DRAFT

TECHNICAL APPENDICES

CITY OF KENT DRAINAGE MASTER PLAN

Prepared for

City of Kent

Public Works Department

Environmental Engineering

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Kent, Washington 98032-5895

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In association with

HDR, Inc.

MGS Engineering Consultants, Inc.

June 2008

TECHNICAL APPENDICES

CITY OF KENT DRAINAGE MASTER PLAN

Due to the volume of technical support materials, most of the supporting materials are presented in electronic format. For each appendix, a brief narrative, or more if necessary, has been prepared to describe the information in the appendix. In some cases, supplemental information may be included to provide a more detailed explanation of the methodologies used in preparation of the Drainage Master Plan. The list below identifies what is printed and what is provided electronically only. All printed materials will also be included in electronic format.

APPENDIX A – PUBLIC INVOLVEMENT DOCUMENTATION

- Narrative – Print
- Citizen's Advisory Committee Recommendations – Print
- Meeting Summaries – DVD
- Presentations – DVD

APPENDIX B – LAND COVER ANALYSIS DOCUMENTATION

- Narrative – Print
- Summary Tables – Print (one for HSPF and one for MGSFlood) and DVD

APPENDIX C – DECEMBER 3, 2007 FLOOD PHOTOGRAPHS AND HIGH WATER MARKS

- High Water Marks Graphic – Print
- Photographs – DVD

APPENDIX D – HYDROLOGIC ANALYSIS DOCUMENTATION

- Narrative – Print
- HSFP Input Files – DVD
- MGSFlood – DVD

APPENDIX E – UPPER MILL CREEK STORAGE EVALUATION

- Narrative – Print
- MGS Engineering Consultants, Inc. Letter Report – Print

APPENDIX F – HYDRAULIC ANALYSIS DOCUMENTATION

- Narrative – Print
- Receiving Waters
  - HEC-RAS Input Files – DVD
  - HEC-RAS Summary Output Tables – DVD
  - Photograph Documentation of Crossings – DVD
- Trunk Storm Drain
  - Spreadsheets – DVD
  - Graphics – DVD

APPENDIX G – PROJECT COST OPINIONS

- Narrative – Print
- Cost Opinions – Print and DVD

APPENDIX A

PUBLIC INVOLVEMENT DOCUMENTATION

APPENDIX A – PUBLIC INVOLVEMENT DOCUMENTATION

1.1 Introduction

The City of Kent (City) retained an independent consultant, Norton-Arnold & Company (Norton-Arnold), to lead the public involvement efforts. Public involvement opportunities consisted of open houses and establishment of a Citizen's Advisory Committee (CAC).

1.2 Open Houses

Two open houses were held—the first in January 2008 and the second in April 2008. The purpose of the first open house was to introduce the public to the Drainage Master Plan (DMP) update process, solicit information about drainage problems that may have not have been previously identified by the City, and to solicit volunteers for the CAC. The second open house was to provide an update on the DMP process, present possible solutions to identified flooding problems, and solicit additional information regarding flooding. A formal presentation was also made at the second open house.

Norton-Arnold prepared written summaries of these open houses that describe the format of the meeting and summarize comments received from the public. These summaries can be found in the electronic Appendix A subfolder "Meeting Summaries." The formal presentation made at the second open house can be found in the electronic Appendix A subfolder "Presentations."

1.3 Citizen's Advisory Committee

The City established a CAC to assist guiding the DMP process. The CAC consisted of concerned citizens and representatives of various business groups from the community. Five CAC meetings were held to discuss the DMP update process, evaluate the importance of various projects to the community, understand the costs of the projects, understand the how the stormwater utility is currently funded, understand how the stormwater utility rates need to change to accommodate construction of the projects and other mandated activities, and finally make a recommendation to the City Council regarding adoption of the DMP.

Norton-Arnold prepared written summaries of these CAC meetings that describe the format of the meeting and summarize comments received from the CAC members. These summaries can be found in the electronic Appendix A subfolder "Meeting Summaries."

The formal presentations made at each of these CAC meetings can be found in the electronic Appendix A subfolder “Presentations.” The CAC recommendation letter is printed here and can be found in the electronic Appendix A subfolder “CAC Recommendations.”

May 6, 2008

Kent City Council
220 Fourth Avenue South
Kent, WA 98032

Dear Councilmembers:

The City of Kent Drainage Master Plan Citizen Advisory Committee (CAC) has completed the task of developing recommendations regarding the City's update of the Drainage Master Plan. The CAC was charged with providing input and guidance on the flooding and water quality problems within the City, solutions to address the problems, and on potential rate structures to help fund the plan.

The CAC was also presented with additional information about other elements of the plan, such as how it will meet regulatory requirements; however, the focus of our work was on reviewing the specific projects intended to address the very real local flooding and water quality problems within our City.

The CAC, comprised of City citizens and businesses, who represent a diverse range of viewpoints, has agreed on its recommendation as a result of five meetings over a two-month period. Our recommendations are included in the body of this letter. Summaries of each of the five meetings are enclosed with this letter.

Our Recommendations

Our recommendations addresses three primary elements: reviewing, identifying, and prioritizing problems; reviewing and providing input to solutions (projects) and the City staff/consultant's benefit assessment (discussed further below), and; reviewing and providing input to the potential rate structures. Throughout the course of our deliberations, we also arrived at a number of other recommendations we believe the City Council and the Department of Public Works should consider as it moves ahead with the plan's review and adoption process. Our recommendations were reached by consensus.

<u>Flooding and water quality problems</u>

The CAC was presented with descriptions and locations of several problems that exist throughout the City. These problems were identified by City staff and its consultant, and by Kent citizens and businesses. The CAC identified additional problems that the plan should address.

Recommendation #1: It is our belief that the problems identified by the means described above accurately represent the local flooding and water quality problems within the City of Kent, and we recommend that these problems be recognized and addressed by the Drainage Master Plan.

The CAC was asked to prioritize problems based on their: frequency, water quality impacts, maintenance considerations, transportation impacts, and regulatory implications (National Pollutant Discharge Elimination System (NPDES) Phase 2 Permit and Total Maximum Daily Loads (TMDL)). The CAC concurred that it was difficult for us to prioritize problems based on these criteria and suggested the following criteria as more practical measures of problems:

Priority 1. Serious, demonstrated public safety risk
Priority 2. Proven serious economic impact
Priority 3. Major, repeated traffic interruption
Priority 4. Other traffic interruption and impacts to water quality and habitat
Priority 5. Citizen complaints and other irritating events

Upon further review the CAC requested that they be provided with a matrix of the solutions, the problems they are intended to address, and an assessment of their priority in light of the suggested criteria.

Solutions to address problems

The CAC was presented with the solutions/problems matrix they requested, and received a summary description of each project and its benefits. The CAC was asked to provide input on the accuracy of the project assessment, which was conducted by City staff and the consultant.

Recommendation #2: While we initially had some questions about the assessment, specifically if some of the problems put the public at serious risk, by in large we agree with the assessment and recommend that it be reflected in the plan and be used to prioritize the order in which projects are undertaken.

The documents that we were presented with and were used to support our recommendations are attached with this letter.

Rate Structure

The CAC was presented with the current rate structures of the City's stormwater utility and with three different structures – a uniform rate, an area specific rate, and a hybrid – that are being considered to help fund the plan. City staff and the consultant explained opportunities and constraints of all structures.

After review of the projected rates for each of the different structures it became apparent that the uniform rate was the most equitable to residents and businesses.

Recommendation #3: We believe that the City should adopt the uniform rate structure. All ratepayers pay more than existing rates, but it is a smaller increase than many would have to pay under a basin structure, and it is simpler to implement and administer. The uniform rate also incorporates the philosophy that the City should address its problems as one community.

Other Recommendations

Throughout our meetings, we discussed and came to agreement on a number of other issues that we think are important for us to provide our input on for your consideration. In general, we strongly believe that the problems that pose the greatest safety risks and that seriously impact Kent's economy should be addressed first.

Therefore, we strongly recommend that:

a. *The City should fix the Mill Creek problems first because they represent the greatest safety and economic risks to the City of Kent and its residents and businesses.*
b. *The City should endeavor to construct the priority projects included in the Drainage Master Plan as scheduled regardless of less defined other needs, e.g. the Green River Levee*
c. *The City should pursue the development of the relocation of the Mill Creek Stream channel between James Street and Chandler Bay Drive because of its multi-purpose benefits (A3, Alternative 1).*

We believe our recommendations are critical to the short- and long-term interests of the City of Kent, and its citizens and businesses. Should you want to discuss our recommendation in further detail, we would be happy to make arrangements to do so. We are also available for consultation and assistance as you move our recommendation forward through the City Council review process. Thank you for the opportunity to be truly engaged in the development the City of Kent's Drainage Master Plan. We also thank the City of Kent staff and the consultants working on the project for the informative presentations, candid discussions, and follow through in support of this committee.

Sincerely,

The City of Kent Drainage Master Plan Citizen Advisory Committee

Committee Signature Page

Sharon Bersaas, Mill Creek Neighborhood

Joe Heltzel, The Lakes at Kent

Karen Hoksbergen, 144th Avenue SE Neighborhood

Bridget Myers, Salt Air Hill Neighborhood

Len McCaughan, Mill Creek Neighborhood

John Nielsen, Mobile Oil & Service, North Kent Industrial

Mark Taylor, Superior Imaging Group, Kent Chamber of Commerce

APPENDIX B

LAND COVER ANALYSIS DOCUMENTATION

APPENDIX B – LAND COVER ANALYSIS DOCUMENTATION

1.1 Introduction

Land cover is one of the most important variables required to develop a hydrologic model. The land cover partitions precipitation into direct runoff, interception, or potential infiltration. To put it another way, one needs to identify the impervious area that contributes to direct precipitation, the vegetative cover that may intercept or transpire a portion of the precipitation, and the underlying soil conditions of the pervious areas that allow for infiltration and returns to surface water or losses to deep aquifers.

Section 4 of the DMP explains in general terms the procedures or processes that were followed when completing the hydrologic analysis of the study area. This discussion and appendix provides a greater level of detail to increase the reader's understanding and provide more detailed data that were used as input into the Hydrologic Simulation Program Fortran (HSPF) model for Mill Creek and the MGSFlood models that were used to evaluate runoff at the subcatchment level.

1.2 Available Data

The City maintains an extensive geographic information system (GIS) database record that was the primary source of information used in the land cover analyses. Those records include, but are not limited to, impervious area cover, soils, wetlands, aerial photography, topographic mapping (2-foot contour interval), storm drainage system infrastructure, existing zoning and comprehensive plan land use, and critical areas inclusive of steep slopes.

Other agency sources of information were used in evaluating the land cover including King County, Washington State Department of Ecology (Ecology), Washington Department of Fish and Wildlife (WDFW), U.S. Fish and Wildlife Service (USFWS), and Natural Resource Conservation Service (NRCS).

1.3 Impervious Area

The City's GIS database provides impervious area coverage that is comprised of roads, buildings, sidewalks, trials, etc., which are also available as separate coverages.

The impervious area coverage was compared to the 2006 aerial photography. It was found that the Green River Valley and much of the older subdivisions were reasonable well represented. However, substantial new commercial and residential development and redevelopment has occurred in West Hill. To update the impervious area coverage, the individual layers were updated and then combined with the impervious area coverage to create an "Existing Conditions" impervious coverage, which is shown on Figure 4-17 of the DMP.

Approximately 2,000 new buildings were added to the building coverage based on interpretation of the aerial photographs. Buffers were added to the sidewalk, trail, and road centerlines coverages (3, 4, and 12 feet, respectively) to map out new impervious transportation corridors. New parking areas were mapped for commercial properties, again based on interpretation of aerial photographs.

1.3.1 Comprehensive Plan Land Use and Land Cover

The City's Comprehensive Plan (City of Kent 2004; all references can be found in the City DMP Section 11 – References) land use designation coverage and zoning coverage was used to fine tune the variables in the existing conditions models as well as the basis for assessment of expected changes in future land use cover for consideration in hydrologic analysis and to maintain consistency of the DMP with that plan. Figure 4-18 of the DMP shows the various City-wide Comprehensive Plan land use designations.

1.3.1.1 Existing Conditions

To assist in calibration of the HSPF model, the land use designation was used as a method to assign "effective" impervious area. In developed commercial areas, roof runoff and parking runoff is collected and rapidly conveyed to the stormwater infrastructure; thus, the impervious area is 100 percent effective. However, in residential areas, it's common that roof runoff, especially the runoff discharged from the back of the house, is not routed to the stormwater system, even more so in low density development. Therefore, the impervious area is less than 100 percent effective. The City's impervious area database does not include driveways for single family homes; consequently, runoff from driveways may offset the runoff from portions of roofs.

1.3.1.2 Future Conditions

To estimate impervious area for future conditions, current zoning and land use designations were compared against individual parcels. Parcels for potential development or redevelopment were identified based on the value of the improvements on the parcel and comparison of the size of the parcel to the land use designation and zoning. For example, a 0.25-acre parcel with $300,000 of improvements in an area with an SR-4.5 land use designation is already developed and would be an unlikely candidate for redevelopment. Whereas a 2-acre parcel with similar land use designation and level of improvement is a candidate for redevelopment. A parcel with less than $50,000 worth of improvements is likely vacant and has potential for development. Commercial parcels were similarly screened.

All parcels identified were then reviewed with the aerial photography to confirm that they were vacant and with the critical area wetland and steep slope coverages to confirm that they were developable. In many cases, parcels that appeared to have potential for redevelopment were not suitable for redevelopment as they had large proportions of wetlands or steep slopes. Other parcels already had projects that were under construction but were not yet identified in the City's database. Ultimately, the parcels considered as available for development or redevelopment (City-wide) are shown on Figure 4-19 of the DMP.

For single family residential areas, land use densities associated with the Comprehensive Plan land use designation were compared to existing development conditions on those parcels, including consideration of critical areas, and engineering judgment was used to assign an estimated number of potential parcels that could be achieved with redevelopment. Impervious areas changes for residential areas were then assigned by applying a unit impervious area of 3,500 square feet per redevelopment parcel (to account for generally larger homes and new roads and sidewalks), and crediting back any existing structures at 2,500 square feet per parcel. The total impervious area was then applied and accounted for in GIS intersections with the drainage subbasins to identify the expected future increase in impervious cover for each (this was not done at the subcatchment level since future land cover was only analyzed for stream systems hydrologic modeling using subbasin-level land cover).

