF STEEP	0.05	10.500	0.0300	400.00	0.2000	0.0000	0.9900	2.0000	2.0000
200, 400, 600	OF	0.75	12.000	2.0000	900.00	0.0500	0.0000	0.9900	2.0000	2.0000
210, 410, 610	OP	0.05	12.000	1.4000	900.00	0.0500	0.0000	0.9900	2.0000	2.0000
220, 420, 620	OG	0.05	12.000	0.8000	900.00	0.0500	0.0000	0.9900	2.0000	2.0000

PERLND ID	Description	DEEPFR	BASETP	AGWETP	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
110, 310, 510	TF MILD	0.00	0.00	0.00	0.2000	2.0000	0.3500	3.0000	0.7000	0.7000
120, 320, 520	TF MODERATE	0.00	0.00	0.00	0.2000	1.0000	0.3500	6.0000	0.5000	0.7000
130, 330, 530	TF STEEP	0.00	0.00	0.00	0.2000	0.6000	0.3500	7.0000	0.3000	0.7000
140, 340, 540	TP MILD	0.00	0.00	0.00	0.1000	1.2000	0.3000	3.0000	0.7000	0.4500
150, 350, 550	TP MODERATE	0.00	0.00	0.00	0.1000	0.6000	0.3000	6.0000	0.5000	0.4500
160, 360, 560	TP STEEP	0.00	0.00	0.00	0.1000	0.4000	0.3000	7.0000	0.3000	0.4500
170, 370, 570	TG MILD	0.00	0.00	0.00	0.1000	1.0000	0.2500	3.0000	0.7000	0.2500
180, 380, 580	TG MODERATE	0.00	0.00	0.00	0.1000	0.5000	0.2500	6.0000	0.5000	0.2500
190, 390, 590	TF STEEP	0.00	0.00	0.00	0.1000	0.3000	0.2500	7.0000	0.3000	0.2500
200, 400, 600	OF	0.00	0.00	0.00	0.2000	1.0000	0.3500	0.0000	0.9000	0.7000
210, 410, 610	OP	0.00	0.00	0.00	0.1000	1.0000	0.3000	0.0000	0.9000	0.4500
220, 420, 620	OG	0.00	0.00	0.00	0.1000	1.0000	0.2500	0.0000	0.9000	0.2500

2.2.1 HSPF Model Application for Long Term Simulations

Using the calibrated HSPF model, WSE simulated a long-term record of existing conditions streamflows. Precipitation data used for this analysis came from the NWS gage at SeaTac transposed to the site using the multipliers described above. Data for the SeaTac gage were provided to WSE by Northwest Hydraulic Consultants (NHC) who is currently working for the City on another hydrologic modeling project. The period of record for the SeaTac data, and thus the long-term simulations is Water Year 1949 to Water Year 2010.

Flow frequency analyses were conducted at key locations in the basin as needed to support the hydraulic modeling and analysis. Peak annual flows were extracted from the HSPF modeling and fit using the methods of Water Resources Council Bulletin 17B. Table 7 shows the results of the frequency analyses. As seen in Table 7 the peak flows estimated for this study show a dramatic reduction downstream of the flow splitter which is located a short distance upstream of 163rd Avenue SE and controls discharges in Vasa Creek to less than 15 cfs in all conditions up to and including the 100-year event. The bulk of the flow that reaches the flow splitter is diverted into the high flow bypass pipe which runs along SE 35th Place. This bypass pipe carries high flows from Vasa Creek directly to Lake Sammamish without any opportunity for discharge back to Vasa Creek. The basin area tributary to Vasa Creek downstream of the flow splitter is only 0.29 square miles (184 acres) thus the estimated increase in 100-year peak flow between the splitter and the mouth (32 cfs or 110 cfs per sq mile) appears reasonable given the low density development in this portion of the basin.

Table 7: Peak Flow Quantiles for Key Locations in Vasa Creek (15-Minute SeaTac Precipitation)

Location	Sub-basin	Area (acres)	Flow Quantile (cfs) by Return Period (years)					
			2-yr	10-yr	25-yr	50-yr	100-yr	500-yr
Eastgate School Gage	133	249	28	54	70	84	99	140
West Fk at Newport Wy	130	277	33	63	82	97	113	157
East Fk at Newport Wy	135	103	13	26	34	40	47	64
WSDOT Pond	115	510	52	95	120	140	161	217
Flow Splitter (12”)	113	510[a]	5	7	9	12	15	31
Flow Splitter (48”)	113	510	48	87	110	127	145	191
WLS Parkway	103	675[a]	21	32	38	43	48	62
Mouth of Vasa Creek	100	693[a]	21	32	38	43	49	63

Note: [a] For locations downstream of the flow splitter the basin area reported includes all upstream subbasins, even though the splitter will divert much of the flow from upstream areas to the high flow bypass. Because of this it is not reasonable to compare runoff per unit area values from the downstream locations with upstream locations or other studies.

