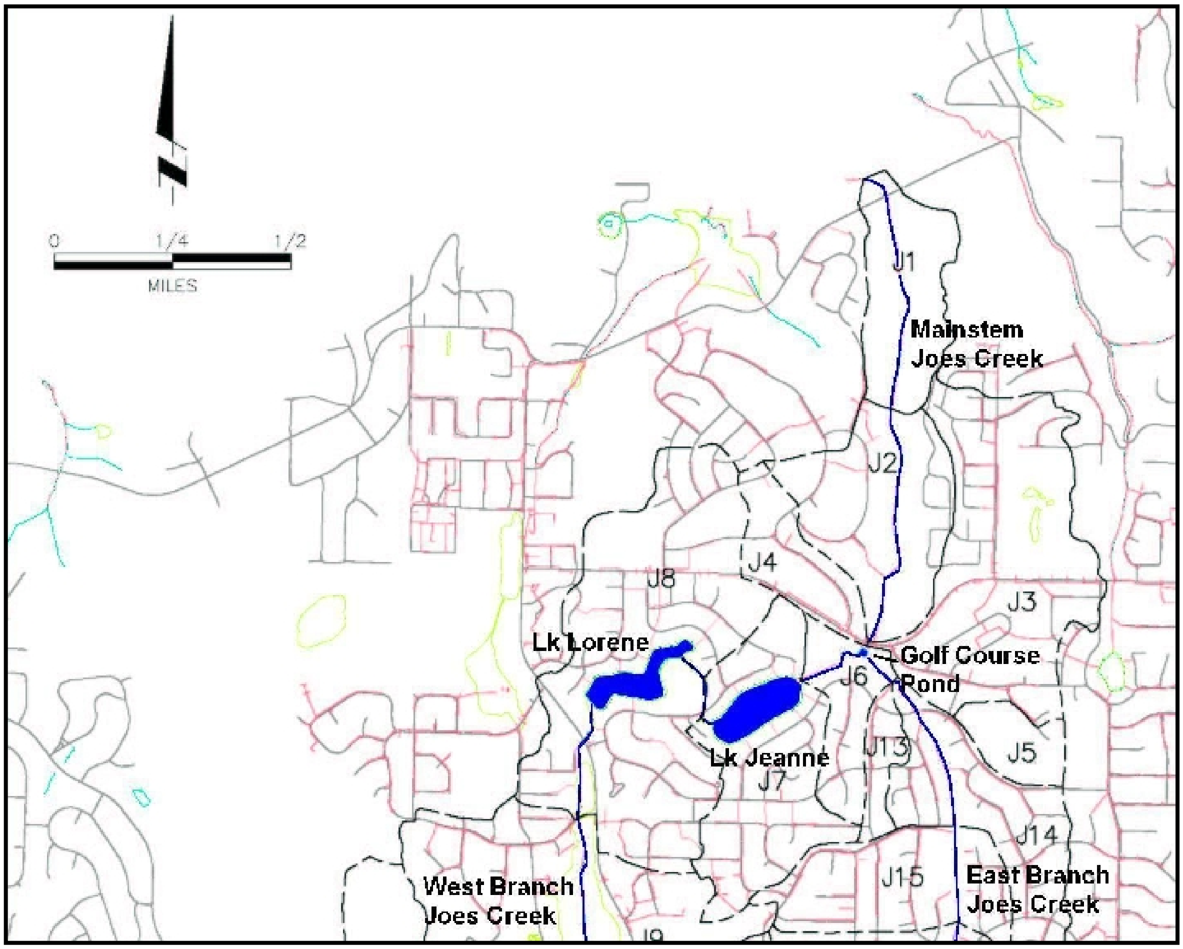
Hydrologic and Hydraulic Analysis of Twin and Easter Lakes Using the HSPF Model



for

The City of Federal Way
and
The Twin Lakes Homeowners Association

by

MGS Engineering Consultants, Inc.

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March 31, 2003 (Revised 6/9/2006)

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Hydrologic Analysis of Joes and Cold Creek Watersheds Using the HSPF Model

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The engineering analyses and technical material presented in this report were prepared under the supervision and direction of the undersigned professional engineer.

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EXECUTIVE SUMMARY

This report presents findings of a hydrologic and hydraulic analysis of the Joes and Cold Creek watersheds using the Hydrological Simulation Program Fortran (HSPF) hydrologic and Stormwater Management (SWMM) Extended Transport hydraulic models. The purpose of the study was to analyze flooding near Twin Lakes and Easter Lake and assess the effectiveness of mitigation alternatives to reduce the frequency of flooding.

In 1996, an engineering analysis was performed by Tetra Tech/KCM, Inc[1] as part of a Comprehensive Surface Water Management Plan for the City of Federal Way and included recommendations to reduce the flooding potential near Twin Lakes and Easter Lake. The Tetra Tech/KCM report recommended increasing the discharge capacity of each lake to reduce the frequency of flooding of lakeside structures. In addition, stormwater detention was recommended downstream of Twin Lakes at an existing pond at the Twin Lakes golf course to mitigate the stormwater detention lost by increasing the discharge capacity at the upstream lakes.

The projects proposed for Twin and Easter Lakes by Tetra Tech/KCM were analyzed as part of the current study using the HSPF hydrologic model. The continuous-flow, rainfall-runoff algorithms in HSPF provided improved estimates of runoff and lake water levels, and a better assessment of the proposed mitigation projects than was achieved with the single-event hydrologic model used previously. These improved assessments were possible because of the capability of the HSPF model to analyze the runoff produced by long-duration storms and sequences of storms that commonly occur in western Washington.

JOES CREEK AND TWIN LAKES

The Joes Creek watershed encompasses approximately 1900 acres of urban land in the cities of Federal Way and Tacoma. The stream consists of two main tributaries; the west and east branch, which headwater in the City of Tacoma and join at the Twin Lakes Golf Course pond. Lake Lorene and Lake Jeane, collectively referred to as Twin Lakes, are located on the west branch upstream of the confluence with the east branch.

Results of the HSPF analysis indicate that the size of the existing outlet structures at Lake Lorene, and Lake Jeane restrict discharges from each lake and would result in flooding of lakeside residences and other structures at a 25-year recurrence interval. Downstream, the Twin Lakes Golf Course pond was predicted to flood nearly every year on average and several times per year in some years.

Increasing the flood discharge capacity from Twin Lakes would reduce the frequency of flooding of lakeside structures beyond the 100-year recurrence interval. The proposed modifications include replacing an undersized culvert in the outlet channel of Lake Lorene and replacing the outlet pipes at Lake Jeane. Increasing the flood

discharge capacity from Twin Lakes had a negligible effect on flood peak rates downstream of the confluence with the east branch because the west branch of Joes Creek (on which the lakes are located) accounts for a small percentage the combined discharge from the east and west branches.

According to the 1990 Hylebos and Lower Puget Sound Basin Plan[5], increased runoff associated with upstream urbanization has increased the rate of erosion in the Joes Creek ravine over historic levels. High flows, in past years have also caused channel incision and lateral erosion that have undermined the system of poles that support the netting used to contain golf balls at the Twin Lakes Driving Range, which is a concern to the Twin Lakes Homeowners Association. To reduce the potential for downstream flood and erosion damage, a regional detention pond is proposed at the Twin Lakes Driving Range to mitigate the increased flood flows associated with upstream urbanization.

The Twin Lakes Golf Course and Homeowners Association have been amenable to the development of a regional stormwater detention pond at the driving range provided that the area occupied by the pond is available for use as a driving range for the majority of the year. A stormwater pond at the driving range was not addressed as part of the Tetra Tech/KCM study and is presented in this report for the first time. The potential stormwater detention volume at the driving range is considerably larger than at the Golf Course Stormwater Pond proposed in the 1996 KCM/Tetra-Tech report. Thus, the performance of a stormwater pond located at the driving range was examined in lieu of providing flood storage at the Golf Course Pond.

Two driving range stormwater detention pond options were analyzed as part of this study. The first option includes an embankment with a maximum height of 13-feet constructed along the northern end of the driving range with a maximum flood storage capacity of 16.6 acre-feet (723,000 cu ft). Under this option, the existing open channel that conveys Joes Creek along the western boundary of the driving range would be filled expanding the driving range area with the creek piped beneath the pond/driving range. Filling of Joes Creek would require permits from local, state, and federal resource agencies. Difficulty in obtaining these permits may preclude further consideration of this option.

The second option includes an embankment with a maximum height of 13-feet constructed along the northern and western sides of the driving range with a flood storage capacity of 12.5 acre-feet (544,000 cu-ft). For this option, Joes Creek would remain in an open channel reconstructed to minimize the erosion potential and enhance fish habitat.

An analysis of flood and erosion reduction benefits showed comparable performance for each pond option. Ten-year recurrence interval flood peaks in the ravine downstream of the project would be reduced by 44-percent for Option 1 and 41-percent for the Option 2 configuration. A flow duration analysis, which provides a relative measure of the amount of erosive work performed on the stream channel, showed a reduction in flow duration for each option. This indicates that the proposed driving range stormwater pond options would reduce the rate of erosion in the Joes Creek ravine, which would benefit downstream fish habitat.