Generally, those parcels in existing commercial or industrial use with high impervious coverage (typically greater than 80 percent by observation) were left unchanged for future conditions since the impervious area coverage on them is already very high, and any redevelopment of them would likely maintain or lower the impervious area on them (detention controls to current standards would also be required under a redeveloped mitigated condition as discussed in Section 6 of the City DMP). For commercial and industrial zoned parcels with lower existing impervious cover and for multi-family zoned parcels, impervious area coverage assumptions of 80 percent and 65 percent were used for future conditions land cover consistent with the City's Transportation Improvement Program (TIP) assumptions (taken from TIP analysis spreadsheets furnished by City staff).

1.4 Pervious Areas

1.4.1 Vegetative Cover

For hydrologic modeling used in the stormwater runoff assessment, it is important to also distinguish between pervious land vegetative covers, namely forest, pasture, or grass. This was completed by visual interpretation of aerial photographs and was assigned at the subbasin level. Forested areas were interpreted where a significant expanse of tree coverage with a closed canopy exists. Otherwise, pasture was used in more natural areas where tree cover was limited and the vegetation is not actively managed (irrigated or mowed), and grass was assumed in other developed pervious areas where tree cover has been removed and has typically been replaced by lawn or other managed landscapes.

Consequently, much of the developed portions of the study area are classified as grass; forested areas are primarily limited steep areas not suitable for development; and pasture is land that has previously been cleared of timber, presumably for agriculture use (grazing), and has not yet been developed.

1.4.2 Wetlands

Wetlands areas are also important vegetative features. Although they may be pervious over the long term, when they are saturated, hydrologically, they behave as impervious areas. Runoff is rapid and generally directly to a water course. Wetlands were identified from City GIS coverage, King County GIS coverage, National Wetland Inventory coverage (USFWS), and from hydric soil mapping (NRCS) within the planning area. Figure 4-21 of the DMP shows the combined wetland areas.

1.4.3 Soils and Geologic Units Hydrologic Classification

When using HSPF or MGSFlood, in western Washington, soils are classified as either outwash, till, or saturated. Pervious land cover soils conditions within the planning area were assessed using the City's GIS database (soils, wetland, and water bodies coverage) along with NRCS soils descriptions and U.S. Geological Survey surficial geology descriptions. Each soil polygon in the City's database was assigned till, outwash, or saturated and the boundaries between like polygons were dissolved. Figure 4-20 in the DMP shows the resulting hydrologic soils classifications used for analysis. On a broad-scale, the Green River Valley floor remaining pervious areas were assigned a saturated soils condition (typically fine-grained floodplain soils in pasture, wetlands, or other water bodies). Wetlands and open water features were also designated saturated for the West and East Hill areas. Limited areas of outwash were also mapped in East and West Hill. The remainder of the West and East Hill pervious land areas were assigned as till.

1.5 Intersections

The land cover information was intersected using ArcView GIS with the drainage basins, subbasins, and subcatchments in two ways depending if the results were to be used for the HSPF or MGSFlood hydrologic models. The intersections for the HSPF model were completed first and the model calibrated to gaged flows in Mill Creek. Based on the calibration, it was determined that for the MGS model, the land use designation was not needed.

1.5.1 HSPF

The drainage subbasins, shown on Figures 4-2 through 4-16 of the DMP, were intersected with the Comprehensive Plan land use designations, then with soil hydrologic classification, and finally with the impervious area coverage. The areas of the resultant polygons were calculated with ArcView GIS and the resultant data exported to a spreadsheet, where the data were sorted, summed, and summarized. The pervious area vegetated cover was then assigned for each subbasin. The spreadsheets that summarize the land cover data for each subbasin evaluated using HSPF are included in the electronic Appendix B subfolder "HSPF Intersections" and one file is printed for reference and attached at the end of this discussion.

1.5.2 MGSFlood

The drainage subcatchments were intersected with the soil hydrologic classification and the impervious area coverage. Again, the resulting polygon areas were calculated and exported to a spreadsheet for sorting and summing. The spreadsheets that summarize the land cover data for each subcatchment evaluated using MGSFlood are included in the electronic Appendix B subfolder "MGSFlood Intersections" and one file is printed for reference and attached at the end of this discussion.

Effective Impervious Area Factors

Ag Resourse	1	Commercial	1
Ag Support	1	Urban Center	1
Parks and Open Space	1	Mixed Use	1
Urban Separator	1	Neighborhood Services	1
Single Family 3 Units/Acre	1	Industrial	1
Single Family 4.5 Units/Acre	1	Manufacturing/Industrial Center	1
Single Family 6 Units/Acre	1		
Single Family 8 Units/Acre	1		
Low Density Multifamily	1		
Medium Density Multifamily	1		
Mobile Home Park	1		

Land Use	Parks and Open Space							Urban Separator							Single Family 4.5 Units/Acre						
HSPF Land Type	Till		Outwash		Saturated		AI/TI	Till		Outwash		Saturated		AI/TI	Till		Outwash		Saturated		AI/TI
Pervious/Impervious	P	I	P	I	P	I	1	P	I	P	I	P	I	1	P	I	P	I	P	I	1
Basin B Subbasins																					
1E					5.71	0.26															
1W																					
2E					0.66																
2W					0.09	0.14															
3E					0.01																
3W						0.02							0.02								
4E																					
4W-1																					
4W-2																					
5E													0.1								
5W																					
6E													0.24								
6W																					
7E									0.12			0.65	1.01		3.92	0.21					
7W																					
8E															14.01	0.12					
8W																					
9E															5.54	0.07					
9W																					
10E															12.03	0.08					
10W																					
11E															17.4	0.19				0.28	

Land Use	Single Family 6 Units/Acre							Low Density Multifamily							Medium Density Multifamily							Mobile Home Park						
HSPF Land Type	Till		Outwash		Saturated		AI/TI	Till		Outwash		Saturated		AI/TI	Till		Outwash		Saturated		AI/TI	Till		Outwash		Saturated		AI/TI
Pervious/Impervious	P	I	P	I	P	I	1	P	I	P	I	P	I	1	P	I	P	I	P	I	1	P	I	P	I	P	I	1
Basin B Subbasins																												
1E																												
1W																												
2E																												
2W																												
3E																												
3W																												
4E																												
4W-1																												
4W-2																												
5E																												
5W																												
6E						0.52							0.01															
6W																												
7E	6.17	0.05			1.7	1.15																						
7W																										1.34	1.11	
8E	9.76				2.97	0.95		17.74	2.85			4.44	4.28		0.06													
8W																												
9E	9.72	0.31						2.39	0.06			0.77	0.16		12.21	5.99			2.39	0.77								
9W																			0.04									
10E	0.2	0.18													17.22	3.35			15.7	11.11								
10W					5.98														5.99	8.48								
11E	41	2.45			7.55										10.95	1.61			3.43	0.82								

Land Use	Commercial							Mixed Use							Industrial							Manufacturing/Industrial Center						
HSPF Land Type	Till		Outwash		Saturated		AI/TI	Till		Outwash		Saturated		AI/TI	Till		Outwash		Saturated		AI/TI	Till		Outwash		Saturated		AI/TI
Pervious/Impervious	P	I	P	I	P	I	1	P	I	P	I	P	I	1	P	I	P	I	P	I	1	P	I	P	I	P	I	1
Basin B Subbasins																												
1E																			0.85							5.91	16.4	
1W																			2.99	0.19						22.99	46.69	
2E																										9.3	3.51	
2W																										14.39	55.74	
3E	0.38				15.39	27.86													9.16	15.35						30.6	89.59	
3W																										5.96	16.77	
4E																										33.05	47.44	
4W-1																										19.94	68.77	
4W-2					0.09	6.82																				34.95	175.9	
5E																										21.7	2.59	
5W																										8.84	30.89	
6E						0.03																				6.06	7.67	
6W					0.02	0.1																				8.58	35.36	
7E																			3.73	1						2.81	5	
7W					4.5	5.32						0.24	0.23						9.34	12.12						1.41	7.93	
8E																0.01			5.89	6.31								
8W					0.26	1.43						1.33	3.45						3.11	13.01								
9E															0.01	0.11			17.43	16.69								
9W												4.37	4.8						10.68	5.85								
10E																			4.75	0.37								
10W																												
11E																												

Land Use	Total						Total	Effective Impervious Area			Pervious Land Cover		
HSPF Land Type	Till		Outwash		Saturated		Area	Till	Outwash	Saturated	Forest	Grass	Pasture
Pervious/Impervious	P	I	P	I	P	I					%	%	%
Basin B Subbasins													
1E	0	0	0	0	12.47	16.66	29.13	0	0	16.66		25	75
1W	0	0	0	0	25.98	46.88	72.86	0	0	46.88			100
2E	0	0	0	0	9.96	3.51	13.47	0	0	3.51			100
2W	0	0	0	0	14.48	55.88	70.36	0	0	55.88		50	50
3E	0.38	0	0	0	55.16	132.8	188.34	0	0	132.8		25	75
3W	0	0	0	0	5.96	16.81	22.77	0	0	16.81		50	50
4E	0	0	0	0	33.05	47.44	80.49	0	0	47.44	75		25
4W-1	0	0	0	0	19.94	68.77	88.71	0	0	68.77		50	50
4W-2	0	0	0	0	35.04	182.8	217.8	0	0	182.76		75	25
5E	0	0	0	0	21.7	2.69	24.39	0	0	2.69		75	25
5W	0	0	0	0	8.84	30.89	39.73	0	0	30.89		50	50
6E	0	0	0	0	6.06	8.47	14.53	0	0	8.47			100
6W	0	0	0	0	8.6	35.46	44.06	0	0	35.46		50	50
7E	10.09	0.38	0	0	8.89	8.16	27.52	0.38	0	8.16	50	25	25
7W	0	0	0	0	16.83	26.71	43.54	0	0	26.71		25	75
8E	41.57	2.98	0	0	13.3	11.54	69.39	2.98	0	11.54	80	10	10
8W	0	0	0	0	4.7	17.89	22.59	0	0	17.89		50	50
9E	29.87	6.54	0	0	20.59	17.62	74.62	6.54	0	17.62	75	10	20
9W	0	0	0	0	15.09	10.65	25.74	0	0	10.65			100
10E	29.45	3.61	0	0	20.45	11.48	64.99	3.61	0	11.48	60	10	30
10W	0	0	0	0	11.97	8.48	20.45	0	0	8.48		25	75
11E	69.35	4.25	0	0	10.98	1.1	85.68	4.25	0	1.1	60	25	15

Basin J

Subcatchment ID		H. Class		SURFACE	Area	Acres
J	01	1	saturated	P	11992.12	0.275301
J	01	1	saturated	I	2687.118	0.061688
J	01	1	till	P	219537.2	5.039881
J	01	1	till	I	8888.593	0.204054
J	02	1	saturated	P	0.965671	2.22E-05
J	02	1	saturated	P	266699	6.122566
J	02	1	saturated	I	1259.398	0.028912
J	02	1	saturated	I	109084.2	2.504229
J	02	1	till	P	652553.4	14.98056
J	02	1	till	I	9769.37	0.224274
J	03	1	saturated	P	97462.13	2.237423
J	03	1	saturated	I	43.88722	0.001008
J	03	1	saturated	I	21787.13	0.500164
J	03	1	till	P	310244.1	7.122224
J	03	1	till	I	8546.008	0.196189
J	04	1	saturated	P	61344.19	1.408269
J	04	1	saturated	P	287961.6	6.610688
J	04	1	saturated	I	215.2393	0.004941
J	04	1	saturated	I	16796.02	0.385584
J	04	1	saturated	I	83229.69	1.910691
J	04	1	till	P	138930.3	3.189401
J	04	1	till	P	1264405	29.02675
J	04	1	till	I	1780.085	0.040865
J	04	1	till	I	140735.1	3.230834
J	05	1	till	P	48822.35	1.120807
J	05	1	till	I	37451.25	0.859762
J	05	2	till	P	288811.5	6.6302
J	05	2	till	I	86213.3	1.979185
J	05	3	till	P	281813.7	6.469552
J	05	3	till	I	89462.61	2.053779
J	05	4	till	P	120189.8	2.759177
J	05	4	till	I	67867.44	1.558022
J	05	5	till	P	368952.3	8.469979
J	05	5	till	I	183258	4.207025
J	05	6	till	P	303569.5	6.968996
J	05	6	till	P	235.8042	0.005413
J	05	6	till	P	24937.09	0.572477
J	05	6	till	I	44792.14	1.028286
J	05	7	till	P	205782.7	4.724122
J	05	7	till	P	73655.14	1.690889
J	05	7	till	I	79474.73	1.824489
J	05	7	till	I	3156.219	0.072457
J	05	8	till	P	198845.8	4.564871
J	05	8	till	P	42658.77	0.979311
J	05	8	till	I	169646	3.894535
J	05	8	till	I	2462.288	0.056526
J	05	9	till	P	67177.37	1.54218
J	05	9	till	I	51258.5	1.176733
J	05	10	till	P	201155.6	4.617896
J	05	10	till	I	53065.82	1.218224
J	05	11	till	P	357385.9	8.20445
J	05	11	till	I	36794.66	0.844689
J	05	12	till	P	255573.9	5.867168
J	05	12	till	I	95571.01	2.194008