2.2.2 HSPF Model Runs with Extended Precipitation Record

In addition to the analysis using the long term SeaTac precipitation record WSE also performed a long run of the HSPF model using an extended precipitation time series available from WSDOT (MGS, 2002). This 158-year hourly precipitation record provides a longer term time series, which allows a more comprehensive analysis of watershed and stormwater facility response to various combinations of storm magnitudes, temporal patterns and sequences of storms. The extended record also allows interpolation of extreme flood quantiles as opposed to extrapolation which is required when using short records available from a single gage. On the negative side the hourly time step of the extended precipitation series may be too long for evaluation of peak flows on smaller basin such as Vasa Creek.

Using the extended precipitation record the HSPF model was run for the 158-year record. Annual maximum hourly discharges at key locations were extracted and fit using a Log Pearson Type III distribution[2]. The results of the frequency analysis are shown in Table 8. When compared to Table 7 it can be seen that the flood quantiles for the extended record are much smaller than those from the SeaTac based analysis (19 – 38% lower at the 100-year recurrence). This is primarily due to the time step of the data. A check of the SeaTac analysis showed that if the annual peaks were aggregated to an hourly time step instead of the native 15-minute step the differences between the two analyses would be much smaller (in fact the extended data set would show slightly higher 100-year flows downstream of West Lake Sammamish Parkway). The results of the analysis using the hourly aggregated data are shown in Table 9. As can be seen in Tables 8 and 9 the data for the Lower Vasa Creek reach are nearly the same, although both are substantially lower than the results reported in Table 7 for the 15-minute SeaTac data. For purposes of the current study it is noted that the flow quantiles produced using the SeaTac precipitation are conservative relative to the extended precipitation record.

Table 8: Peak Flow Quantiles for Key Locations in Vasa Creek (Extended Precipitation Record)

Location	Sub-basin	Area (acres)	Flow Quantile (cfs) by Return Period (years)					
			2-yr	10-yr	25-yr	50-yr	100-yr	500-yr
Eastgate School Gage	133	249	17	32	42	51	61	91
WSDOT Pond	115	510	34	62	78	92	108	149
WLS Parkway	103	675[a]	16	25	30	34	39	52
Mouth of Vasa Creek	100	693[a]	16	25	30	34	39	53

Note: [a] For locations downstream of the flow splitter the basin area reported includes all upstream subbasins, even though the splitter will divert much of the flow from upstream areas to the high flow bypass. Because of this it is not reasonable to compare runoff per unit area values from the downstream locations with upstream locations or other studies.

Table 9: Peak Flow Quantiles for Key Locations in Vasa Creek (SeaTac Precipitation, Hourly Flows)[a]

Location	Sub-basin	Area (acres)	Flow Quantile (cfs) by Return Period (years)					
			2-yr	10-yr	25-yr	50-yr	100-yr	500-yr
Eastgate School Gage	133	249	18	35	46	56	68	97
WSDOT Pond	115	510	37	72	94	113	135	195
WLS Parkway	103	675	16	23	27	30	34	42
Mouth of Vasa Creek	100	693	16	23	27	31	34	42

Note: [a] Flow frequency analyses reported in this table were performed by first aggregating the simulated flows to an hourly time step and then conducting the annual frequency analyses using the Log Pearson Type III distribution as was done for the extended data set.

[2] A standard Bulletin 17B analysis could not be conducted on the extended data set since some of the algorithms do not work with data sets longer than 147 years. However the Log Pearson Type III distribution used in the analysis of the extended data is the same theoretical fit used in the Bulletin 17B analysis and the results in Table 8 are therefore comparable with the results shown in Table 7.

3.0 SUMMARY

WSE developed and calibrated an HSPF hydrologic model of the Vasa Creek basin and applied the model to estimate flood flows for use in updating floodplain mapping for portions of the creek. Estimated peak flows are provided in Table 7. These data will be used as input to a HEC-RAS hydraulic model in a subsequent task under this contract. Key assumptions made in the analysis are considered reasonable, based on WSE's past experience conducting hydrologic analyses for FEMA related floodplain mapping studies. In cases where engineering judgment was required conservative approaches were taken to ensure that the data would not under-represent flood risks.