COLD CREEK AND EASTER LAKE

Results of the hydrologic and hydraulic analysis of Easter Lake in the Cold Creek watershed showed that lakeside structures currently flood at approximately a 50-year recurrence interval. A 24-inch culvert located at the lake outlet restricts the lake discharge capacity. Hydrologic/hydraulic model simulations showed that increasing the discharge capacity of Easter Lake by replacing the culvert with a 36-inch diameter pipe reduced the frequency of structural flooding beyond the 100-year recurrence interval. The Tetra Tech/KCM report also recommended grading the outlet channel from the lake in addition to replacing the culvert. It was found that grading the outlet channel in combination with the culvert replacement further reduced the 100-year water surface elevation by 0.5 feet. Increasing the discharge rate from the Lake would not increase the flooding or erosion potential downstream because the discharge from the lake represents a small fraction of the total discharge entering the Cold Creek ravine downstream. Thus, no projects were proposed downstream to provide mitigation for increased flows from Easter Lake.

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Hydrologic and Hydraulic Analysis of Twin and Easter Lakes Using the HSPF Model

INTRODUCTION/BACKGROUND INFORMATION

Flooding problems have been identified at three lakes located in the City of Federal Way: Lake Lorene, Lake Jeane, and Easter Lake. Lake Lorene and Lake Jeane (also known as Twin Lakes) are located along the west branch of Joes Creek, a tributary to Puget Sound. During large storms, an undersized culvert located in the channel connecting the lakes restricts discharge from Lake Lorene and results in high water in the lake. Similarly, undersized outlet pipes from Lake Jeane results in high water levels during large storms and causes flooding of lakeside structures.

Flooding problems have been identified near Easter Lake during large winter storms. Easter Lake is located at the headwaters of Cold Creek, a small urban tributary to Puget Sound. Flooding surrounding the lake occurs due to restrictions in the outlet channel and an undersized culvert at the downstream end of the outlet channel.

An engineering analysis was performed on these lakes as part of a Comprehensive Surface Water Management Plan for the City of Federal Way by Tetra Tech/KCM, Inc. in 1996[1]. The Tetra Tech/KCM report recommended upgrading the discharge capacity of each lake to reduce the frequency of flooding. In addition, stormwater detention was recommended downstream of Twin Lakes at an existing pond at the Twin Lakes golf course to mitigate the stormwater detention lost by increasing the discharge capacity of the lakes upstream.

The Tetra Tech/KCM study analyzed the hydrology and hydraulics of the major surface water tributaries using the US EPA Stormwater Management Model (SWMM)[2]. SWMM can be operated in either continuous or single-event mode. For the Federal Way Stormwater Management Plan, Tetra Tech/KCM used the single event method with the SCS 24-hour Type 1A synthetic rainfall distribution. SWMM also contains routines for routing flows in channels and pipe systems subjected to changing downstream hydraulic control.

The projects proposed for Twin and Easter Lakes by Tetra Tech/KCM were analyzed as part of the current study using the US EPA, Hydrological Simulation Program-Fortran (HSPF)[3] hydrologic model. Precipitation timeseries 158-years in length were used as input to the model, which produced a 158-year flow timeseries at a 15-minute timestep. The continuous-flow, rainfall-runoff algorithms in HSPF together with the extended precipitation timeseries provided improved estimates of runoff and lake water levels, and a better assessment of the proposed mitigation projects. These improved assessments were possible because of the capability of the HSPF model to analyze the runoff produced by long-duration storms and sequences of storms that commonly occur during the wet season in western Washington. The hydraulic routing routines of the SWMM model were used in conjunction with the discharge rates computed by HSPF to simulate water surface elevations in the channel/pipe systems at the lake outlets.

HSPF MODEL ANALYSIS APPROACH

SUBBASIN DELINEATION

The Joes Creek watershed encompasses approximately 1900 acres (approximately three square miles) of urban land in the cities of Federal Way and Tacoma. The stream consists of two main tributaries, the west and east branch, which headwater in the City of Tacoma. The west branch originates at the North Shore Golf Course and receives runoff from residential development before discharging to Lake Lorene and Lake Jeane (collectively referred to as Twin Lakes). The east branch originates in a residential area of Tacoma and is piped to a ravine located in Olympic View Park. The two branches join at a small pond located at the Twin Lakes Golf Course south of SW 320th Street. Flows from the pond are piped beneath SW 320th Street and discharge to a ravine that drops approximately 160 feet in less than a mile to Puget Sound (Figure 1).

The Cold Creek watershed consists of approximately 500 acres of urban land. The stream headwaters at Easter Lake and is piped for approximately 700 feet before discharging to a ravine that drops approximately 400 feet in 1.5 miles to Puget Sound (Figure 2). The area surrounding Easter Lake consists mainly of multi-family and some commercial development with the remainder of the watershed composed of single-family residential development.

HSPF model input was developed by the USGS[4] and utilized by King County as part of the 1991 Hylebos and Lower Puget Sound Basin Plan[5]. The model input included eight subbasins for the Joes Creek watershed and three subbasins for the Cold Creek watershed. In the current analysis, the watersheds were further divided to provide more detailed flood routing with 23 subbasins utilized in the Joes Creek model and nine subbasins in the Cold Creek model.

FLOOD ROUTING INFORMATION

Model routing information was derived from survey of the stream channel and pipe systems provided by the City of Federal Way and EXTRAN model input developed as part of the Tetra-Tech KCM study[1]. This information was used to develop hydraulic tables (called FTABLES) that are used in the HSPF model to simulate the movement of water in streams, lakes, pipes, and other hydraulic structures.

A diversion structure constructed by the City of Tacoma in the mid 1990's located at the outlet of subbasin J23 in the headwaters of the West Branch of Joes Creek was included in the model. This structure diverts flows in excess of 15 cfs from Subbasin J23 to Subbasin J12, which is outside of the Joes Creek watershed. Subbasin J12 flows to the south and does not contribute flow to Joes Creek.

The SW 340th St. Regional Stormwater Pond, constructed by the City of Federal Way in the upper East Branch of Joes Creek in the mid 1990's, was also included in the model. This pond has a storage volume of 11 acre-feet and receives runoff from Subbasins J22 and J20.