APPENDIX C

DECEMBER 3, 2007 FLOOD PHOTOGRAPHS AND HIGH WATER MARKS

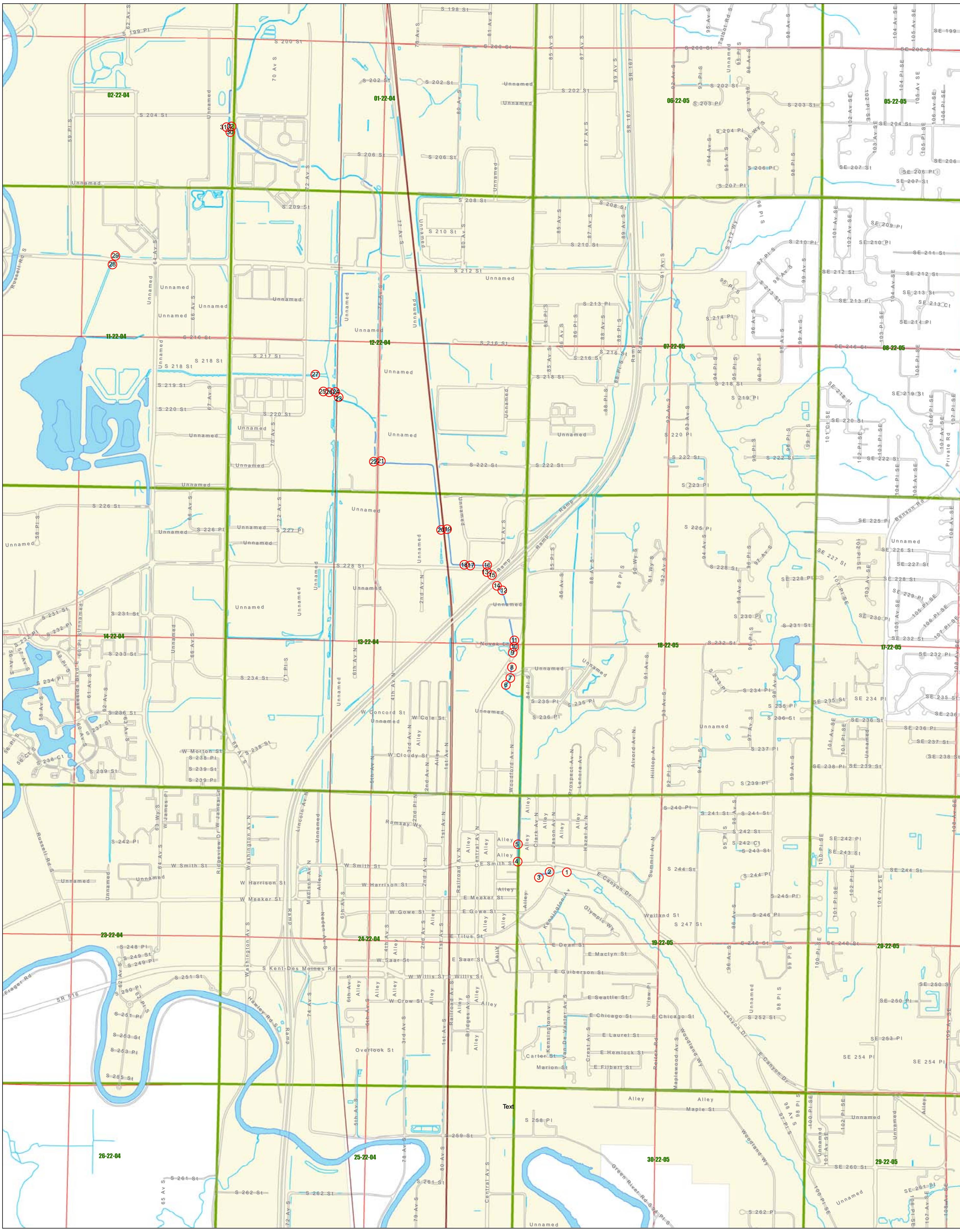
APPENDIX C – DECEMBER 3, 2007 FLOOD PHOTOGRAPHS AND HIGH WATER MARKS

On December 3, 2007, much of the Puget Sound region experienced a high intensity rainstorm after receiving moderate amounts of rainfall in the preceding days. Although compared to communities to the north (Renton and Bellevue) or the east (Bremerton), the City of Kent did not receive an extraordinary amount of precipitation. However, the rainfall event resulted in substantial flooding in the City along Mill Creek and Springbrook Creek.

Analysis of the gage data at Earthworks Park indicate that the flood event had a 2-year recurrence interval, which means that there is a 50 percent chance that a similar flood may occur in any particular year or on average a similar flow may occur every other year.

Anchor Environmental, L.L.C. (Anchor), staff toured the flooded areas, took photographs of the flooding, and placed stakes at the high water marks. The City survey crew later came back and surveyed the elevation of the high water marks. The survey data and photographic evidence was used to assist in calibration of the Mill Creek and Springbrook Creek hydraulic models.

Photographs taken during the flood can be found in the electronic Appendix C subfolder "Photographs." The high water mark survey data is printed and can be found in the electronic Appendix C subfolder "High Water Marks."



2007 Mill Creek High Water Study

#	Location	Description	Elevation
1	Earthworks Park Gauge @ 5 AM on 12/3/07	Water Level	44.81
2	Titus Street Bridge-downstream	HWM Stake	43.18
3	Culvert at Senior Center/Smith Street-upstream	HWM Stake	44.99
4	Smith Street-downstream	HWM Stake	40.36
5	Pedestrian Bridge downstream of Smith Street	Low Chord	39.45
6	Pedestrian Bridge upstream of Chandler Bay Apts. Drive	Low Chord	37.64
7	Chandler Bay Apts. Culvert-upstream	HWM Stake	36.42
8	Central Ave Culvert-upstream	HWM Stake	36.19
9	Central Ave Culvert-downstream	HWM Stake	35.71
10	Novak Lane-upstream	HWM Stake	35.76
11	Novak Lane-downstream	HWM Stake	35.68
12	SR 167-upstream	HWM Stake	34.83
13	SR 167-downstream	HWM Stake	33.61
14	SR 167-upstream	East 52" CMP Culvert IE	29.62
		West 52" CMP Culvert IE	29.54
		West 52" Iron Pipe Culvert IE	29.94
15	SR 167-downstream	East 52" CMP Culvert IE	28.59
		West 52" CMP Culvert IE	28.58
		East 52" CMP Culvert IE	29.19

#	Location	Description	Elevation
16	South 228th Street-downstream	HWM Stake	34.16
17	Fisher Industrial Park-upstream	HWM Stake	33.80
18	Fisher Industrial Park-downstream	HWM Stake	33.74
	BNRR Crossing-downstream of S. 228th St.		
19	Upstream Side	North 36" CMP Culvert IE	28.6
		South 36" CMP Culvert IE	28.81
20	Downstream Side	North 36" CP Culvert IE	27.56
		South 36" CP Culvert IE	27.87
21	76th Ave-upstream	HWM Stake	31.89
22	76th Ave-downstream	HWM Stake	31.18
23	UPRR Crossing-upstream of Interurban Bike Trail	Box Culvert Upstream IE	23.74
		Box Culvert Downstream IE	23.04
24	Interurban Bike Trail-upstream	HWM Stake	28.18
25	Interurban Bike Trail-downstream	HWM Stake	28.14
26	Interurban Bike Trail Bridge	Low Chord	32.69
27	Mill Creek Diversion Structure	Water Surface	28.22
28	Lagoon Discharge Canal-upstream	HWM Stake	26.04
29	Lagoon Discharge Canal-downstream	HWM Stake	26.17
30	Boeing Ditch confluence with Mill Creek	HWM Stake	23.35
31	Boeing Ditch confluence with Mill Creek	Water Surface	23.58
32	Staff Gauge at Boeing Ditch confluence with Mill Creek	Ground Level	17.43

All locations on map are for illustrative purposes only.

P:\Survey\Projects\Environmental\2007 Mill Creek High Water Marks

APPENDIX D

HYDROLOGIC ANALYSIS DOCUMENTATION

APPENDIX D – HYDROLOGIC ANALYSIS DOCUMENTATION

1.1 Introduction

The receiving waters and the trunk storm drain (TSD) systems were analyzed using continuous simulation models. As described in the DMP, HSPF was used for the receiving waters and a specially developed version of MGSFlood was used to generate flows for subcatchment areas for TSD hydraulic analyses.

1.2 HSPF

HSPF was used to model the hydrology of the Mill Creek drainage from its headwaters in West Hill to the boundary with Renton on the north side of the City. Several models are used to represent the entire Mill Creek system. In addition, several other model runs were developed to show the benefits of diverting a portion of the flow Basin A directly to the Green River Natural Resource Area (GRNRA) and another model to show the combined benefits of this diversion plus a pump station from the GRNRA to the Green River.

The electronic Appendix D subfolder “HSPF” contains HSPF model input files and the Watershed Data Management (WDM) file:

- Upper Mill Creek (upstream of EarthWorks Park) HSPF model (Existing 2008 conditions): *UppMillEx_v4.uci* (dated 04/01/08)
- Lower Mill Creek (downstream of EarthWorks Park) HSPF model (Existing 2008 conditions): *LowerMillEx_v6e.uci* (dated 05/19/08)
- Lower Mill Creek (with recommended improvements) HSPF model: *LowerMill_May2008_Alt1.uci* (dated 05/27/2008)
- Lower Mill Creek (with improvements including GRNRA pumping) HSPF model: *LowerMill_May2008_Alt2.uci* (dated 05/27/2008)
- Springbrook Creek (Existing 2008 Conditions) HSPF model: *SpringbkEx_v4.uci* (dated 04/21/08)
- Garrison Creek/Upper Springbrook HSPF model (Pre-existing Conditions model from others): *GarSpkExPhase1_v1.uci* (dated 04/21/08)
- HSPF database: *Kent.WDM* (dated 05/29/08)

1.3 MGSFlood

MGSFlood was run for approximately 2,500 subcatchments to estimate flows for evaluation of the TSD system. The electronic Appendix D subfolder "MGSFlood" contains a graphic for each drainage basin to show the density of subcatchments, a summary of flows for the Phase 1 and Phase 2 basins, and a subfolder for each drainage basin. In each of these subfolders are additional subfolders for subbasins or groups of subbasins. In each of these subfolders there are at least two files. The first is the MGSFlood input file "**.fld*," the second is the MGSFlood summary report file "**.rpt*," and there may be one or more "**.GSP*" files, which are temporary graphic driver files and cannot be viewed directly.

APPENDIX E

UPPER MILL CREEK STORAGE EVALUATION

APPENDIX E – UPPER MILL CREEK STORAGE EVALUATION

MGS Engineering Consultants, Inc. (MGS), was tasked with evaluating the flood protection benefits of raising the spillway elevation to increase storage and reconfiguring the diversion structure and the outlet works of the Upper Mill Creek Detention Facility.

MGS Engineering Consultants, Inc.

7326 Boston Harbor Road NE
Olympia, WA 98506
(360) 570-3450
www.mgsengr.com

MEMORANDUM

May 23, 2008

To: Jerry Bibee, P.E., Anchor Environmental

From: Bruce Barker, P.E., MGS Engineering Consultants, Inc.

Subject: Upper Mill Creek Watershed Hydrologic Analysis

Analysis Overview/Summary

This memorandum summarizes results of a hydrologic analysis of the upper Mill Creek tributary located in the City of Kent. The analysis was performed as part of the Kent Drainage Master Plan Update in cooperation with Anchor Environmental.

The Hydrologic Simulation Program-Fortran (HSPF)[1] model was used with existing and future build-out land use, and included an assessment of the performance of two existing regional detention facilities; the Upper Mill Creek Pond and the Mill Creek Canyon Pond. In addition, the effectiveness of a proposal to increase the flood storage at the Upper Mill Creek Pond was evaluated.

Results of the analysis shows that expansion of the Upper Mill Creek Pond reduces the 100-year peak discharge rates by ⅔ relative to current conditions in the reaches immediately downstream of the Upper Pond. Downstream of this location, additional runoff enters from urbanized areas, principally from the north, increasing the peak discharge and volume. Peak flow rates are again reduced at the Mill Creek Canyon Pond because of the increased storage from the proposed improvements to the structure required by the State Dam Safety office. Downstream of the Mill Creek Canyon Pond, the 100-year peak discharge rate is reduced by about 10-percent and the duration of the 100-year peak discharge is also significantly reduced.

HSPF Model Calibration

The HSPF model used in the analysis was configured using runoff parameters developed by the USGS for the Puget Sound Lowlands[2]. The model was calibrated by comparing simulated and recorded streamflow at the Mill Creek Canyon detention facility for the period of January 1994 through September 2005. The gage is operated by the USGS (Gage 12113347) in cooperation with the City of Kent. Local precipitation data supplemented with data from the Sea-Tac gage were used as input to the model for calibration purposes (Table 1).

Table 1 – Precipitation Gages Used for Model Calibration

Period	Gage	Time Step
4/1992-10/1998	King County Springwood Gage	15-Minutes
10/1998-10/2000	Sea-Tac Airport	1-Hour
10/2000-10/2005	Sequoia Jr. High School	15-Minutes

Comparisons of simulated and recorded mean daily discharge are presented in Figures 1-4. While hourly or 15-minute comparisons would have been preferable, only mean daily and annual maximum recorded flow data were readily available.

Results of the Calibration show a reasonably close match between simulated and recorded discharge across the range of discharges simulated. The coefficient of determination (R^2) in Figure 2 provides an indication of the overall strength of the relationship between the simulated and recorded discharge. In this case, 73% of the variance in the recorded flows is explained by the regression with simulated flows. This is typical of continuous model calibration accuracy achieved for stormwater applications in the Puget Sound lowlands

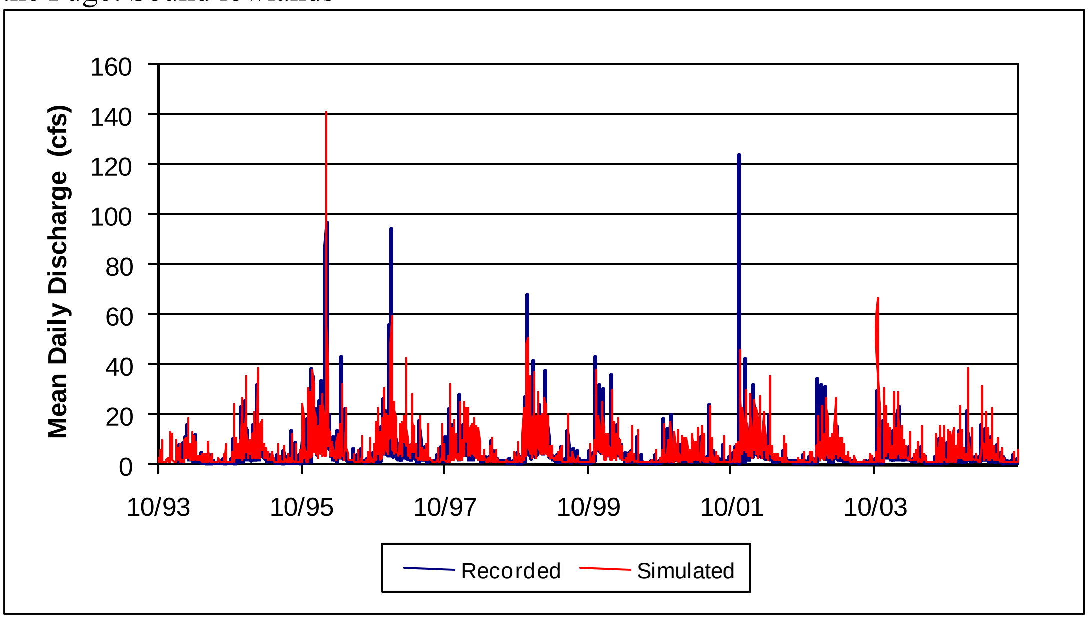


Figure 1 – Comparison of Simulated and Recorded Mean Daily Discharge at Mill Canyon Pond Outlet (USGS Gage 12113347) (10/1/1993-9/30/2005)