4.0 REFERENCES

Hydrologic Engineering Center, January 2010, HEC-RAS River Analysis System, Version 4.1, US Army Corps of Engineers Hydrologic Engineering Center, Davis, CA.

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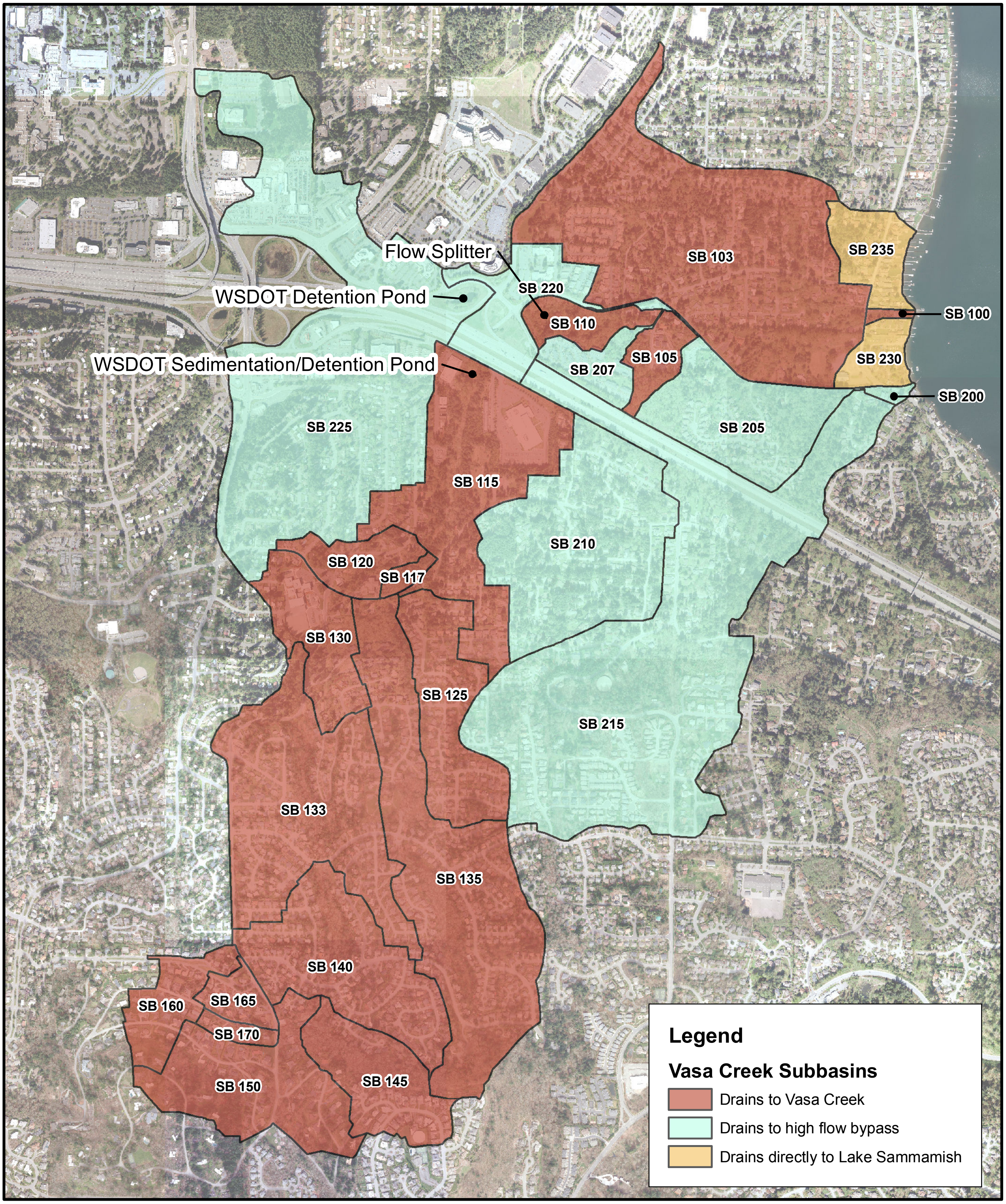
US Environmental Protection Agency, July 2010, Surface Water Management Model, Version 5.0, US EPA National Risk Management Research Laboratory, Cinncinati, OH.

US Department of Transportation, April 2014, HY-8 Culvert Analysis Program, Version 7.3.1, Federal Highway Administration.