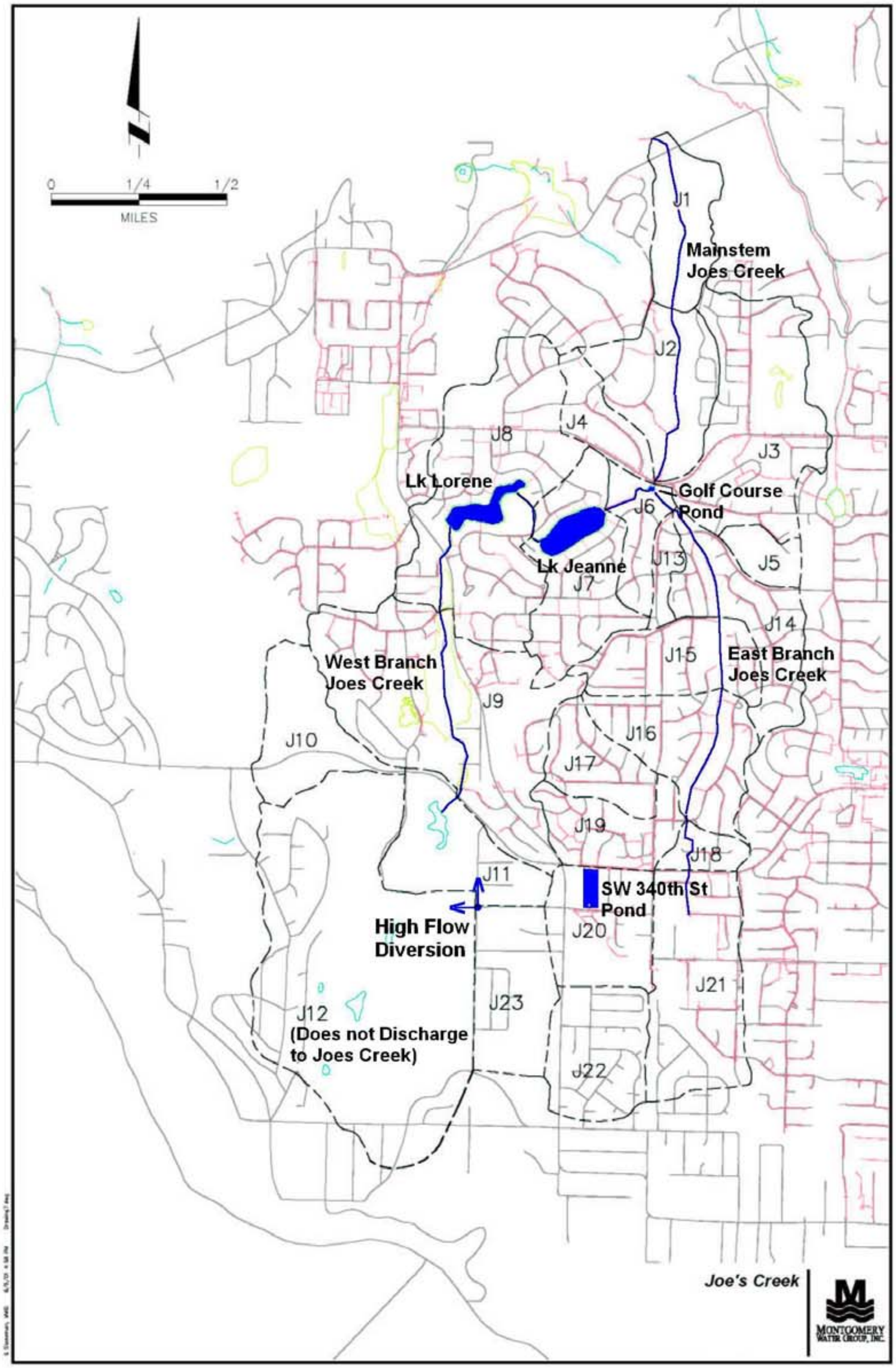

Figure 1 –Joes Creek Watershed and Subbasin Map

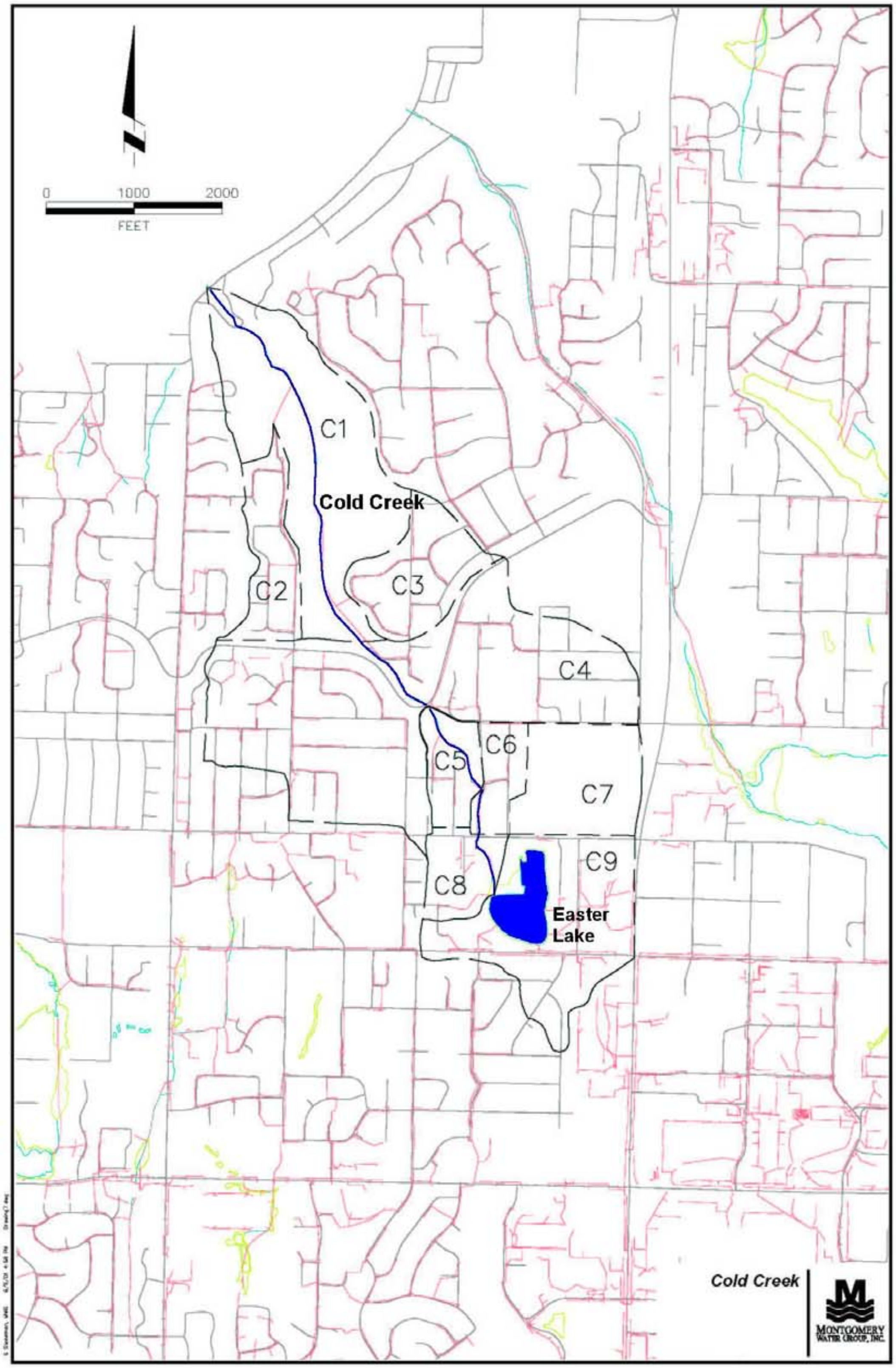

Figure 2 – Cold Creek Watershed and Subbasin Map

The FTABLES for complex drainage systems, including the outlets of Lakes Lorene, the Golf Course pond, and Easter Lake were developed using the Extended Transport (EXTRAN) module in the Stormwater Management Model (SWMM)[2]. The EXTRAN routine was particularly useful in analyzing those features where the hydraulic control changes during a flood. For example, the water level in Lake Lorene is controlled by the elevation of the outlet channel at low flows, however, a 24-inch culvert downstream restricts the discharge and controls the lake elevation at high discharge rates. The EXTRAN routine provided a means to analyze the lake outlet control with changing downstream conditions.

GEOLOGY AND LAND COVER

The area within each subbasin was classified into areas of common land cover and geologic/soil type, called *PERLNDS*. The HSPF model computes the hydrologic response of each PERLND within a subbasin on a per-unit-area basis and proportions the amount of surface runoff, interflow and groundwater entering the stream within each subbasin consistent with the PERLND area total for the subbasin. The geology and land cover of the Cold and Joes Creek watersheds was determined from GIS mapping obtained from the City of Federal Way[6]. Existing (year 2002) and future build-out land uses were analyzed for the Joes Creek watershed, and existing land use was analyzed for the Cold Creek watershed. Future land use was not analyzed for the Cold Creek watershed because the upper watershed near Easter Lake is built out and there would be little or no difference between runoff computed under existing and future build out conditions.

For hydrologic modeling purposes, each geologic association in the watershed was assigned to one of three categories; till, outwash, or wetland according to the HSPF modeling methodology developed by the USGS[4,7]. These were combined with surface cover categories consisting of urban grass, forest, wetland/saturated soils, and impervious to form the PERLND groups shown in Table 1.

Table 1 – HSPF Land Cover/Geology (Perlnd) Combinations used in Joes and Cold Creek Watershed Analysis

HSPF Perlnd	Land Characteristics
Till Forest	Glacial till soils mature cover, all slopes
Till Urban Grass	Glacial till soils urban grass, all slopes Includes impervious surfaces not directly connected to the drainage network.
Outwash Forest	Glacial outwash soils mature cover, all slopes
Outwash Urban Grass	Glacial outwash soils urban grass, all slopes. Includes impervious surfaces not directly connected to the drainage network.
Wetland/Saturated Soils	Wetlands or areas with saturated soils
Impervious (HSPF Implnd)	Impervious surfaces that are directly connected to the drainage network.

HSPF MODEL CALIBRATION

Calibration of the HSPF model was performed to ensure that the hydrologic processes simulated by the model were representative of the conditions in the Joes and Cold Creek watersheds. Calibration is the process whereby the model input parameters are adjusted until simulated and recorded discharge and water surface elevation data match to the greatest extent possible.

Initial HSPF model runoff parameters used in this study were adapted from the King County Hylebos and Lower Puget Sound Basin Plan[5]. These model parameters were refined through calibration using elevation data collected at Twin Lakes and Easter Lake over the past year (October 2001-November 2002) and discharge data used in the original calibration collected by the USGS during water years 1987 and 1988 near the mouth of each watershed.

Local precipitation data collected at a 15-minute frequency from King County Gage 24V located at SW 376th St and 18th Ave South was used as input to the model for calibration purposes. Daily evaporation data were developed from data collected at the Puyallup 2 West Experimental Station (station number 45-6803).

Calibration of the model to the lake water surface elevation data was accomplished by adjusting model parameters until simulated and recorded lake elevation data matched to the greatest extent possible. Parameters affecting the inflow and outflow of groundwater to the lakes, evaporation input to the lake surface, and minor adjustments to the hydraulic tables (FTABLES) were used to calibrate the model to the observed lake levels and discharge rates.

The calibration period of lake water surface elevation spanned October 1, 2001-November 8, 2002. Regular recording of water surface elevations did not begin until June with only three lake level measurements taken during the winter. Thus, there was little data available for model calibration during high flow conditions. A large storm occurred on November 15, 2001, with a 24-hour precipitation total of 3.77 inches (recorded at King County Gage 24V), which corresponds to approximately an 80-year recurrence interval. Lake elevation data was not recorded during this storm, however, estimates of water surface elevation were made from photographs taken by the City of Federal Way and Twin Lakes Home Owners Association. The data points derived from photographs are indicated on the calibration plots as “Estimated”. It is recommended that the calibration be revisited following collection of additional elevation data through at least one winter season.