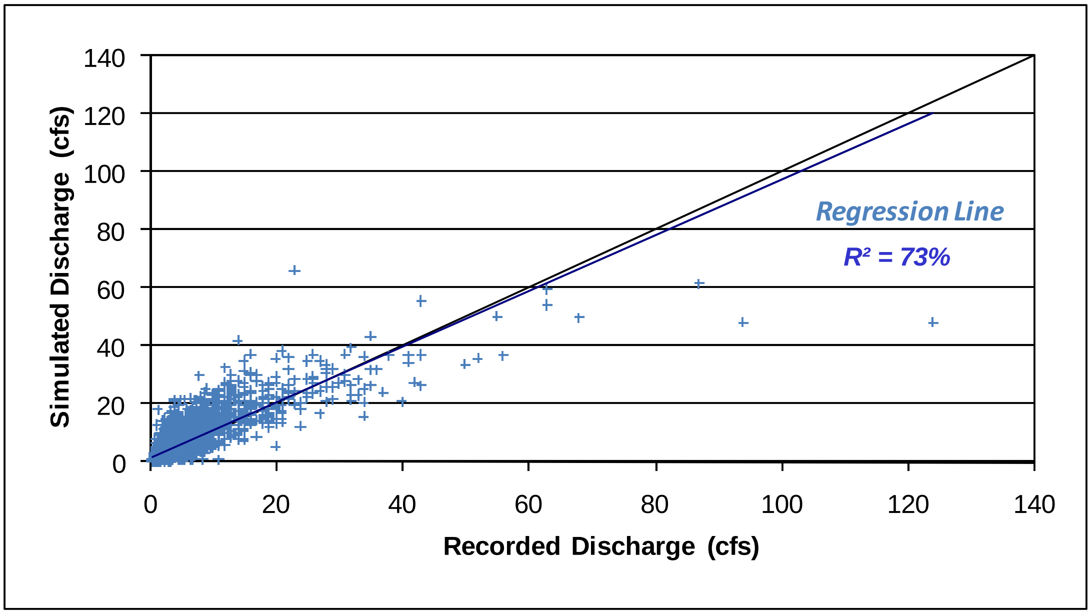


Figure 2 – Comparison of Simulated and Recorded Mean Daily Discharge at Mill Canyon Pond Outlet (USGS Gage 12113347)

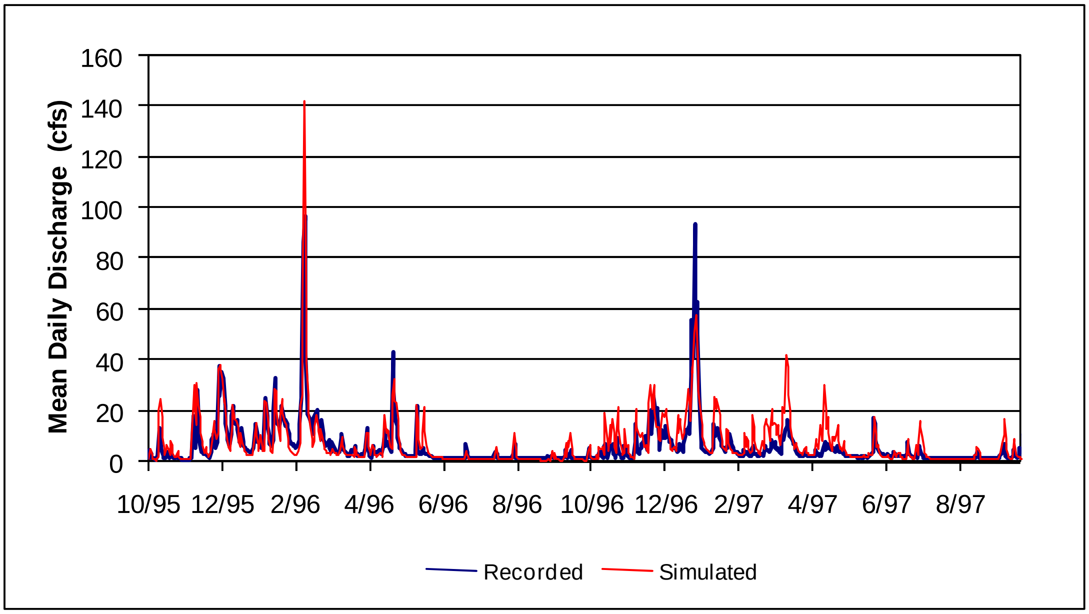


Figure 3 – Comparison of Simulated and Recorded Mean Daily Discharge at Mill Canyon Pond Outlet, Water Years 1996-1997 (USGS Gage 12113347)

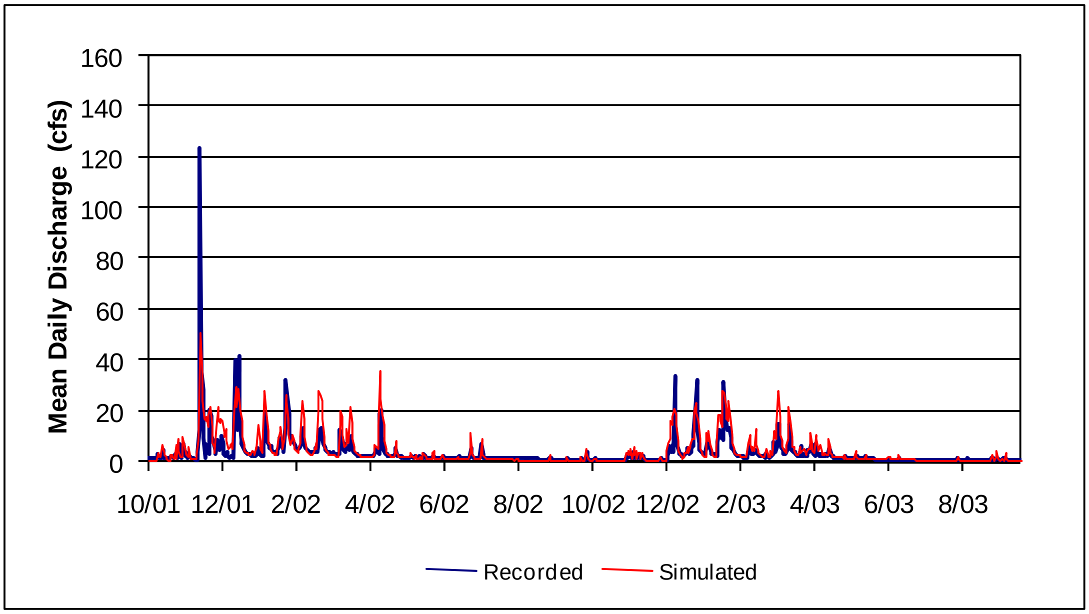


Figure 4 – Comparison of Simulated and Recorded Mean Daily Discharge at Mill Canyon Pond Outlet, Water Years 2002-2003 (USGS Gage 12113347)

Simulated and recorded annual maximum peak discharge rates are summarized in Table 2.

Table 2 – Comparison of Recorded and Simulated Peak Annual Maximum Discharge Rate for Calibration Period

	Annual Maximum Discharge Rate (cfs)	
Peak Discharge Date	**Recorded**	**Simulated**
Mar 03, 1994	31	39
Nov 30, 1994	52	54
Jan 01, 1997	160	76
Dec 16, 1997	56	62
Nov 21, 1998	92	85
Feb 01, 2000	88	72
Nov 26, 2000	74	68
Nov 14, 2001	233	70
Jan 02, 2003	114	52
Nov 20, 2003	58	84
May 20, 2005	50	56

The model underestimated peak discharge for two significant floods in the calibration period; January 1, 1997 and November 14, 2001. Under-simulation of the January 1997 flood was likely the result of runoff being augmented by snowmelt. Several inches of snow were present throughout the watershed at the onset of the January storm. Simulation of snow accumulation and melt was not included in the HSPF model because large snowmelt floods are rare in the Puget Lowlands.

Model under-simulation of the November 2001 flood was likely the result of vandalism at the Upper Mill Creek dam. According to City personnel, vandals opened the slide gates at the upper dam during the November 2001 storm causing a much higher flow rate in the downstream reaches than would have occurred normally.

Another source of model prediction uncertainty may be attributed to the accuracy of discharge measurements. Flow depth is recorded at the control manhole at the Mill Canyon Pond and converted to discharge using culvert hydraulic calculations. During times of high discharge, turbulent flow conditions in the outlet structure make accurate flow depth measurements difficult. It is not known whether the high flow measurements indeed have a higher degree of uncertainty; however, the data and gage location should be examined in cooperation with the USGS to determine their accuracy and adjustments made if necessary to improve their quality.

Simulation Scenarios Evaluated

Two scenarios were analyzed with the HSPF model; existing conditions and future land use conditions with flow mitigation. The existing land use condition was developed using impervious surface and aerial photograph GIS coverages of the watershed. Summary tables of existing and future land use are listed in the Appendix.

The future land use scenario was developed by identifying those parcels that would likely be developed or redeveloped in the future. This was accomplished by comparing their present level of development with the development level allowed by current zoning. Parcels with development density substantially less than the current zoning and those that did not contain sensitive areas (steep slopes or wetlands) were assumed to be redeveloped at current zoning levels.

On-site detention was included for the parcels that were determined to be developed in the future. On-site detention was simulated in the model by including a reach in each subbasin that represents the aggregate routing effect of future stormwater detention in the subbasin. The dominant land use type associated with the redeveloped parcels in each subbasin was used to assign one of the four on-site stormwater ponds listed in Table 3 to the future developed area in each subbasin.

Table 3 – Detention Ponds Assigned to Redeveloped Land Use in Each Subbasin
(One Detention Pond Was Assigned to Future Developed Areas in Each Subbasin)

Pond	Release Standard*	Predeveloped Land Use	Developed Land Use
Valley Residential	Level 1	25% Impervious, 75% Valley Perlnd	60% Impervious, 40% Valley Perlnd
Valley Commercial	Level 1	25% Impervious, 75% Valley Perlnd	90% Impervious, 10% Valley Perlnd
Upland Residential	Level 2	25% Impervious, 75% Till Grass	60% Impervious, 40% Till Grass
Upland Commercial	Level 2	25% Impervious, 75% Till Grass	90% Impervious, 10% Till Grass

* Release Standards are defined in the 2005 King County Surface Water Design Manual[3]

Modifications to the two existing regional detention projects were analyzed as part of the future land use scenario. The intent of these projects was to reduce the magnitude and flooding along Mill Creek to the greatest extent possible relative to current land use condition scenario. The regional stormwater projects included expansion of the Upper Mill Creek Stormwater Pond and inclusion of proposed dam safety modifications to the Mill Canyon Pond per design plans by RW Beck[4].

The improvements at the Upper Mill Creek Pond included a redesigned inflow diversion structure and a 5.5 foot dam raise. The redesigned diversion structure will allow fish passage in Mill Creek above the diversion, which the current structure does not afford. The structure will maintain approximately 10 cfs in the stream before flows are diverted to the Upper Mill Creek Pond. The outlet at the Upper Mill Creek Dam was simulated as a 36” pipe with a sluice gate to regulate flow. The sluice gate opening operations were designed to reduce flows to the greatest extent possible without discharging through the overflow spillway. The simulated sluice gate operations as simulated in the model are summarized in Table 4. The proposed modifications would increase the effective detention storage from 90 acre-feet to 150 acre-feet. A comparison of the existing and proposed pond hydraulic rating curves is shown in Figure 5.

Table 4 – Upper Mill Creek Pond Proposed Principal Outlet Gate Operations

Water Surface Elevation in Pond (feet NAVD88)	36" HDPE Outlet Sluice Gate Opening (inches)	Notes
333.00	8 inches	Outlet Invert Elevation
345.00	10 inches	
348.50	Full Open	Emergency Spillway Crest

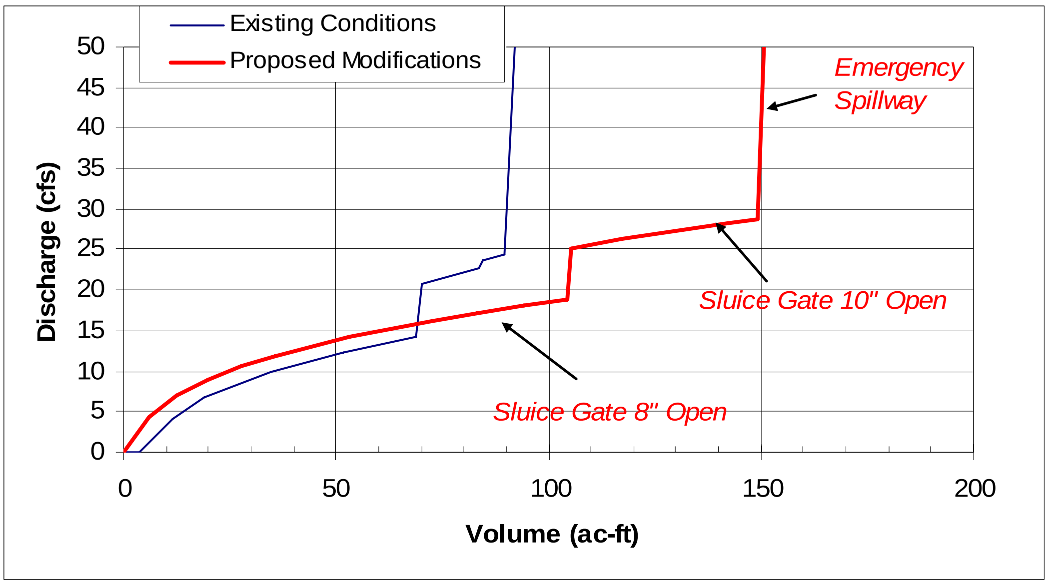


Figure 5 – Upper Mill Creek Pond, Comparison of Existing and Proposed Hydraulics

The modifications designed by RW Beck for the Mill Canyon Pond were intended to increase the discharge capacity for extreme floods to meet State Dam Safety design criteria. The improvements included raising the dam crest by 2-feet, constructing a new 46-foot wide emergency spillway, and raising the crest elevation of the drop inlet structure by 1-foot. While the goal of these improvements was to meet dam safety design criteria, they also provide a flood control benefit because the detention storage would be increased by approximately 3 acre-feet (Figure 6).