City of Bellevue

Vasa Creek

Subbasin Delineations

0 1,000 2,000 Feet

N

Scale: 1:18,000

August 2014

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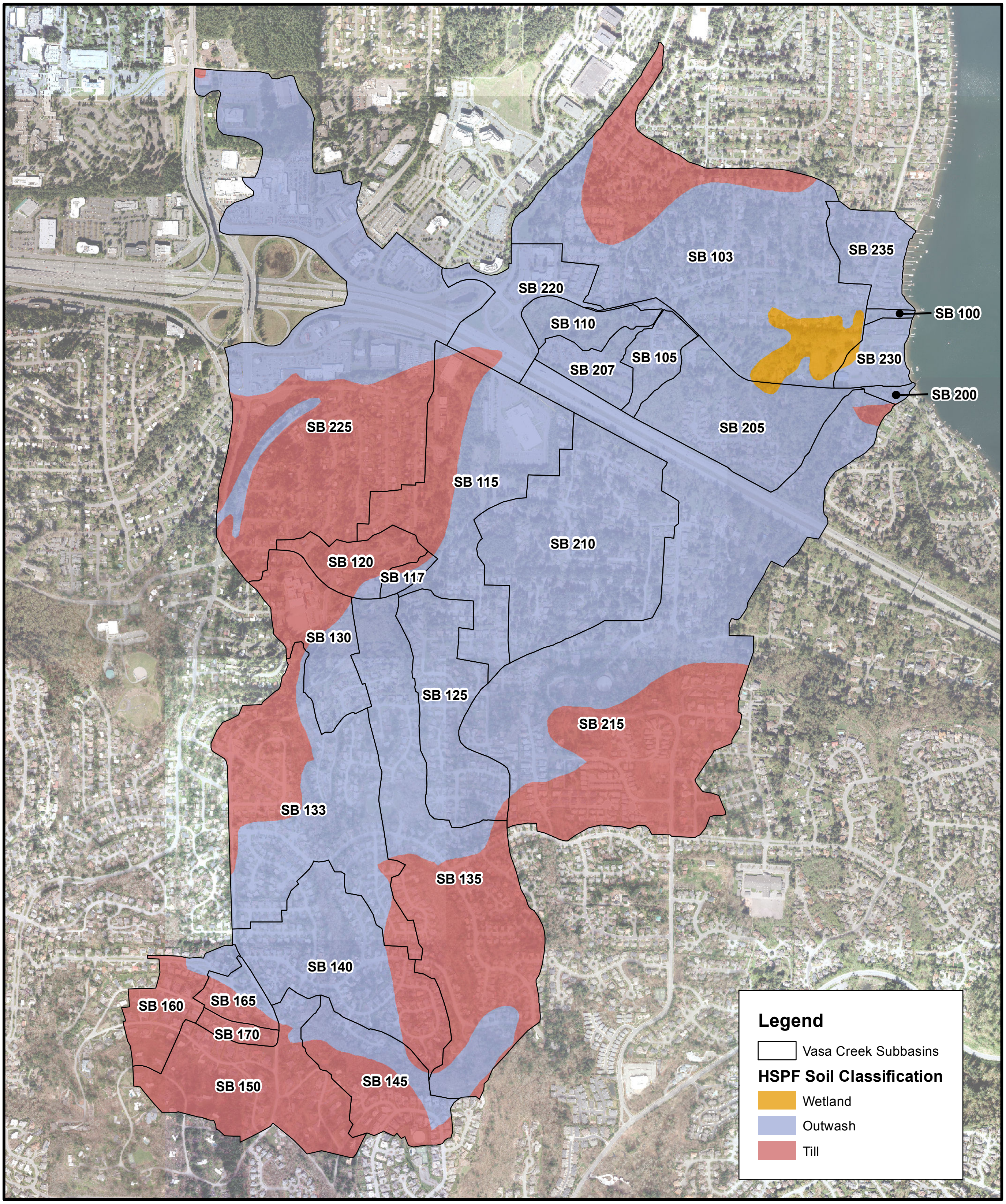
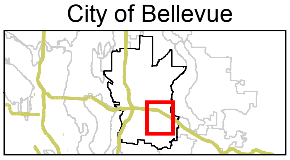
Background Image: 2012 Orthophoto provided by the City