Mean daily discharge rates recorded by the USGS during water years 1987 and 1988 at the outlet of Joes and Cold Creeks were used to validate the model calibration. After calibrating the model to the observed lake data, the discharge rates at the mouth of each creek were simulated and compared to the USGS data collected in 1987 and 1988. This step ensured that model still produced valid discharge results at the mouth of each creek following calibration of the lake levels.

Calibration plots comparing simulated and recorded lakes elevations in the Joes Creek watershed are shown in Figures 3a-3d and for Easter Lake in the Cold Creek watershed in Figure 4. In general, the magnitude and timing of peaks compared well between simulated and recorded water surface elevations at each lake. The exception is Lake Lorene where simulated and recorded levels diverged during the late summer. The recorded lake elevation increased by about 0.5 feet over the months of August to October during a relatively dry period, which likely indicates the lake outlet was partially dammed with debris, probably by children.

Validation plots comparing simulated and recorded discharge during water years 1987 and 1988 are shown in Figures 5a and 5b. The general shape of simulated winter storm flows and the magnitude of summer base flows matched well with the recorded streamflow for this period.

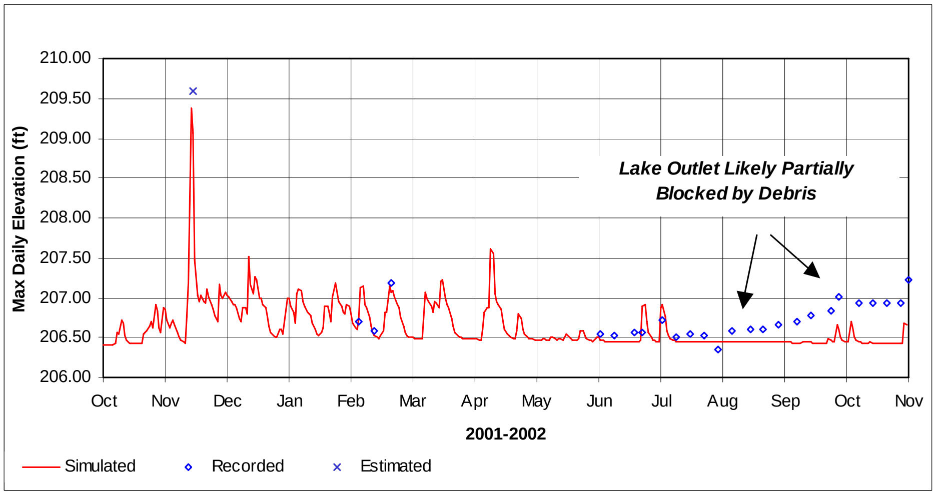

Figure 3a – HSPF Model Calibration
Lake Lorene Simulated and Recorded Water Surface Elevation

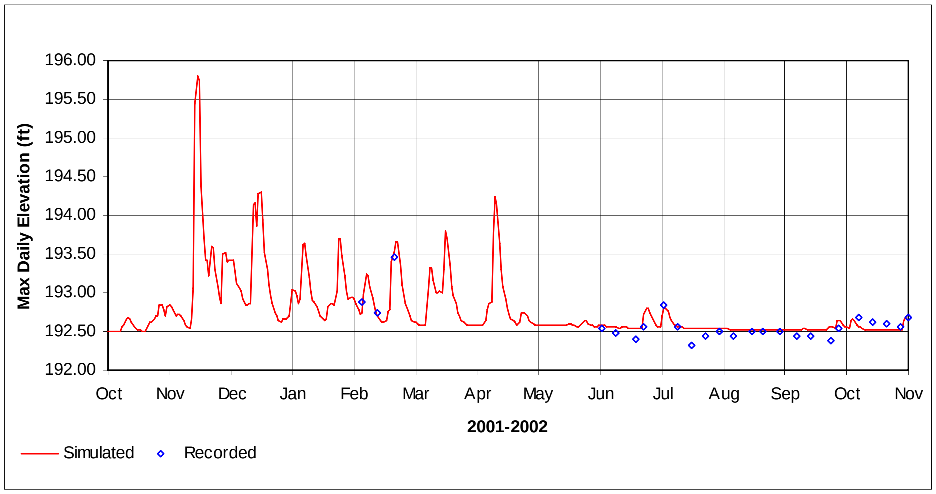

Figure 3b – HSPF Model Calibration
Lake Jeane Simulated and Recorded Water Surface Elevation

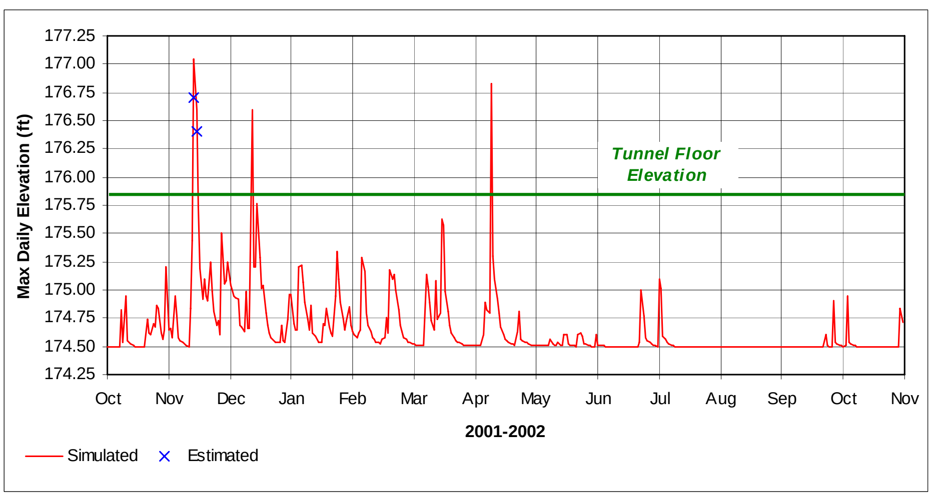

Figure 3c – HSPF Model Calibration
Golf Course Pond Simulated and Estimated Water Surface Elevation

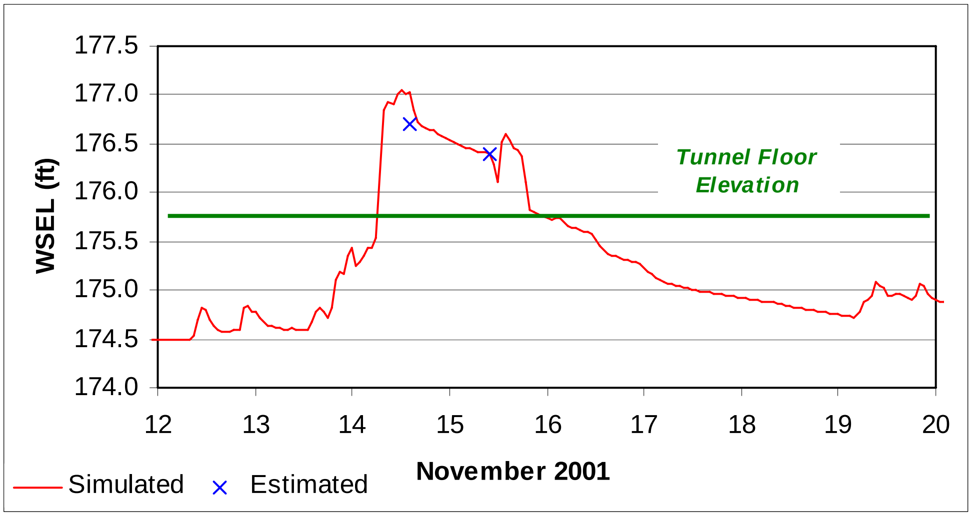

Figure 3d – HSPF Model Calibration
Golf Course Pond Simulated and Estimated Water Surface Elevation (November 2001 Flood)

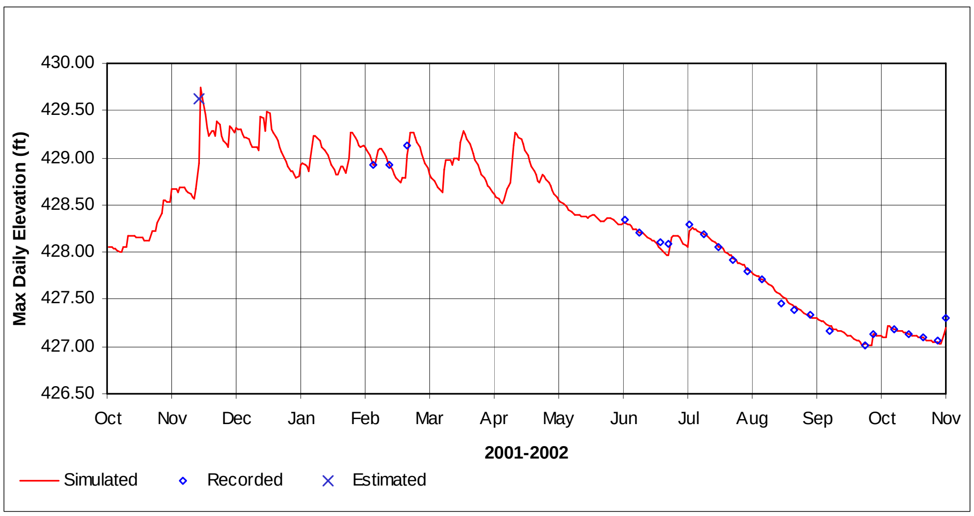

Figure 4 – HSPF Model Calibration
Easter Lake Simulated and Recorded Water Surface Elevation