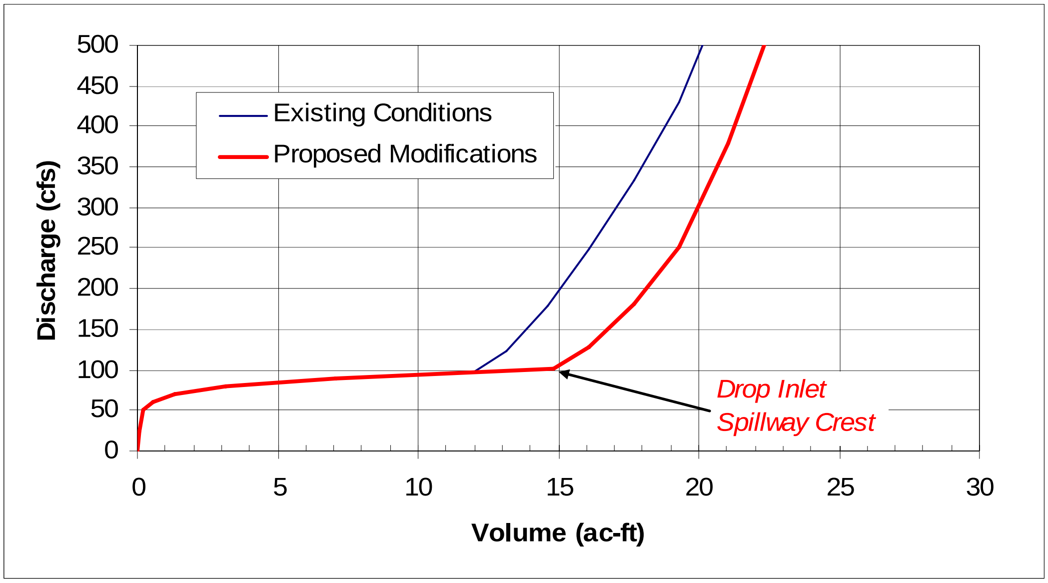


Figure 6 –Mill Creek Canyon Pond at Earthworks Park, Comparison of Existing and Proposed Hydraulics

Hydrologic Analysis Methods
The calibrated HSPF model was used to compute flood frequency and duration statistics for locations along the Upper Mill Creek watershed to quantify the likelihood of flooding along the stream and evaluate the effectiveness of proposed mitigation options.

The Pierce County Extended Precipitation Time Series for Continuous Hydrologic Modeling[5], 40-inches mean annual precipitation was used as input to the HSPF model for the hydrologic analysis of the Upper Mill Creek sub-watershed. The rainfall data has a time step of 15-minutes, is 158-years in length, and represents the rainfall characteristics of the Upper Mill Creek watershed.

Peak flow and water surface elevation magnitude-frequency estimates were computed at locations of interest in the model. Peak flow and elevation magnitude-frequency relationships were computed using the Gringorten[6] plotting position formula (Equation 1).

$$Tr = \frac{N + 0.12}{i - 0.44} \qquad (1)$$

Where: Tr is the recurrence interval of the peak flow,
i is the rank of the annual maxima peak flow or water surface elevation ordered from highest to lowest,
N is the total number of years simulated (158 in this case).

Flow duration analyses were also performed at locations along the main tributary. Flow duration statistics provide a convenient method for characterizing streamflow computed with a continuous hydrologic model. Duration statistics are computed by tracking the fraction of simulation time that a specified flow rate is equaled or exceeded. The program does this by dividing the range of flows simulated into discrete increments and then tracks the fraction of time that each flow is equaled or exceeded.

Analysis Results, Current Conditions Scenario

Computed flood-frequency results along the mainstem of Upper Mill Creek are shown in Figures 7 and 8 for the 25-year and 100-year recurrence intervals, respectively.

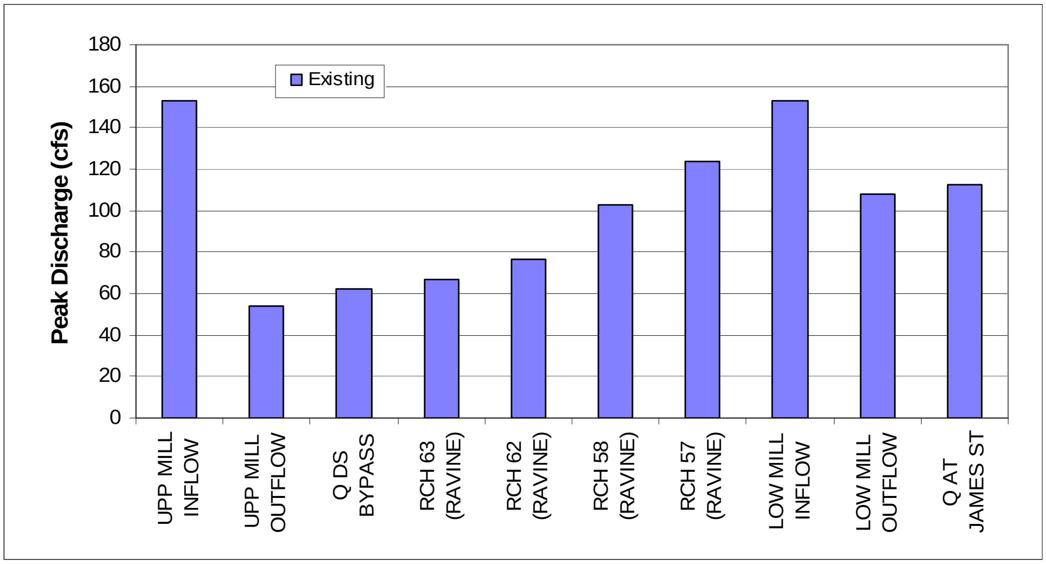


Figure 7 – Upper Mill Creek Mainstem, 25-Year Flood Recurrence Interval Summary Existing Conditions

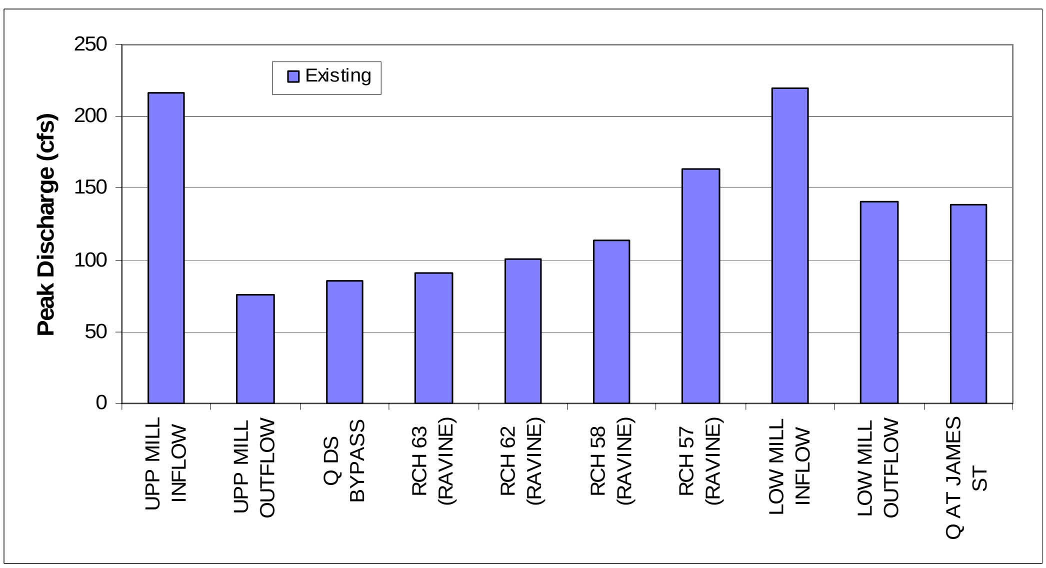


Figure 8 – Upper Mill Creek Mainstem, 100-Year Flood Recurrence Interval Summary Existing Conditions

Figures 7 and 8 show the progression of flood peak discharge from the upper watershed, through the Upper Mill Creek Stormwater Pond, the upper ravine, through Mill Canyon Pond, and finally to the James Street Crossing. Examination of these figures shows a dramatic reduction in flood peak discharge through the Upper Mill Creek Pond. Downstream of the Upper Mill Pond, additional runoff enters from urbanized areas, principally from the north, increasing the peak discharge rate and volume.

Peak flow rates are again dramatically reduced at the Lower Mill Creek Canyon Pond. While this facility has a low storage volume relative to the tributary area, the facility is nonetheless effective because the floods entering the facility are flashy, with high peak rate relative to the runoff volume. Floods larger than about a 25-year recurrence interval discharge through the overflow spillway (Figure 9).

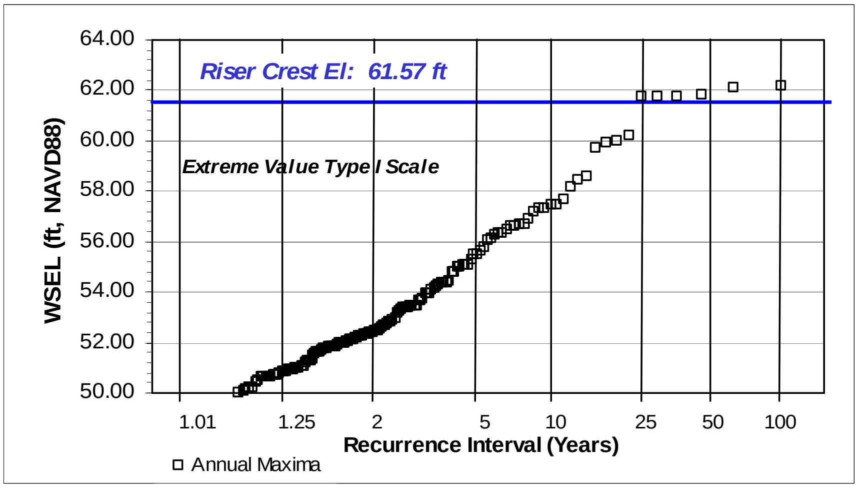


Figure 9 – Mill Canyon Pond Water Surface Elevation-Frequency, Existing Conditions (Note: Overflow Spillway Operates at between a 25-year Recurrence Interval)

The Upper Mill Creek Pond is currently providing substantial peak flow reduction for runoff entering from the highly urban upper watershed for floods up to about a 20-year recurrence interval (Figure 10). Floods larger than this overflow through the spillway and the flow reduction is not as great but still considerable. The 100-year flood peak is reduced from 215 cfs to 75 cfs. Additional flood storage at this location would provide better attenuation for more rare floods (out to the 100-year recurrence interval or larger).

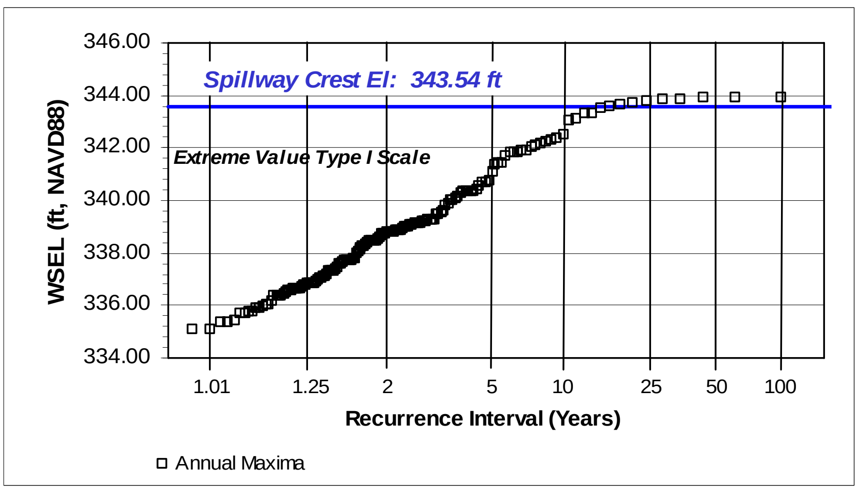


Figure 10 – Upper Mill Creek Pond Water Surface Elevation-Frequency Existing Conditions (Note: Overflow Spillway Operates at a 20-year Recurrence Interval)

Analysis of Future Land Use with Flow Reduction Projects
Flooding has been identified downstream of the Mill Creek Canyon Pond in the vicinity of Central Avenue and James Street. Reducing the flooding potential at this location will require a combination of channel capacity improvements and upstream flow reduction. Locations for additional stormwater control in the upper watershed are limited and on-site detention associated with the development and redevelopment of parcels in the watershed provides a relatively small benefit because of the high level of current development.

Simulation results demonstrating the effectiveness of expanding the flood storage capacity at the Upper Mill Creek Pond and the implementation of the Mill Creek Canyon Pond dam safety improvements is shown in Figure 11. Downstream of the Upper Mill Creek Pond, the 100-year peak discharge rate is reduced by ⅔ relative to current conditions. Downstream of this location, runoff enters from urbanized areas increasing the peak discharge rate and volume. The increased detention volume associated with the proposed facility expansion reduced the likelihood of discharge through the overflow spillway from a 20-year recurrence interval currently, to near a 500-year recurrence interval (Figure 12).

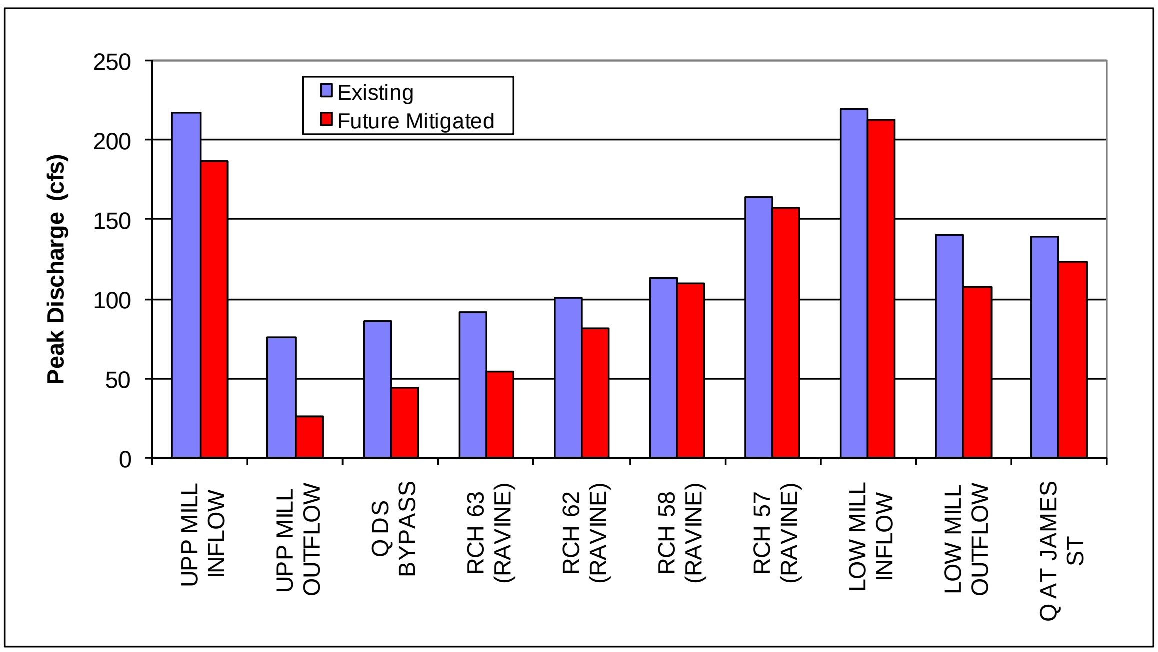


Figure 11 – Upper Mill Creek Mainstem, 100-Year Flood Recurrence Interval Summary Comparison of Existing Conditions and Future Land Use with Mitigation