Figure 1



City of Bellevue



Vasa Creek

HSPF Modeled Soils

0 1,000 2,000 Feet

Scale: 1:18,000

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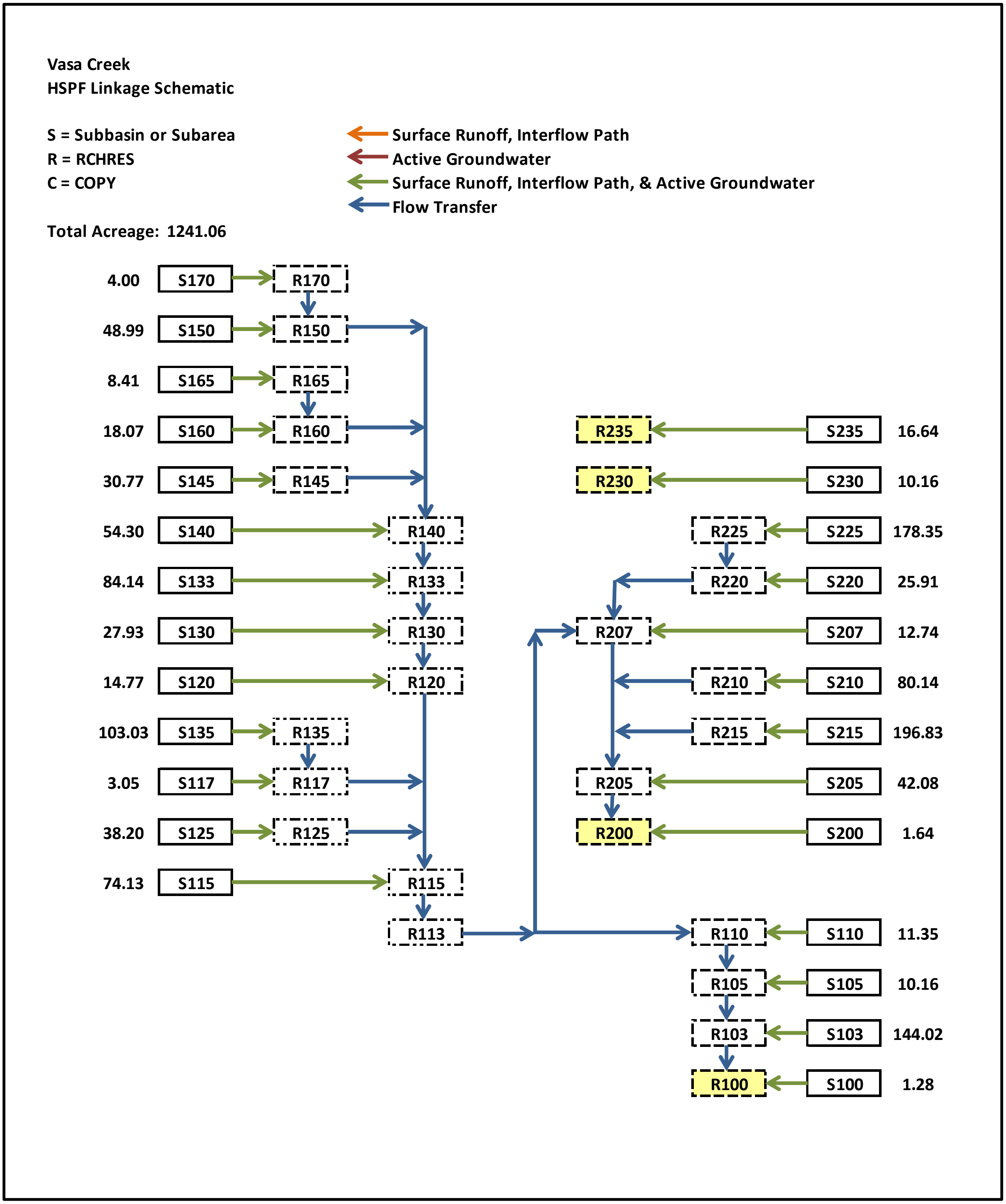
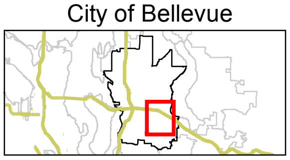
Background Image: 2012 Orthophoto provided by the City