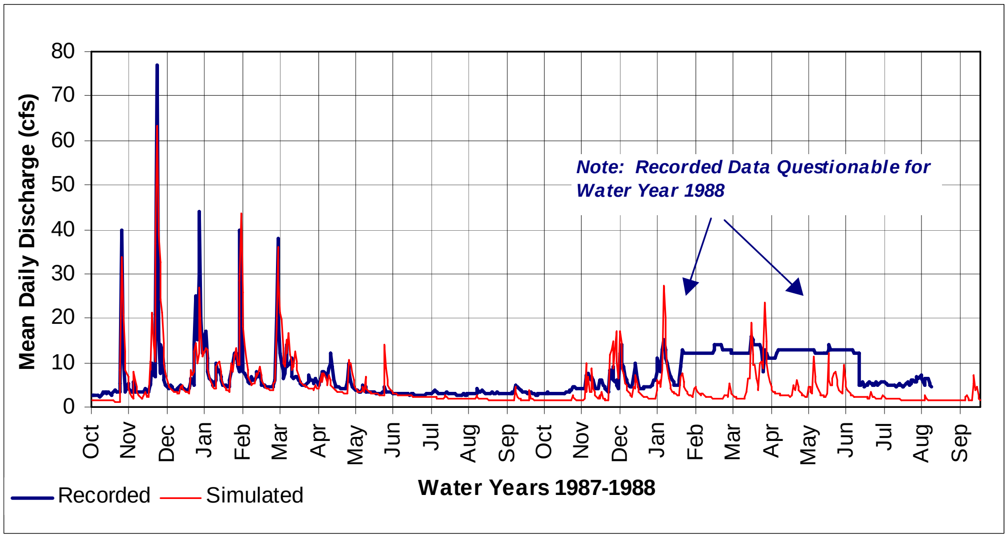

Figure 5a – HSPF Model Calibration
Joes Creek at Mouth Simulated and Recorded Mean Daily Discharge (WY 1987-1988)

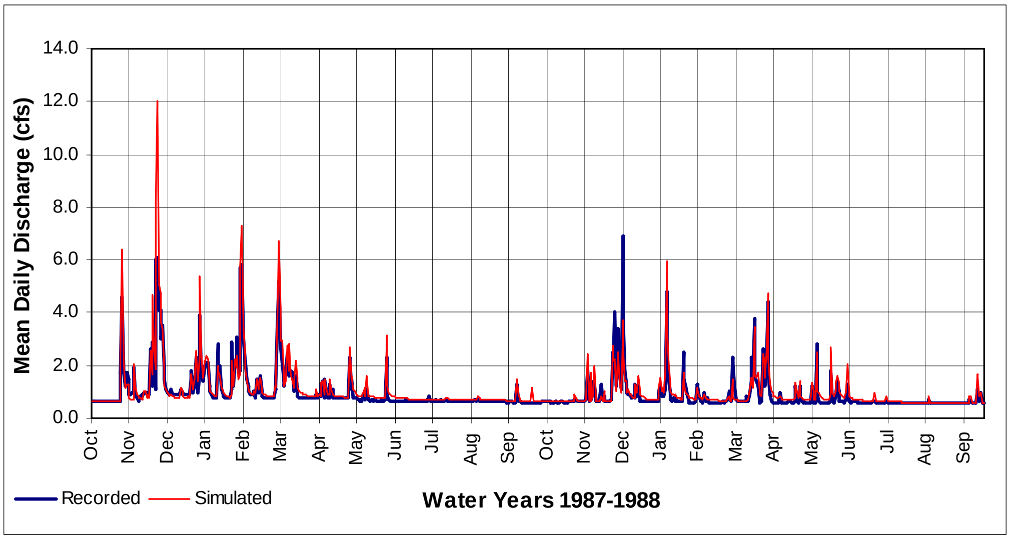

Figure 5b – HSPF Model Calibration
Cold Creek at Mouth Simulated and Recorded Mean Daily Discharge (WY 1987-1988)

HSPF WATERSHED MODEL – ANALYSIS/PREDICTION APPROACH

Simulation Period

Following the calibration phase, the model may be used for analysis and prediction of streamflows for various land use conditions and to assess the performance of mitigation projects. For this application, long-term, high-quality, precipitation timeseries are needed that are representative of the hourly, daily, weekly and monthly precipitation characteristics that have occurred in the past, and can be expected to occur in the future.

The Pierce County Extended Precipitation Timeseries for Continuous Hydrologic Modeling[8] was used as input for the analysis of the Joes and Cold Creek watersheds. This timeseries has a timestep of 15-minutes, is 158-years in length, and represents the rainfall characteristics of the Joes and Cold Creek watersheds.

Peak Flow/Water Surface Elevation Magnitude-Frequency Statistics

Peak flow and water surface elevation magnitude-frequency estimates were computed at locations of interest in the study area using the HSPF model. The annual maxima discharge rates were saved at each location from the 158-years simulated. Peak flow and elevation magnitude-frequency relationships were computed using the Gringorten[9,12] plotting position formula (Equation 1). This approach was taken because probability distributions commonly used in flood-frequency analyses, such as the Log-Pearson III[10] distribution, typically do not fit annual maxima flows from watersheds regulated by lakes and stormwater ponds.

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

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

Flow Duration Statistics

Modifications to the land surface during urbanization increases both the runoff peak rate and volume. The increase in runoff volume is the result of the loss of water storage in the soil column because of the compaction of the soil or the introduction of impervious surface. The increase in runoff volume combined with the increase in runoff rate results in higher stream discharges occurring for a longer duration. The increase in duration of a given flow rate results in more erosive work being performed on the stream channel over time, particularly when the discharge rate exceeds the threshold for stream bedload movement in the receiving channel.

A flow duration analysis was performed using the HSPF model for the Cold and Joes Creek watersheds to determine the effect of the proposed mitigation projects on stream erosion rates. A flow duration analysis provides a measure of the relative amount of erosive work performed on the stream channel under each alternative examined.

HYDROLOGIC PERFORMANCE OF STRUCTURES IN THE JOES CREEK WATERSHED

INTRODUCTION

Precipitation timeseries 158-years in length at a 15-minute timestep and daily evaporation derived from the Puyallup 2 West Experimental Station (station number 45-6803) were used as input to the model, which resulted in a 158-year, 15-minute timeseries of flow at the outlet of each subbasin simulated. Flood magnitude-frequency and duration analyses were subsequently performed on the flow timeseries at locations of interest in the watershed. Mitigation alternatives were then added to the model and their effectiveness at reducing flood peak, lake water surface elevation, flow duration, and erosion potential assessed.

EXISTING FLOODING PROBLEMS

Lake Lorene Flooding

Flooding of lakeside residences is predicted to occur at a 25-year recurrence interval under existing and future land use (Figure 6). Flooding occurs because of an undersized culvert located downstream of the lake outlet which restricts discharge from the lake during large floods.

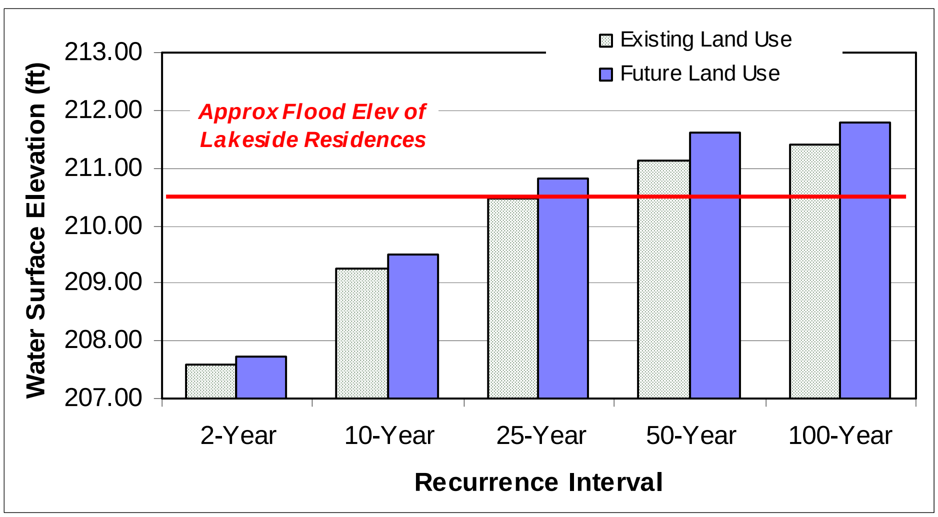

Figure 6 – Comparison of Simulated Water Surface Elevation, Existing and Future Land Use, Existing Conveyance System – Lake Lorene

Lake Jeane Flooding

Flooding of lakeside residences is predicted to occur at a 25-year recurrence interval under existing and future land use (Figure 7). Flooding is the result of inadequate outlet capacity and the tendency for the outlet to become obstructed by debris.

It should be noted that the flood elevation noted on Figure 7 is an approximate value. Representatives of the Twin Lakes homeowners association stated that owners of flooded property near the lake had constructed flood protection levees following floods that occurred in the early and mid 1990's. A detailed survey should be performed to determine whether structures would still flood under existing conditions and if the proposed outlet modifications would need to be revised.