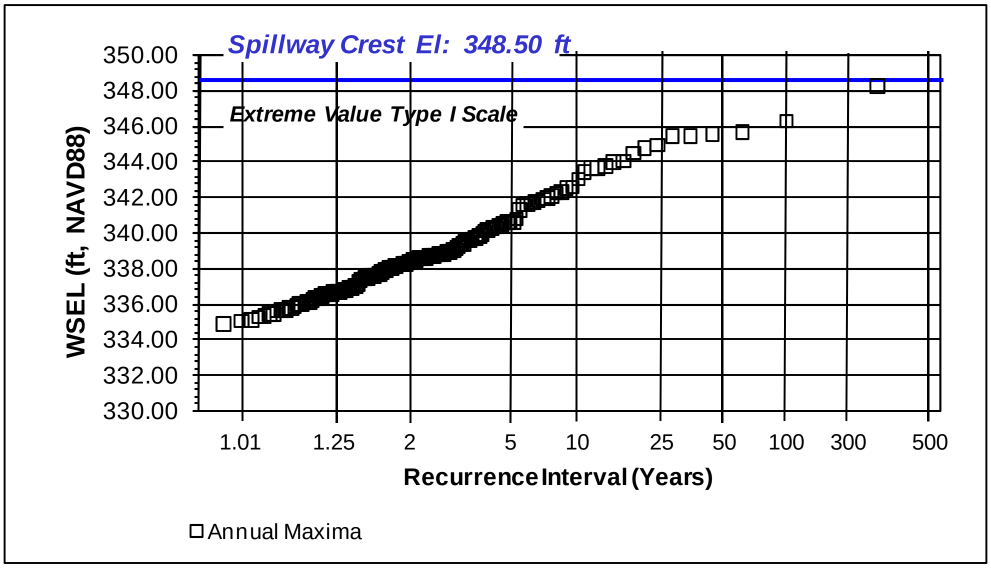


Figure 12 – Upper Mill Creek Pond Water Surface Elevation-Frequency
Future Mitigated Conditions
(Note: Overflow Spillway Operates at Approximately a 500-year Recurrence Interval)

The additional 3 acre-feet of flood storage at the Mill Creek Canyon Pond provides a modest increase in flood reduction benefit. The 100-year outflow from the pond was reduced from 140 cfs under current conditions to 105-cfs. At James Street, the 100-year peak discharge was reduced from 140 cfs to about 125 cfs. The increased detention volume reduced the likelihood of discharge through the overflow spillway from about a 25-year recurrence interval currently, to near a 100-year recurrence interval (Figure 13).

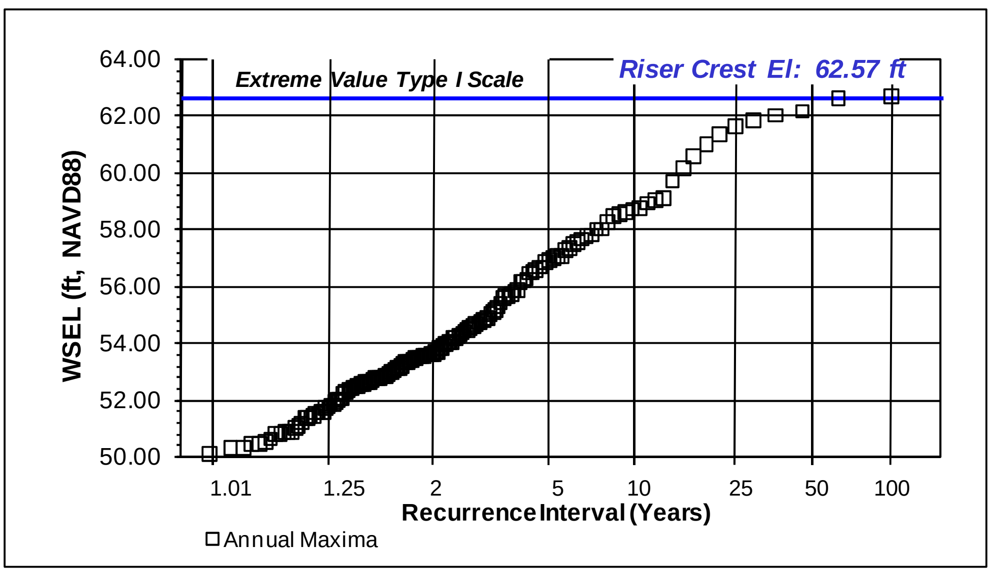


Figure 13 – Mill Canyon Pond Water Surface Elevation-Frequency
Future Mitigated Conditions
(Note: Overflow Spillway Operates at a 100-year Recurrence Interval)

On-site detention associated with future development in the watershed had a minor effect on the simulation results. This was due to the relatively small number of parcels that are expected to be developed or redeveloped in the near future. These areas accounted for approximately 20 percent of the watershed area. In reality, the effectiveness of on-site detention controls would be expected to be greater than the simulations indicate because these ponds were sized conservatively small for this analysis.

In addition to reducing the flood peak discharge, the future mitigated condition also reduced the duration of flooding relative to current conditions. Flow duration statistics were used to compute the number of hours during the simulation that the current condition 100-year flood was exceeded (Table 5).

Values in Table 5 show the reduction in the duration of flooding for future mitigated conditions relative to current conditions. In the upper watershed, the increased stormwater detention at the upper Mill Creek Pond reduced runoff rates for the future mitigated condition such that the maximum discharge was below the current 100-year discharge. This resulted in values of 0 hours for the upper three reaches listed in the table for the future mitigated condition scenario. Downstream at the James Street crossing, the 100-year discharge duration was reduced from 8 hours under current conditions to 3 hours under the future mitigated scenario.

Table 5 – Comparison of 100-year Peak Exceedance Duration, Existing and Future Mitigated Conditions

Location	Existing Condition 100 Year Discharge (cfs)	Total Hours Current 100-Year Flow is Exceeded During 158-Year Simulation	
		Existing Conditions	Future Mitigated Conditions
Upper Mill Pond Inflow	215	0.7	0
Upper Mill Pond Outflow	75	4	0
Middle Ravine (Reach 62)	100	4	0
Mill Canyon Pond Inflow	220	0.4	0.2
Mill Canyon Pond Outflow	140	4	2
James Street Crossing	***140***	***8***	***3***

Recommendations

The following summarize recommendations based on the hydrologic analysis presented in this memorandum.

1. Raise Upper Mill Creek Pond Dam
   The spillway at the Upper Mill Creek Pond spillway currently operates at around a 20-year recurrence interval. For larger floods, the reduction provided by the pond will be progressively less and result in a dramatic increase in flooding along Lower Mill Creek. It is recommended that the Upper Mill Creek Pond dam be raised 5.5-feet to reduce the likelihood of overtopping to at least a 100-year recurrence interval.

   Because of the high discharge rates that occur when the capacity of this structure is exceeded, and the amount of infrastructure that would be impacted by flood waters along the lower reaches of Mill Creek, it would be prudent to increase the design level to a 1 in 500 Annual Exceedance Probability (AEP) or larger. This recommendation follows a risk-based design approach whereby the design conservatism is a function of the consequences of potential downstream flood damages. Model simulations show that the 5.5-foot raise recommended here meets the 1 in 500 AEP design goal.

2. Flow Monitoring at Upper and Lower Ponds
   The performance of the Upper Mill Creek Pond is key to mitigating the high peak discharge rates from the upper basin. Monitoring of flows immediately downstream of the pond and water surface elevation data in the pond and at the diversion structure should be performed using continuous recording devices.

   The gage at the Mill Creek Canyon Pond should be evaluated to ensure that accurate measurements are being made for high discharge rates. Turbulence in the control manhole may necessitate moving the gage to another location where high flows can be more accurately measured. The data recorded previously, and the current gage configuration should be evaluated in coordination with the USGS to determine the suitability of the current gage site and any adjustments that may be needed to improve data quality.

   The monitoring data should be analyzed periodically to evaluate the performance of the stormwater ponds. The operation plan for each pond should be adjusted as necessary to maximize the flood control benefit. The monitoring data could also be used to refine the HSPF model developed for this study and aid in future assessments of the stormwater facility performance.

3. Install Debris Barriers/Trash Racks at Upper Mill and Mill Canyon Ponds
   The performance of the two regional ponds in the Upper Mill Creek basin is dependent on the outlets being free of debris, which is often mobilized during large floods. Debris barriers and trash rack systems should be designed to minimize the head loss through the outlets of these ponds during floods.

4. Central Basin Flow Reduction through Enhanced On-Site Controls
   Downstream of the upper dam, additional runoff enters from urbanized areas, principally from the north, increasing the peak discharge and volume.

   A combination of on-site detention and Low Impact Development (LID) methods could be implemented to reduce the high flows entering the Upper Mill Creek ravine. LID methods could include downspout disconnection, rain gardens, open ditches that promote infiltration, and others.

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6. Stedinger JR, Vogel RM, and Foufoula-Georgiou E, Frequency Analysis of Extreme Events, Chapter 18, *Handbook of Hydrology*, McGraw Hill, 1992.

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APPENDIX

Peak Discharge Estimates at Locations Along Upper Mill Creek for Existing Conditions Scenario

Scenario 1 Existing Conditions Magnitude-Frequency Statistics					
Tr (Years)	**UPP MILL INFLOW (cfs)**	**UPP MILL OUTFLOW (cfs)**	**Q DS BYPASS (cfs)**	**RCH 63 (RAVINE) (cfs)**	**RCH 62 (RAVINE) (cfs)**
1.01	28	6	11	13	17
1.5	54	10	17	19	26
2	63	11	18	21	29
5	92	14	22	32	40
10	131	26	33	46	67
25	153	54	62	67	76
50	213	72	81	86	93
100	217	76	86	91	101

Scenario 1 Existing Conditions Magnitude-Frequency Statistics (Continued)					
Tr (Years)	**RCH 58 (RAVINE) (cfs)**	**RCH 57 (RAVINE) (cfs)**	**LOW MILL INFLOW (cfs)**	**LOW MILL OUTFLOW (cfs)**	**Q AT JAMES ST (cfs)**
1.01	21	26	33	32	38
1.5	33	44	55	53	62
2	37	48	62	57	67
5	52	68	91	74	86
10	87	105	143	92	102
25	102	124	153	108	112
50	111	154	201	119	129
100	113	164	220	141	139

Peak Discharge Estimates at Locations Along Upper Mill Creek for Future Mitigated Scenario

Scenario 2 Future Mitigated Conditions Magnitude-Frequency Statistics					
Tr (Years)	UPP MILL INFLOW (cfs)	UPP MILL OUTFLOW (cfs)	Q DS BYPASS (cfs)	RCH 63 (RAVINE) (cfs)	RCH 62 (RAVINE) (cfs)
1.01	29	7	15	17	22
1.5	52	11	22	25	33
2	60	12	24	27	35
5	87	15	29	35	47
10	121	18	36	45	61
25	139	22	39	49	70
50	183	26	42	53	74
100	187	26	44	55	81

Scenario 2 Future Mitigated Conditions Magnitude-Frequency Statistics (Continued)					
Tr (Years)	RCH 58 (RAVINE) (cfs)	RCH 57 (RAVINE) (cfs)	LOW MILL INFLOW (cfs)	LOW MILL OUTFLOW (cfs)	Q AT JAMES ST (cfs)
1.01	27	34	41	41	48
1.5	40	51	64	60	69
2	43	56	71	64	74
5	62	81	102	80	91
10	82	110	140	93	109
25	92	122	156	98	112
50	102	140	193	101	117
100	109	157	213	107	123

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Flow Duration Statistics for Locations Along Upper Mill Creek for Existing and Future Mitigated Scenarios

Scenario 1 – Existing Conditions

Location	Discharge Corresponding to Exceedance Probability (cfs)			
	90%	50%	20%	10%
UPP MILL INFLOW	0.09	0.57	1.3	1.9
UPP MILL OUTFLOW	0.11	0.71	1.6	3.0
Q DS OF BYPASS	0.18	1.2	4.1	7.2
REACH 63 RAVINE	0.19	1.2	4.3	7.7
REACH 62 RAVINE	0.20	1.3	4.6	8.6
REACH 58 RAVINE	0.22	1.4	5.1	9.7
REACH 57 RAVINE	0.25	1.7	5.8	10.9
LOW MILL INFLOW	0.28	1.9	6.5	12.2
LOW MILL OUTFLOW	0.28	1.9	6.5	12.2
Q AT JAMES ST	0.30	2.0	7.0	13.1

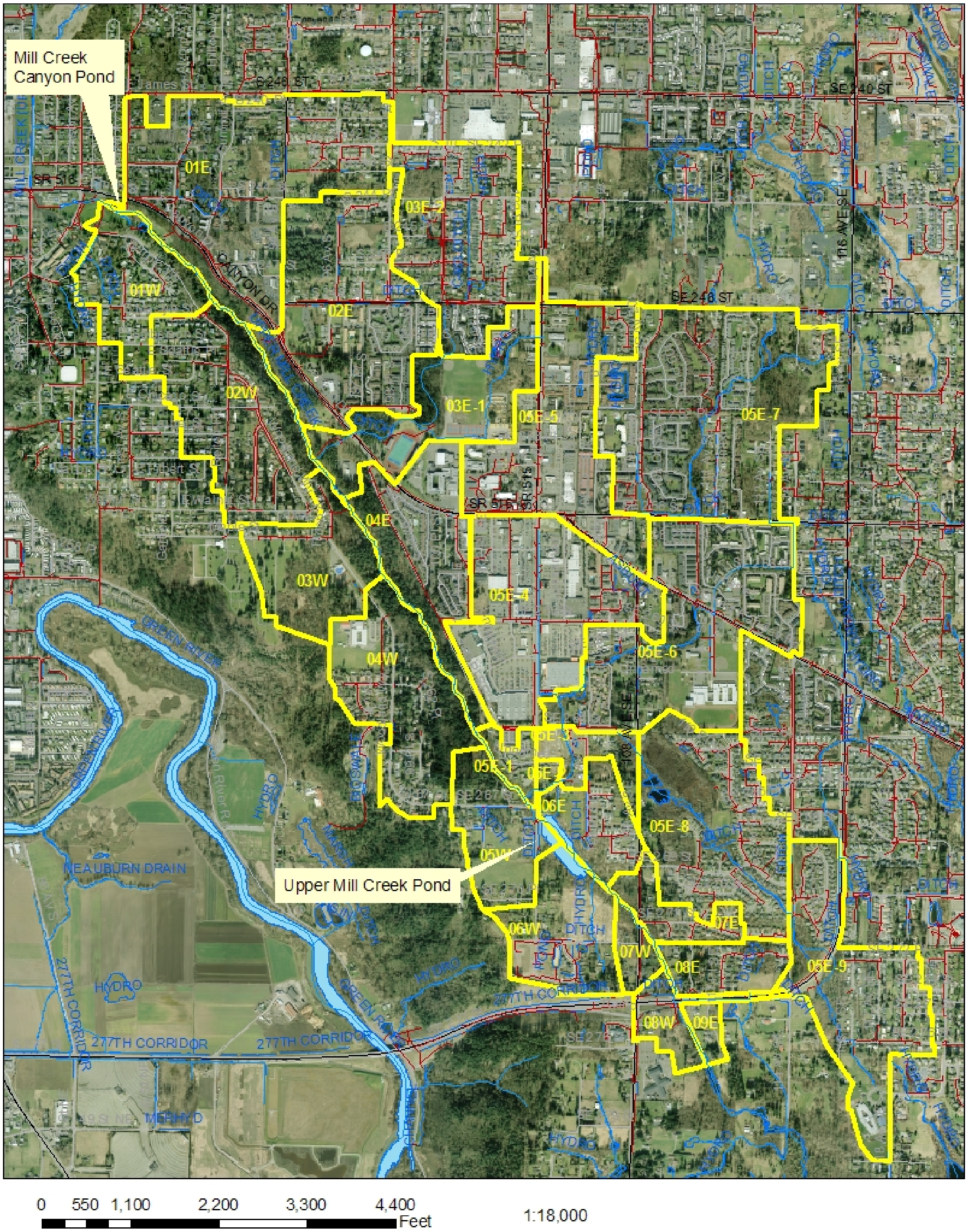
Scenario 2 – Future Mitigated Conditions