Figure 2



City of Bellevue



Vasa Creek

HSPF Model Schematic

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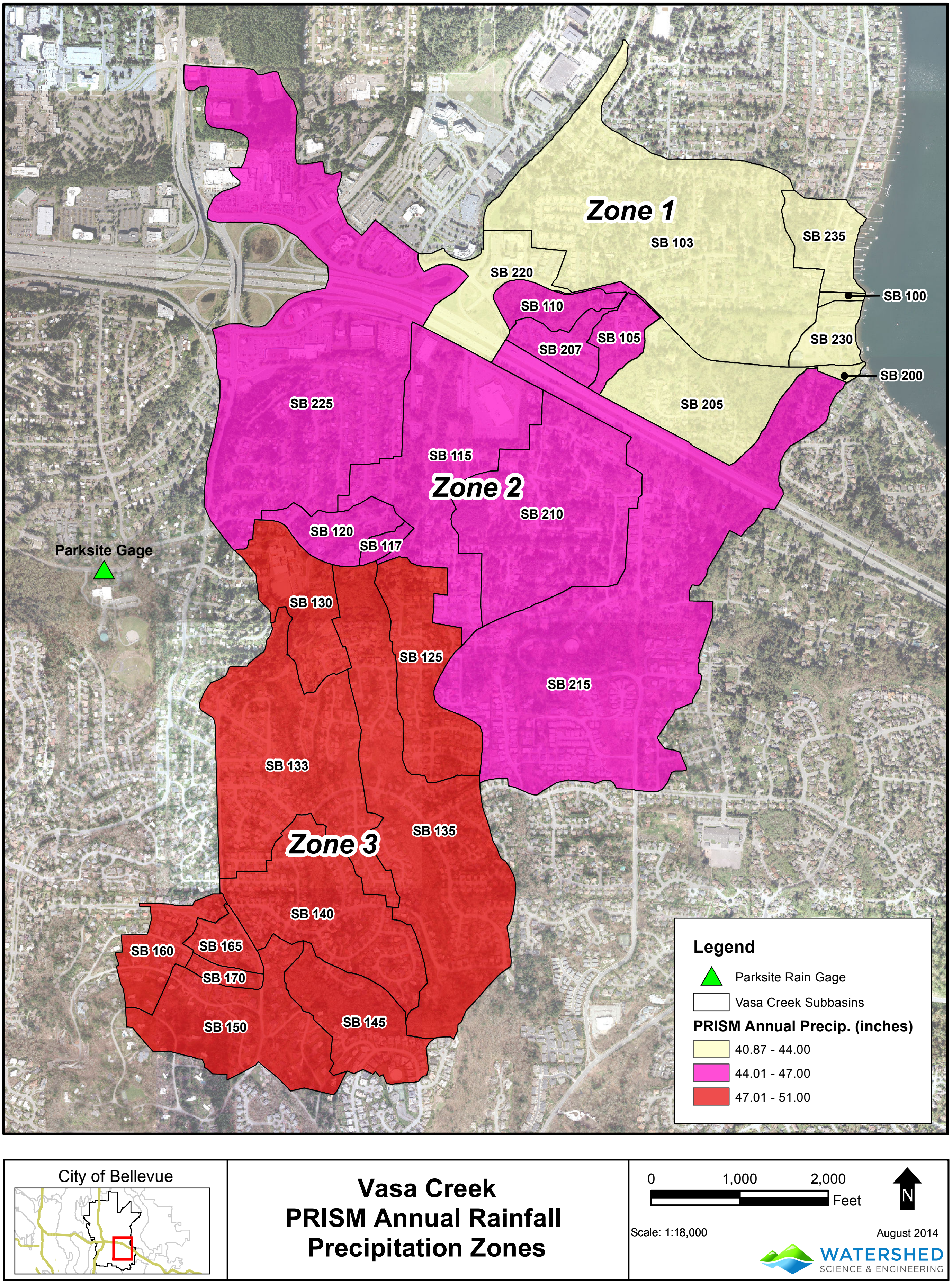
Figure 3