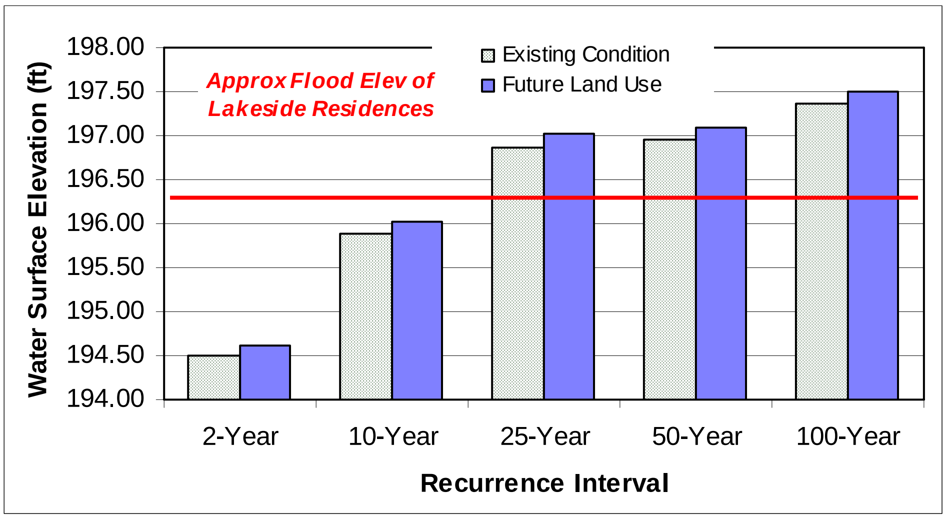

Figure 7 – Comparison of Simulated Water Surface Elevation, Existing and Future Land Use, Existing Conveyance System – Lake Jeane

Golf Course Pond Flooding

The Twin Lakes Golf Course pond is located at the confluence of the east and west forks of Joes Creek south of SW 320th Street. Flooding through the pedestrian underpass beneath SW 320th Street occurs nearly every year under existing and future land use (Figure 8). The underpass was designed to function as an overflow for the pond, however, a high point located at the outlet of the underpass backs water up in the pond an additional ¾ of a foot at the upstream end and 2 feet at the downstream end. This results in standing water in the underpass for extended periods during floods and creates a potentially hazardous condition for pedestrians.

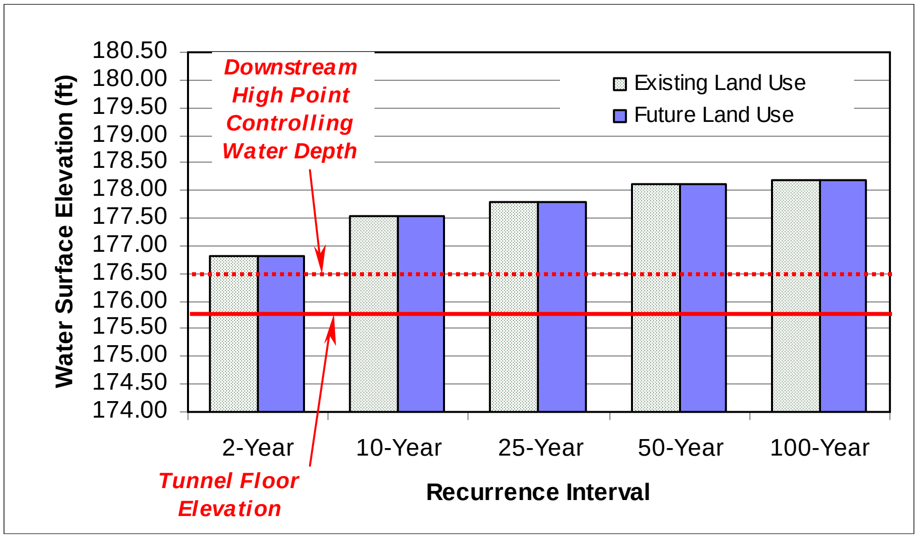

Figure 8 – Comparison of Simulated Water Surface Elevation, Existing and Future Land Use, Existing Conveyance System – Twin Lakes Golf Course Pond
Lines Indicate Tunnel Floor Elevation at Upstream end of Pedestrian Underpass and Elevation of Sill at Downstream end that Controls the Pond Water Surface Elevation during Floods

Joes Creek Channel Erosion

The Joes Creek ravine is located downstream of the Twin Lakes Golf Course. Flows from the Golf Course pond are piped via a 36-inch concrete pipe beneath SW 320th Street and discharge to an open channel located along the western boundary of the Twin Lakes Golf Course driving range. The 36-inch pipe was shortened sometime in the 1980's resulting in a discharge point further upstream than the previous outfall constructed when the driving range was built. Flow discharging at the new upstream point eroded a new channel upstream of the original discharge point. This new channel has continued to incise and erode laterally into the driving range damaging several net support poles. The eroded sediment has been and continues to be, carried downstream and deposited at the mouth of Joes Creek near Puget Sound.

Downstream of the driving range, Joes Creek enters a ravine that drops steeply to Puget Sound. According to the 1990 King County Basin Plan[5], increased flows in the ravine associated with urbanization have resulted in acceleration in the rate of stream channel erosion over historic levels. The Joes Creek watershed is approaching full build out and the anticipated increase in flood peak discharge is expected to be negligible in the future (Figures 9 and 10).

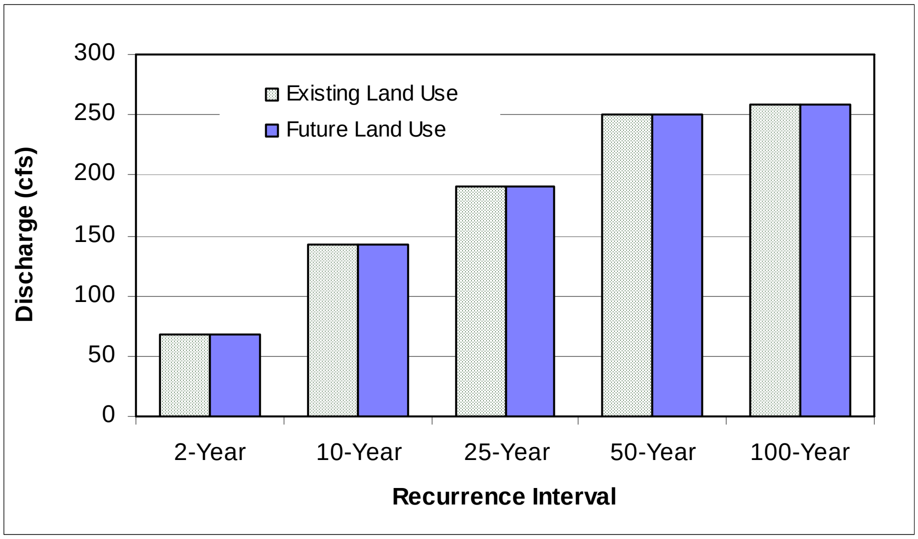

Figure 9 – Comparison of Simulated Flood Peak Discharge
Joes Creek at Top of Ravine (Upper Subbasin J2)

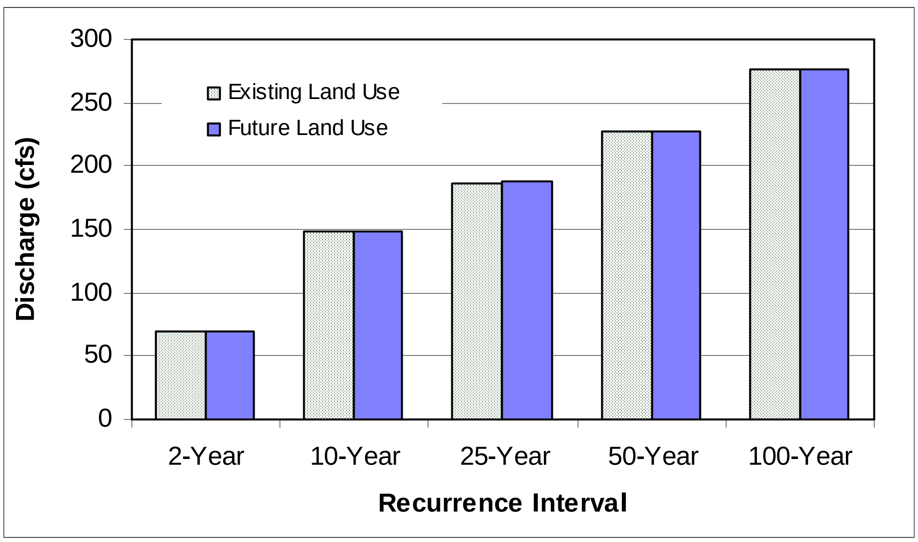

Figure 10 – Comparison of Simulated Flood Peak Discharge
Joes Creek Mouth at Puget Sound (Subbasin J1 Outlet)

MITIGATION PROJECT DESCRIPTION

Mitigation projects to correct the flooding deficiencies near Twin Lakes and Easter Lake are presented in this section. These projects were identified in the City of Federal Way, Comprehensive Surface Water Management Plan[1] with the exception of the stormwater pond options at the Twin Lakes Golf Course driving range, which is a new project presented in this report.