Location	Discharge Corresponding to Exceedance Probability (cfs)			
	90%	50%	20%	10%
UPP MILL INFLOW	0.08	0.55	1.3	1.8
UPP MILL OUTFLOW	0.11	0.70	1.6	3.1
Q DS OF BYPASS	0.17	1.1	3.9	8.2
REACH 63 RAVINE	0.17	1.1	4.2	8.8
REACH 62 RAVINE	0.18	1.2	4.5	9.8
REACH 58 RAVINE	0.20	1.3	4.9	10.9
REACH 57 RAVINE	0.22	1.4	5.6	12.3
LOW MILL INFLOW	0.24	1.6	6.3	13.9
LOW MILL OUTFLOW	0.24	1.6	6.4	13.9
Q AT JAMES ST	0.25	1.6	6.8	14.8

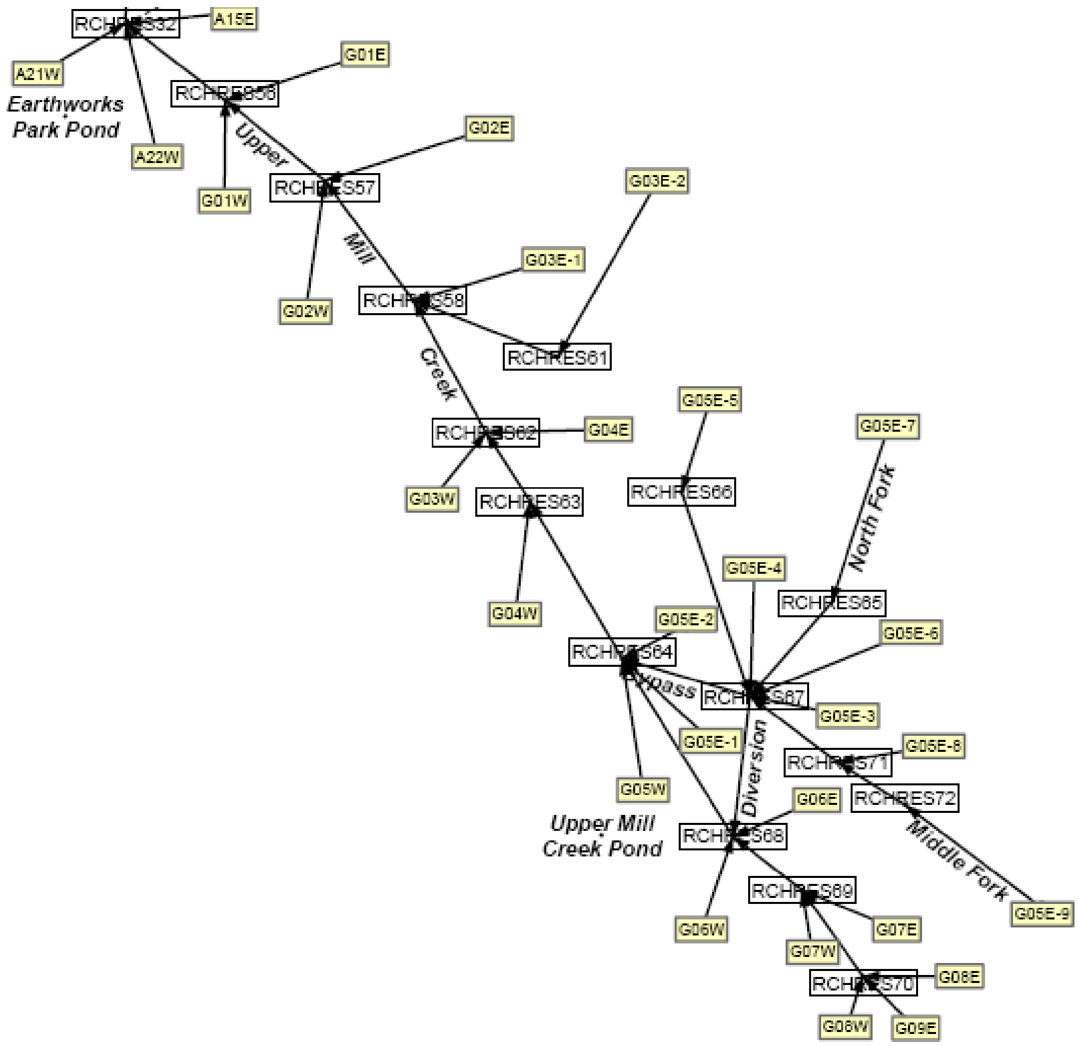
Comparison of 100-year Peak Discharge Exceedance Duration, Existing and Future Mitigated Conditions

Location	Current Condition 100 Year Discharge (cfs)	Total Hours Current 100-Year Discharge is Exceeded During Simulation	
		Existing Conditions	Future Conditions
UPP MILL INFLOW	215	0.7	0.0
UPP MILL OUTFLOW	75	4.0	0.0
Q DS OF BYPASS	85	4.3	0.0
REACH 63 RAVINE	90	3.8	0.0
REACH 62 RAVINE	100	3.5	0.0
REACH 58 RAVINE	115	4.4	0.3
REACH 57 RAVINE	165	1.3	0.4
LOW MILL INFLOW	220	0.4	0.2
LOW MILL OUTFLOW	140	4.2	1.5
Q AT JAMES ST	140	8.3	2.8

Upper Mill Creek HSPF Model Subbasin Map



Upper Mill Creek HSPF Model Schematic



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Existing Land Use Summary (acres)										
Subbasin	Till Forest	Till Grass	Outwash Pasture	Outwash Forest	Outwash Grass	Pasture	Valley	Saturated	Impervious	Total
1E	22.38	44.76	44.76	0.00	0.00	0.00	0.00	2.06	25.31	139.28
1W	9.39	22.53	5.63	0.00	0.00	0.00	0.00	2.79	4.42	44.76
2E	30.20	22.65	22.65	3.57	2.68	2.68	0.00	0.40	24.14	108.98
2W	8.64	25.91	0.00	9.68	29.05	0.00	0.00	1.36	7.54	82.18
3E-1	21.19	10.59	10.59	3.87	1.94	1.94	0.00	1.12	11.17	62.41
3E-2	3.41	47.75	17.05	0.00	0.00	0.00	0.00	0.94	13.30	82.46
3W	17.17	3.43	13.73	4.38	0.88	3.50	0.00	1.11	4.25	48.45
4E	26.98	3.37	3.37	2.80	0.35	0.35	0.00	1.48	23.74	62.45
4W	31.20	31.20	0.00	0.00	0.00	0.00	0.00	1.09	7.70	71.18
5E-1	1.71	2.85	1.14	0.00	0.00	0.00	0.00	0.97	2.51	9.18
5E-2	0.11	2.10	0.00	0.00	0.00	0.00	0.00	0.18	0.15	2.54
5E-3	1.34	5.35	6.69	0.00	0.00	0.00	0.00	2.15	1.13	16.66
5E-4	0.00	20.78	13.85	0.00	0.00	0.00	0.00	1.14	63.82	99.59
5E-5	0.00	24.98	16.65	0.00	0.00	0.00	0.00	0.04	51.37	93.05
5E-6	3.32	46.50	16.61	0.34	4.81	1.72	0.00	2.42	42.16	117.86
5E-7	0.00	34.91	52.36	0.00	0.00	0.00	0.00	16.15	41.85	145.27
5E-8	0.00	14.82	34.58	0.00	0.00	0.00	0.00	32.07	8.02	89.49
5E-9	15.62	15.62	31.25	0.00	0.00	0.00	0.00	6.34	13.09	81.93
5W	10.34	10.34	13.78	0.00	0.00	0.00	0.00	2.43	1.59	38.47
6E	0.00	10.12	10.12	0.00	0.00	0.00	0.00	7.04	0.78	28.05
6W	0.00	23.65	15.77	0.00	0.00	0.00	0.00	4.63	0.80	44.85
7E	0.00	10.74	3.58	0.00	0.00	0.00	0.00	2.20	2.49	19.01
7W	0.00	6.12	2.04	0.00	0.00	0.00	0.00	1.17	0.82	10.15
8E	0.77	6.94	7.71	0.05	0.41	0.45	0.00	5.08	0.98	22.38
8W	0.00	10.06	3.35	0.00	0.35	0.12	0.00	1.63	1.35	16.87
9E	0.00	2.48	0.83	0.00	0.60	0.20	0.00	1.75	0.38	6.23

Future Build Out Land Use Summary With On-Site Detention (acres)												
Sub	**Till Forest**	**Till Grass**	**Till Pasture**	**Outwash Forest**	**Outwash Grass**	**Outwash Pasture**	**Valley**	**Saturated**	**Imperv**	**Detained Area (acres)**	**Total**	**On-Site Detention Standard/ Land Use**
1E	13.72	27.44	27.44	0.00	0.00	0.00	0.00	1.26	25.31	44.10	139.28	Level 2, Res,
1W	7.87	18.90	4.72	0.00	0.00	0.00	0.00	2.34	4.42	6.50	44.76	Level 2, Res,
2E	20.49	15.37	15.37	2.43	1.82	1.82	0.00	0.27	24.14	27.27	108.98	Level 2, Res,
2W	7.61	22.83	0.00	8.53	25.60	0.00	0.00	1.20	7.54	8.86	82.18	Level 2, Res,
3E-1	17.74	8.87	8.87	3.24	1.62	1.62	0.00	0.93	11.17	8.34	62.41	Level 2, Comm,
3E-2	2.60	36.41	13.00	0.00	0.00	0.00	0.00	0.72	13.30	16.43	82.46	Level 2, Res,
3W	17.02	3.40	13.61	4.34	0.87	3.47	0.00	1.10	4.25	0.38	48.45	Level 2, Res,
4E	26.88	3.36	3.36	2.79	0.35	0.35	0.00	1.47	23.74	0.14	62.45	Level 2, Comm,
4W	30.31	30.31	0.00	0.00	0.00	0.00	0.00	1.06	7.70	1.80	71.18	Level 2, Res,
5E-1	1.20	2.00	0.80	0.00	0.00	0.00	0.00	0.68	2.51	1.98	9.18	Level 2, Res,
5E-2	0.04	0.76	0.00	0.00	0.00	0.00	0.00	0.06	0.15	1.52	2.54	Level 2, Res,
5E-3	0.72	2.89	3.62	0.00	0.00	0.00	0.00	1.16	1.13	7.14	16.66	Level 2, Res,
5E-4	0.00	17.41	11.61	0.00	0.00	0.00	0.00	0.96	63.82	5.80	99.59	Level 2, Comm,
5E-5	0.00	22.10	14.73	0.00	0.00	0.00	0.00	0.04	51.37	4.80	93.05	Level 2, Comm,
5E-6	2.76	38.61	13.79	0.29	3.99	1.43	0.00	2.01	42.16	12.85	117.86	Level 2, Res,
5E-7	0.00	26.20	39.31	0.00	0.00	0.00	0.00	12.12	41.85	25.79	145.27	Level 2, Res,
5E-8	0.00	13.53	31.58	0.00	0.00	0.00	0.00	29.29	8.02	7.07	89.49	Level 2, Res,
5E-9	13.41	13.41	26.83	0.00	0.00	0.00	0.00	5.45	13.09	9.74	81.93	Level 2, Res,
5W	2.82	2.82	3.76	0.00	0.00	0.00	0.00	0.66	1.59	26.82	38.47	Level 2, Res,
6E	0.00	5.83	5.83	0.00	0.00	0.00	0.00	4.06	0.78	11.56	28.05	Level 2, Res,
6W	0.00	6.07	4.05	0.00	0.00	0.00	0.00	1.19	0.80	32.74	44.85	Level 2, Res,
7E	0.00	6.23	2.08	0.00	0.00	0.00	0.00	1.28	2.49	6.93	19.01	Level 2, Res,
7W	0.00	1.29	0.43	0.00	0.00	0.00	0.00	0.25	0.82	7.36	10.15	Level 2, Res,
8E	0.46	4.15	4.62	0.03	0.24	0.27	0.00	3.04	0.98	8.59	22.38	Level 2, Res,
8W	0.00	6.80	2.27	0.00	0.24	0.08	0.00	1.10	1.35	5.03	16.87	Level 2, Res,
9E	0.00	0.35	0.12	0.00	0.08	0.03	0.00	0.24	0.38	5.03	6.23	Level 2, Res,

APPENDIX F

HYDRAULIC ANALYSIS DOCUMENTATION

APPENDIX F – HYDRAULIC ANALYSIS DOCUMENTATION

1.1 Introduction

The receiving waters and the TSD systems were analyzed using various hydraulic tools. As described in the DMP, HEC River Analysis System (HEC-RAS) was used for the receiving waters and spreadsheet-based tools were used for TSD hydraulic analyses.