Vasa Creek
PRISM Annual Rainfall
Precipitation Zones

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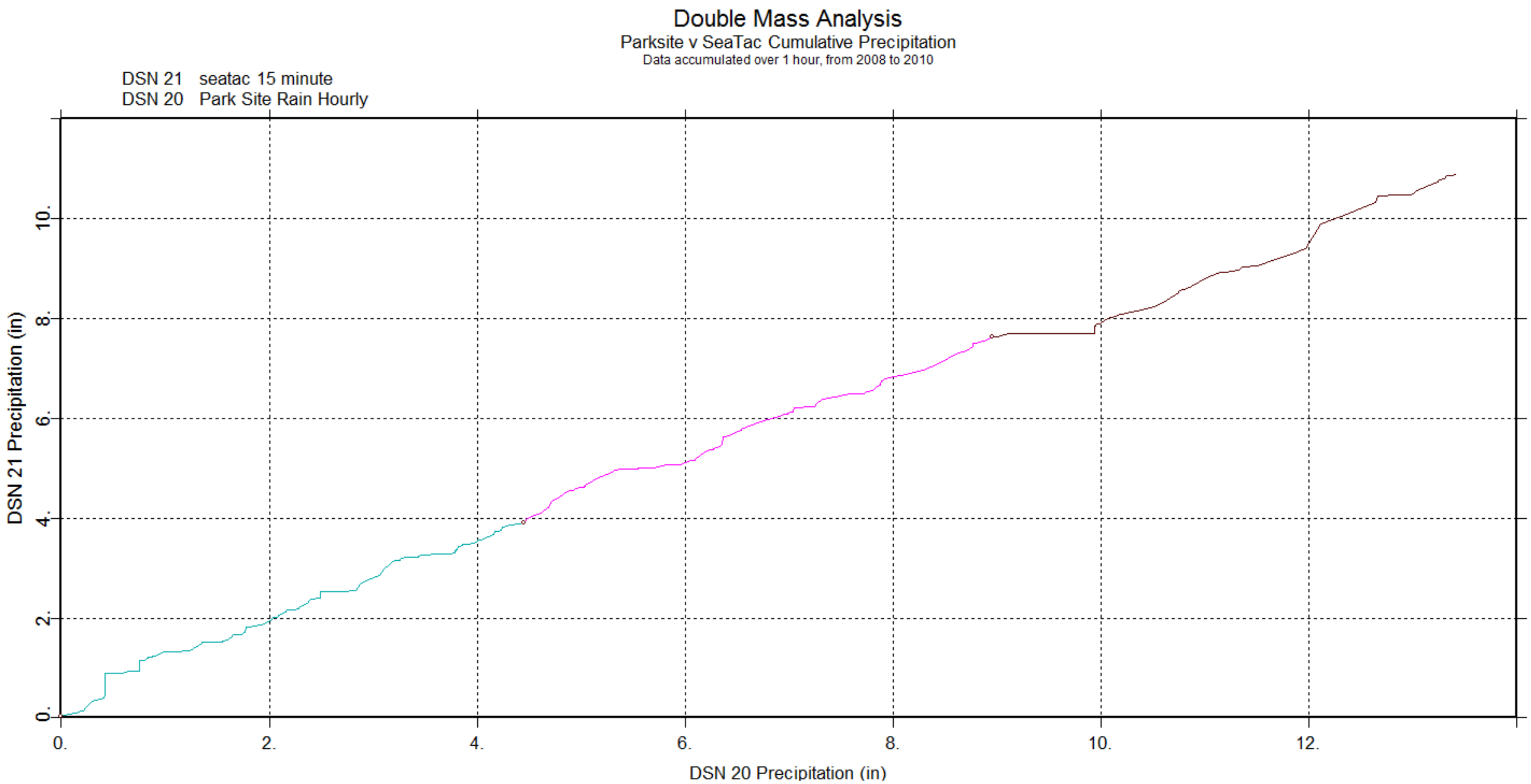
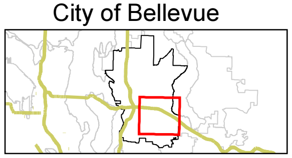
Background Image: 2012 Orthophoto provided by the City