Project JOE-4: Lake Lorene Outlet Improvement

High water levels at Lake Lorene are the result of an undersized culvert (24-inch diameter) located in the lake outlet channel. During high flow conditions, this culvert restricts the lake outflow resulting in elevated water levels. The project proposal is to replace the existing culvert with a 42-inch concrete pipe to increase the high-flow discharge capacity. A 60-inch diameter riser structure with a 21-inch low-level orifice will be constructed at the upstream end of the culvert to maximize the flood storage of the lake. The riser structure will be open on top to function as an overflow with a crest elevation of 209.6 feet. With the revised outlet configuration, the 100-year lake water surface elevation was computed to be 210.2 feet, which is below the 210.5-foot water surface elevation where structural flooding occurs.

A comparison of the 100-year surface water profile in the lake outlet channel under existing conditions and with the proposed modification is shown in Figures 11a and 11b.

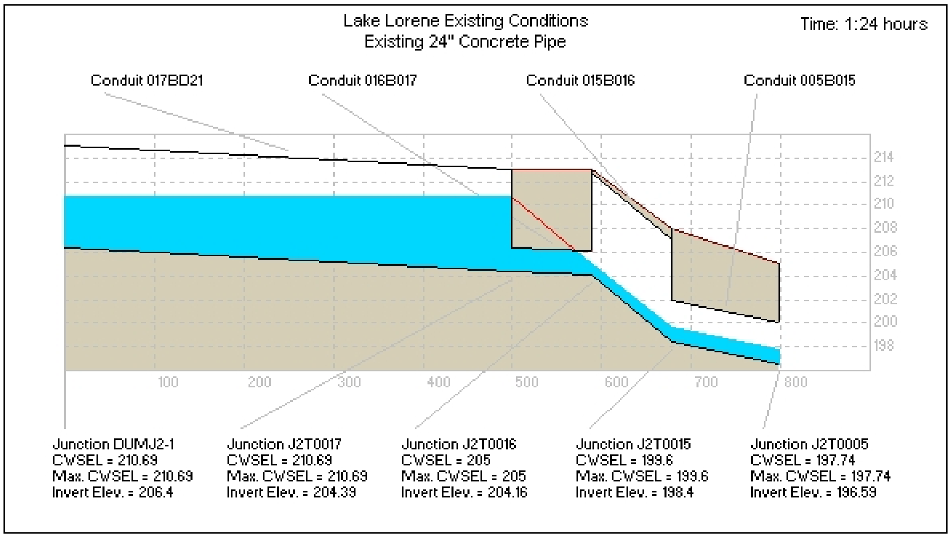

Figure 11a - Lake Lorene Existing Outlet Channel, 100-year Water Surface Elevation
(Computed using SWMM EXTRAN Program)

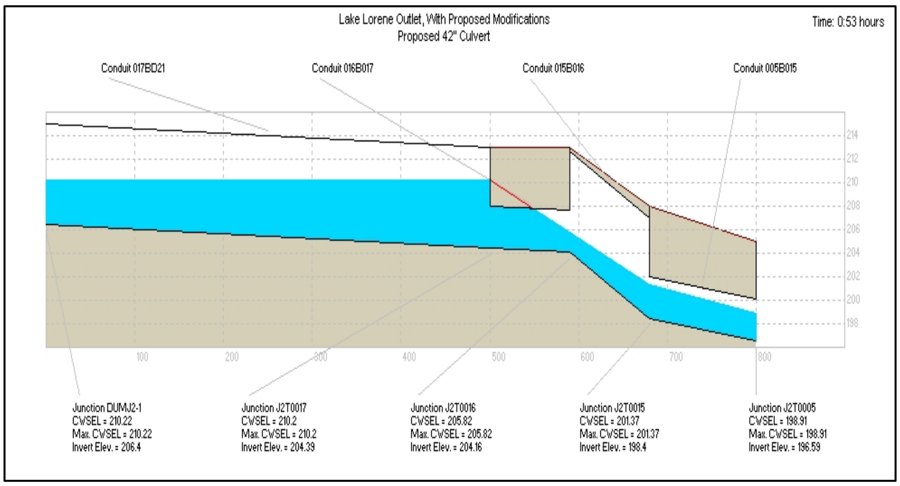

Figure 11b - Lake Lorene Proposed Outlet Channel, 100-year Water Surface Elevation
(Computed using SWMM EXTRAN Program)

Project JOE-1: Lake Jeane Outlet Improvement

The existing Lake Jeane outlet conduits do not have sufficient capacity to discharge floods up to the 100-year recurrence interval without flooding lakeside residences. The proposed project would replace the existing 18-inch and 24-inch outlet pipes with a single 36-inch concrete pipe, a new control structure, and energy dissipator at the downstream end. The control structure would consist of a 21-inch orifice at an elevation of 192.3 feet, and 9.5-foot weir at elevation 194.3 feet. With this proposed outlet configuration, the 100-year lake water surface elevation was computed to be 195.4 feet, which is below the 196.3-foot water surface elevation where structural flooding occurs.

It was reported by representatives of the Twin Lakes Homeowners Association that owners of flooded property near the lake had constructed flood protection levees following floods that occurred in the early and mid 1990's. A detailed survey should be performed to determine whether structures would still flood under existing conditions and whether the proposed modifications are still appropriate.

Project JOE-13: Twin Lakes Golf Course Pond Improvements

Modifications to the Twin Lakes Golf Course pond include replacing several sections of pipe on the north side of SW 320th Street. The pipes to be replaced are undersized and restrict the discharge from the Golf Course pond. In addition, the pipe connecting SPJ1TO120 to SPJ1TO105 has been damaged and a sinkhole exists near manhole SPJ1TO105. The pipe section downstream of SPJ1TO105 will be replaced or extended depending on the Twin Lakes Golf Course Driving Range Stormwater Pond option selected (described in the next section). A conceptual site plan of the Twin Lakes Golf Course under existing conditions is shown in Figure 12 with the proposed Golf Course pond pipe modification project shown in Figure 13.