1.2 Receiving Waters

HEC-RAS was used to model the hydraulics of the Mill Creek drainage from Earthworks Park downstream to the boundary with Renton on the north side of the City. Several models are used to represent the entire Mill Creek system. In addition, several other model runs were developed to show the benefits of implementing the proposed improvements.

The model geometry files were created from existing models from various consultants that had previously done work for the City. The original models were created in HEC Water Surface Profiles (HEC-2) and thus needed to be updated for the current version of HEC-RAS. Anchor engineering staff went to the field to verify each of the hydraulic structures and measure the degree of obstruction at each of these structures. The subfolder “Photo Documentation of Hydraulic Structures” within the electronic Appendix F subfolder “Receiving Waters” includes photographs taken at each of these structures. Although some of the pictures are poor due to limited light, they serve as a record to support the model calibration. Anchor engineering staff also directed City survey crews to pick up supplemental information.

After updating the geometry files, the roughness and other loss factors were adjusted to calibrate the calculated water surface elevations to the measured water elevations from the December 3, 2007 flood event.

The “Receiving Waters” electronic Appendix F subfolder has several subfolders that contain the HEC-RAS input files, listed below; summary output tables; and photographs to document the hydraulic structures.

- Lower Mill Creek HEC-RAS (Existing Conditions) model:
  - Project: *MillCreek-Anchor_2007*
  - Plan: *May_calibrated_existing7b*

  - Geometry: *May2008simple5(NAVD)*
  - Flow: *HSPF-Frequency_flows5(NAVD)*
  - Associated Summary Table: *Mill_Creek-existing.txt*
- GRNRA loop HEC-RAS (Existing Conditions) model:
  - Project: *MillCreek-Anchor_2007*
  - Plan: *May(full_model)_multQ-3b*
  - Geometry: *May2008_full4(NAVD)*
  - Flow: *May2008_split6(NAVD)*
  - Associated Summary output Table: *GRNRA_loop-existing.txt*
- Lower Mill Creek HEC-RAS (Recommended Improvements):
  - Project: *MillCreek-Anchor_2007*
  - Plan: *May2008simple-improvements-b*
  - Geometry: *May2008_combined_improvements(NAVD)*
  - Flow: *May2008improvementsQ(NAVD)*
  - Associated Summary Output Table: *Mill_Creek_proposed_improvements.txt*
- GRNRA loop HEC-RAS (Improvements) model:
  - Project: *MillCreek-Anchor_2007*
  - Plan: *May2008_Improvements_3b*
  - Geometry: *Modified Geometry(NAVD)*
  - Flow: *May2008_futuresplit2(NAVD)*
  - Associated Summary Output Table: *GRNRA_loop-proposed.txt*
- Springbrook Creek (Existing Conditions) model:
  - Project: *Springbrook HEC-2 Data Import*
  - Plan: *Existing5_May200-8b*
  - Geometry: *ExistingGeometryFeb2008rev(NAVD)*
  - Flow: *HSPF_freqflows_May2008_2(NAVD)*
  - Associated Summary Output Table: *Springbrook_existing.txt*

1.3 Spreadsheet Tools

A step backwater spreadsheet tool was used to screen the TSD infrastructure. Figures were created to illustrate what was analyzed and the conclusions of these analyses. The “Trunk Storm Drains” electronic Appendix F subfolder contains several subfolders: “Graphics” and “Worksheets and Calculations.” Within each of these subfolders is a separate subfolder for each drainage basin. Within the drainage basin subfolders are either graphics or spreadsheets for the subbasins evaluated. In several basins (H and J), other tools (HEC-RAS and Culvert Master) were used as needed. When these other tools were used, the subfolder contains the summary output files and input files needed to use the tools.

APPENDIX G

PROJECT COST OPINIONS

APPENDIX G – PROJECT COST OPINIONS

Detailed cost opinions were developed for each project described in the DMP. Electronic Appendix G subfolders have been created for each drainage basin, and the cost opinions are distributed to the subfolders based on their location within the City. One cost opinion has been printed and is attached as an example.

City of Kent Drainage Master Plan Update
Order-of-Magnitude Stormwater CIP Project Cost Opinion
Basin A - Subbasin 15E, CIP Project: A-2

Bid Item	Est. Quantity	CIP Link	Unit	Item	Spec. Section	Unit Cost		Amount
Division 1 - General Requirements								
1	1		LS	Surveying (1.5%)	1-05.4	$8,000		$8,000
2	1		LS	Temporary Water Pollution/Erosion Control (3%)	1-07.15	$16,000		$16,000
3	1		LS	Utilities Locate and Protection (0.5%)	1-07.17	$2,000		$2,000
4	1		LS	Utilities Relocation (Assumes Franchise Utilities Location by Others) (2%)	1-07.17	$11,000		$11,000
5	1		FA	Force Account (2%)	1-09.6	$11,000		$11,000
6	1		LS	Mobilization (7.5%)	1-09.7	$42,000		$42,000
7	1		LS	Temporary Traffic Control (1%)	1-10.5	$5,000		$5,000
Subtotal Division 1								$95,000
Division 2 - Earthwork								
8	0.3		AC	Clearing and Grubbing	2-01.5	$15,000		$3,750
9	1		LS	Removal of Structures and Obstructions	2-02.5			$31,800
			LF	Existing TSD removal/disposal		$20	$0	
			EA	Existing Catch Basin removal/disposal		$1,500	$0	
	1,325		LF	Existing AC Pavement Sawcut, Removal & Disposal		$24	$31,800	
			LF	Existing Concrete Curb and Gutter Saw cut, Removal & Disposal		$6	$0	
			LF	Existing Concrete Sidewalk Saw cut, Removal & Disposal		$12	$0	
10	1		LS	Excavation, Incl. Haul, Stockpile, Comp. Embankment Fill, Disposal	2-03.5			$98,500
	800		CY	Stripping Incl. Offsite Disposal (5 mile haul)		$20	$16,000	
	1,350		CY	Excavation Incl. Haul to On-site Stockpile		$8	$10,800	
	900		CY	Compacted Embankment Fill from Stockpile		$10	$9,000	
	1,050		CY	Compacted Embankment Fill from Import (5 mi. haul)		$18	$18,900	
	1,150		CY	Excess Excavation for Offsite Disposal (5 mile haul)		$12	$13,800	
	1		LS	Temporary Shoring, Sheet Piles		$30,000	$30,000	
11	180		CY	Gravel Backfill for Walls	2-03.5	$35		$6,300
12	430		CY	Foundation Material	2-03.5	$35		$15,050
13			CY	Streambed Gravel Mix	2-03.5	$45		$0
14	400		CY	Gravel/Cobble Mix	2-03.5	$60		$24,000
Subtotal Division 2								$179,400
Division 4 - Bases								
15	2,650		LF	Crushed Surfacing, 12' Width, 3" Depth	4-04.5	$4		$10,600
Subtotal Division 4								$10,600
Division 5 - Surface Treatments and Pavements								
16	1,325		LF	Asphalt Concrete Pavement, Class B (HMA Class 3/4"), 12' Width, 4" Depth	5-04.5	$30		$39,750
Subtotal Division 5								$39,750
Division 6 - Structures								
17	200		CY	Concrete Class 4000D (4' Height Flood Wall + Footings)	6-02.5	$600		$120,000
18	100		SF	Pre-cast Culvert Headwalls	6-02.5	$40		$4,000
19			LF	Pre-cast Conc. Box Culvert ($16.50 per SF cross-sectional area)	6-02.5	$0		$0
20			LF	Pre-cast Conc. 3- Sided Box w/Footings ($19.50 per SF cross-sectional area)	6-02.5	$0		$0
21	1		LS	Steel Structures	6-03.5	$0		$0
22			SF	Platform Grating	6-03.5	$28		$0
23			LF	Handrail	6-03.5	$40		$0
24			EA	Safety Bar Rack	6-03.5	$3,000		$0
Subtotal Division 6								$124,000
Division 7 - Drainage Structures, Storm Sewers, Sanitary Sewers, Water Mains, and Conduits								
25			LF	RCP Storm Sewer Pipe, 12 In. Diam.	7-04.5	$0		$0
26	300		LF	RCP Storm Sewer Pipe, 18 In. Diam.	7-04.5	$67		$19,980
27			LF	RCP Storm Sewer Pipe, 24 In. Diam.	7-04.5	$0		$0
28			LF	RCP Storm Sewer Pipe, 30 In. Diam.	7-04.5	$0		$0
29			LF	RCP Storm Sewer Pipe, 36 In. Diam.	7-04.5	$0		$0
30			LF	RCP Storm Sewer Pipe, 42 In. Diam.	7-04.5	$0		$0
31			LF	RCP Storm Sewer Pipe, 48 In. Diam.	7-04.5	$0		$0
32			LF	RCP Storm Sewer Pipe, 54 In. Diam.	7-04.5	$0		$0
33			LF	RCP Storm Sewer Pipe, 60 In. Diam.	7-04.5	$0		$0

34		LF	RCP Storm Sewer Pipe, 66 In. Diam.	7-04.5	$0	$0
35		LF	RCP Storm Sewer Pipe, 72 In. Diam.	7-04.5	$0	$0
36		LF	RCP Storm Sewer Pipe, 84 In. Diam.	7-04.5	$0	$0
37		LF	Aluminized Steel Arch Culvert (Unit Cost = 1.2 X equiv. area circular SD)	7-04.5	$0	$0
38		EA	Energy Dissipator - 12-18 In. Diam. Outfall	7-05.5	$3,000	$0
39		EA	Energy Dissipator - 24-30 In. Diam. Outfall	7-05.5	$7,000	$0
40		EA	Energy Dissipator - 36-42 In. Diam. Outfall	7-05.5	$12,000	$0
41		EA	Energy Dissipator - 48-54 In. Diam. Outfall	7-05.5	$18,000	$0
42		EA	Energy Dissipator - 60-66 In. Diam. Outfall	7-05.5	$25,000	$0
43		EA	Energy Dissipator - 72-84 In. Diam. Outfall	7-05.5	$33,000	$0
44		EA	Modify/Adjust Existing Catch Basin or Manhole	7-05.5	$750	$0
45	5	EA	Catch Basin, Type 1	7-05.5	$1,500	$7,500
46	5	EA	Catch Basin Type 2, 48 In. Diam.	7-05.5	$2,500	$12,500
47		EA	Catch Basin Type 2, 54 In. Diam.	7-05.5	$0	$0
48		EA	Catch Basin Type 2, 60 In. Diam.	7-05.5	$0	$0
49		EA	Catch Basin Type 2, 72 In. Diam.	7-05.5	$0	$0
50		EA	Catch Basin Type 2, 84 In. Diam.	7-05.5	$0	$0
51		EA	Catch Basin Type 2, 96 In. Diam.	7-05.5	$0	$0
52		EA	Catch Basin Type 2, 108 In. Diam.	7-05.5	$0	$0
53		EA	Catch Basin Type 2, 120 In. Diam.	7-05.5	$0	$0
54	20	EA	Catch Basin, Extra Depth Beyond 6 ft., 48 In. Diam., Per Foot	7-05.5	$200	$4,000
55		EA	Catch Basin, Extra Depth Beyond 6 ft., 54 In. Diam., Per Foot	7-05.5	$0	$0
56		EA	Catch Basin, Extra Depth Beyond 6 ft., 60 In. Diam., Per Foot	7-05.5	$0	$0
57		EA	Catch Basin, Extra Depth Beyond 6 ft., 72 In. Diam., Per Foot	7-05.5	$0	$0
58		EA	Catch Basin, Extra Depth Beyond 6 ft., 84 In. Diam., Per Foot	7-05.5	$0	$0
59		EA	Catch Basin, Extra Depth Beyond 6 ft., 96 In. Diam., Per Foot	7-05.5	$0	$0
60		EA	Catch Basin, Extra Depth Beyond 6 ft., 108 In. Diam., Per Foot	7-05.5	$0	$0
61		EA	Catch Basin, Extra Depth Beyond 6 ft., 120 In. Diam., Per Foot	7-05.5	$0	$0
62		EA	FRP Flap Gate, 12 In. Diam.	7-05.5	$1,800	$0
63	5	EA	FRP Flap Gate, 18 In. Diam.	7-05.5	$3,400	$17,000
64		EA	FRP Flap Gate, 24 In. Diam.	7-05.5	$4,200	$0
65		EA	FRP Flap Gate, 30 In. Diam.	7-05.5	$6,100	$0
66		EA	FRP Flap Gate, 36 In. Diam.	7-05.5	$7,100	$0
67		EA	FRP Flap Gate, 42 In. Diam.	7-05.5	$8,500	$0
68		EA	FRP Flap Gate, 48 In. Diam.	7-05.5	$9,200	$0
69		EA	FRP Flap Gate, 54 In. Diam.	7-05.5	$11,900	$0
70		EA	FRP Flap Gate, 60 In. Diam.	7-05.5	$13,300	$0
71		EA	FRP Flap Gate, 72 In. Diam.	7-05.5	$16,800	$0
72		EA	FRP Flap Gate, 84 In. Diam.	7-05.5	$20,800	$0
Subtotal Division 7						$60,980
Division 8 - Miscellaneous Construction						
73	1,400	SY	Erosion Control Matting	8-01.5	$4.50	$6,300
74	250	CY	Topsoil Type A	8-02.5	$25	$6,250
75	125	CY	Compost	8-02.5	$38	$4,750
76	1,400	SY	Landscaping	8-02.5	$18.00	$25,200
77	2,650	LF	Cement Conc. Traffic Curb and Gutter	8-04.5	$30.00	$79,500
78	600	LF	Chain Link Fence, Type 3 (6' height)	8-14.5	$20.00	$12,000
79		LF	Cement Conc. Sidewalk, 6' Width	8-14.5	$60.00	$0
80	50	CY	Quarry Spalls	8-15.5	$35.00	$1,750
81		CY	Light Loose Rip-Rap	8-15.5	$45.00	$0
82	10	EA	Large Woody Debris (Rootwad, Bank Logs, Fallen Tree)	8-15.5	$1,500.00	$15,000
Subtotal Division 8						$150,750
			Subtotal			$660,480
			Sales Tax (1)		0.0%	$0
			Estimated Construction Subtotal			**$660,480**
			Undefined Items at Planning-Level Estimate		10.0%	$66,048
			Construction Contingency at Planning-Level Estimate		30.0%	$198,144
			Estimated Construction Total			**$924,672**
			Land/Easement Acquisition Costs (0.5 ac @ $50,000/ac.)			$25,000
			Engineering, Design, Permitting, Construction Management Costs		25.0%	$231,168
			Total Estimated CIP Implementation Cost (2)			**$1,180,840**

(1) Sales Tax Not Included For Improvements Constructed on City-owned Properties

(2) Order-of-Magnitude Estimate Level; April 2008