Figure 4





Vasa Creek

Parksite v. SeaTac Cumulative Precipitation

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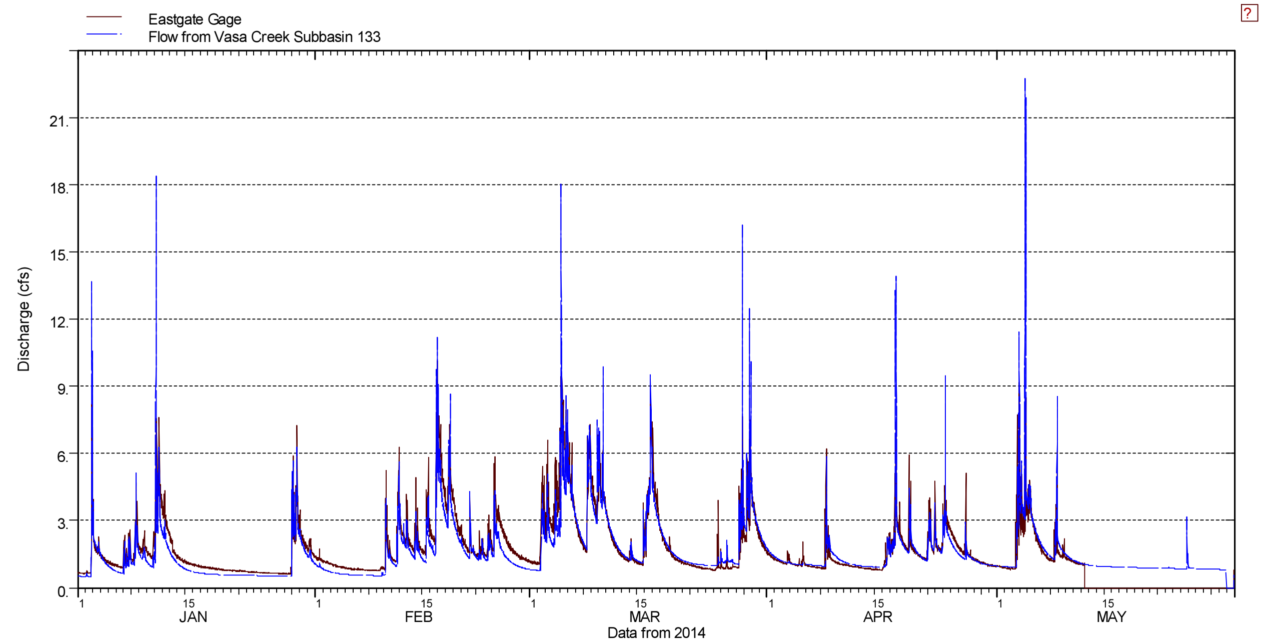
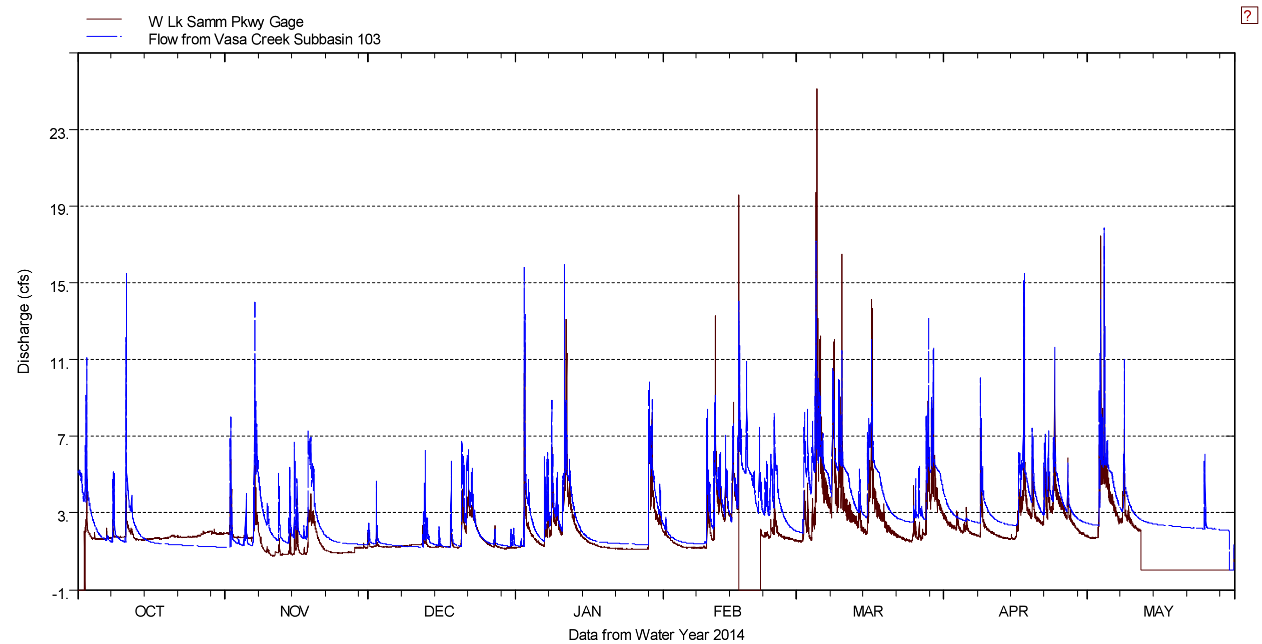
Figure 5





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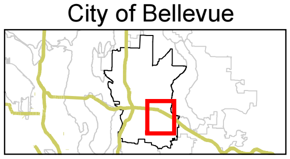

Vasa Creek

HSPF Model Calibration

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Figure 6