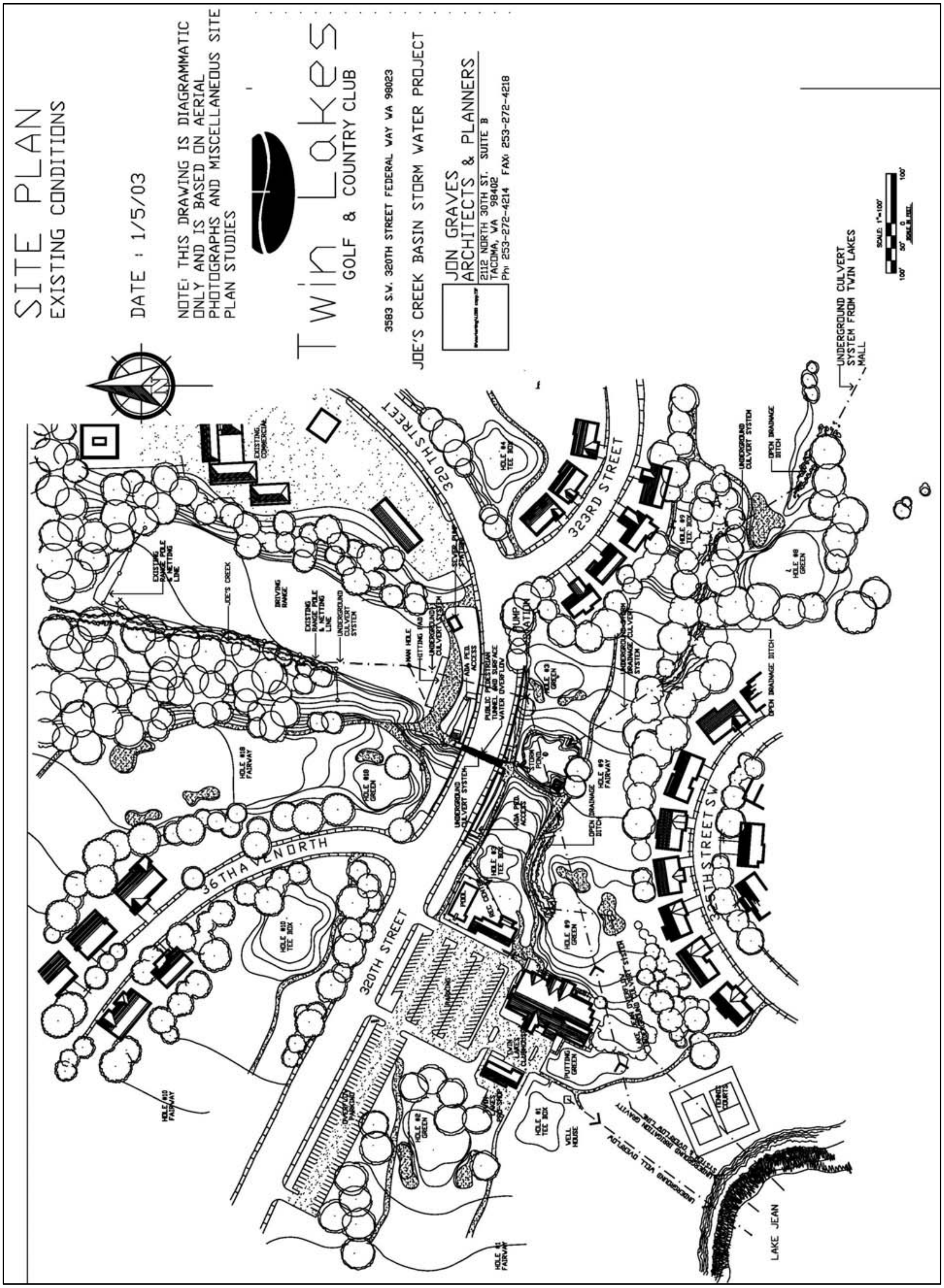

Figure 12 – Twin Lakes Golf Course Site Plan, Existing Condition

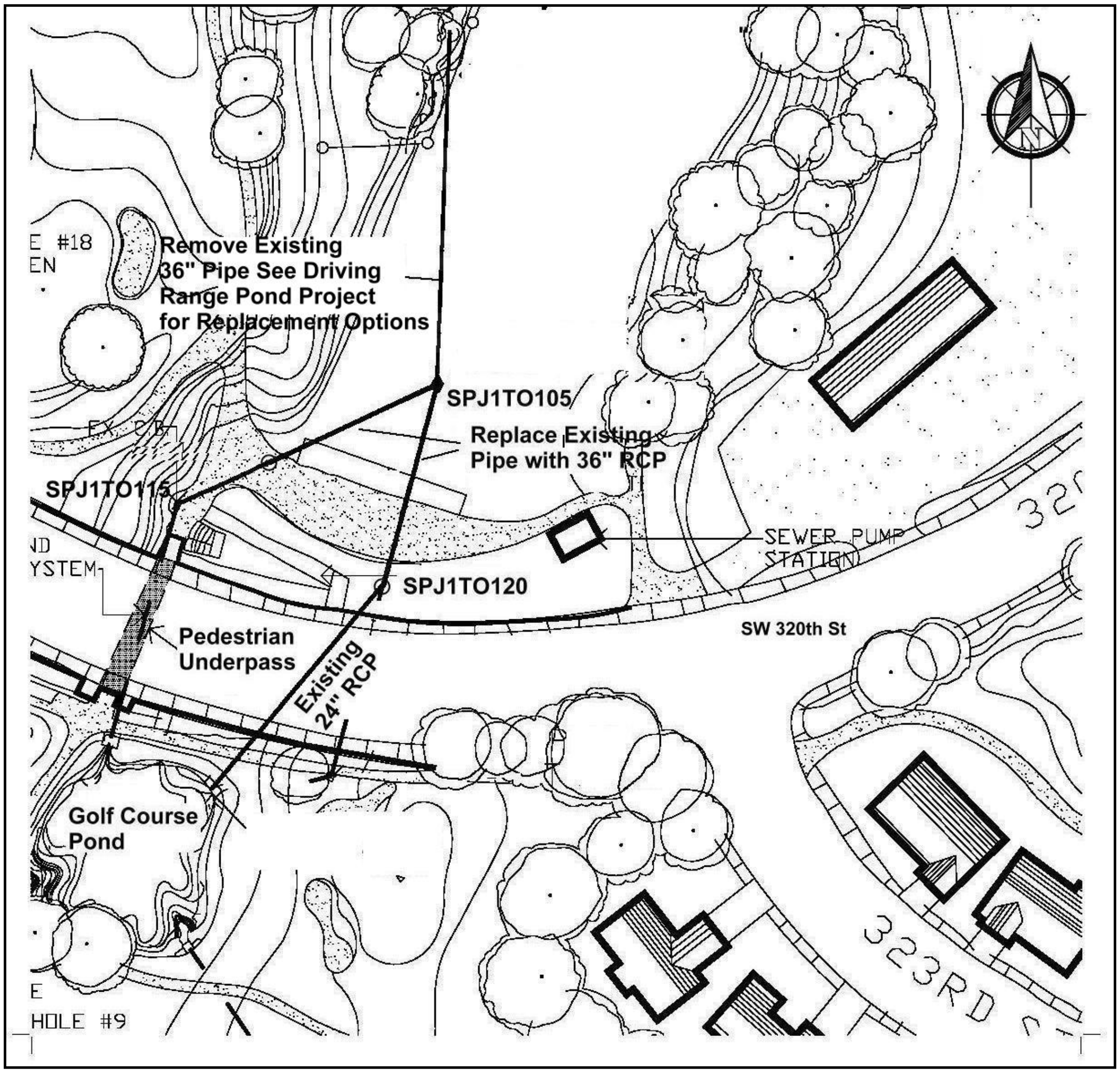

Figure 13 – Project JOE-13, Twin Lakes Golf Course Pond Outlet Pipe Improvements

Twin Lakes Golf Course Driving Range Stormwater Pond (New Project)

The Twin Lakes Golf Course driving range is located adjacent to Joes Creek at the head of the ravine on the north side of SW 320th Street. Currently, Joes Creek is piped beneath SW 320th Street and outfalls to a channel along the western boundary of the driving range. High flows have caused channel incision and lateral erosion that have undermined the system of poles that support the netting used to contain golf balls on the driving range. In addition, overflows from the Golf Course pond via the pedestrian walkway beneath SW 320th Street have caused erosion of the driving range.

The Twin Lakes Golf Course and Homeowners Association have expressed interest in the construction of a regional stormwater detention pond at the driving range provided that the channel located along the west side of the driving range is stabilized, the erosion potential of flows crossing the driving range is reduced, and the driving range is available for use for the majority of the year. This project was not analyzed as part of the Tetra Tech/KCM report and is discussed here for the first time.

A stormwater pond at the driving range is ideally located to provide mitigation of runoff from the upstream watershed before entering the Joes Creek ravine. A reduction in flood discharge rate and duration would decrease the erosion rate in the ravine and provide a flow regime that would be more conducive to supporting fish habitat.

Grading the high point at the southern end of the driving range would also be included as part of this project and would reduce the depth of flooding in the underpass and the Golf Course pond, while still allowing the pedestrian underpass to function as an overflow. The grading would require reducing the elevation by approximately 2 feet at the southwest corner of the driving range near the pedestrian underpass. This would direct discharge from the underpass along the base of the hillslope at the western edge of the driving range, providing a direct path to the proposed detention pond while reducing the potential for erosion of the driving range.

Two stormwater detention pond options were analyzed, each of which includes an embankment with a maximum height of 13-feet. An option that would include an embankment with a maximum height of 20-feet was examined and rejected because it would backwater the system of pipes leading from the Twin Lakes Golf Course pond and the embankment footprint was too large.

Each of the two proposed options would include a flow splitter at the southern end of the driving range that would convey flow in excess of approximately ½ of the 2-year rate to the proposed pond with the remainder of flows passed directly to Joes Creek. The pond would also receive discharge from the Golf Course pond when it overflows through the pedestrian underpass. The two pond configuration options are described below.

> Driving Range Pond Option 1 includes a 13-foot high embankment constructed along the northern end of the driving range, a control structure to regulate discharge from the pond, and a system of catch basins to collect surface runoff from the driving range and convey it to the control structure (Figure 14a). The existing open channel that carries Joes Creek along the western boundary of the driving range would be filled providing an expanded area for the driving range and the creek would be piped to the end of the driving range. This option would provide approximately 16.6 acre-feet of flood storage at maximum reservoir elevation.

> Driving Range Pond Option 2 consists of a 13-foot high embankment constructed along the northern and western perimeter of the driving range, a control structure to regulate discharge from the pond, and a system of catch basins to collect surface runoff from the driving range and convey it to the control structure (Figure 14b). This option differs from Option 1 in that the stormwater pond is confined to the existing driving range area (driving range not expanded) and the existing channel along the western boundary of the driving range would be retained. The channel would be reconstructed to minimize the erosion potential and enhance fish habitat. This option would provide approximately 12.5 acre-feet of flood storage at maximum reservoir elevation.

A qualitative comparison of the performance, cost, and potential impacts to stream habitat of the two Driving Range Pond options is shown in Table 2. In general, each option had similar hydrologic performance in terms of erosive flow and flood peak reduction. Option 1 provided slightly better flood peak reduction because it would have slightly more storage volume than Option 2. Details of the hydrologic performance of each option are discussed in the next section.

The primary differences between the options are in the areas of stream habitat impact and project cost. Option 1 includes filling approximately 400 feet of the Joes Creek stream channel along the western project boundary and expanding the driving range area. Option 2 retains and includes measures to improve stream habitat in the channel adjacent to the driving range. The stream channel enhancement and the additional berm length to contain water on the existing driving range resulted in Option 2 costing approximately $260,000 more than Option 1.

Based on preliminary indications by the City of Federal Way Department of Community Development and Washington State Fish and Wildlife, it may be difficult (or impossible) to secure the permits required to fill the section of Joes Creek as proposed under Option 1. The downstream reaches of Joes Creek that would benefit from the project should be further investigated to determine if the larger pond volume under Option 1 would provide sufficient additional erosion and habitat benefits relative to Option 2 to compensate for the loss of open stream channel adjacent to the driving range. The project proponents should fully consider the cost, time, and environmental impacts when deciding which project option to pursue.

Table 2 – Relative Comparison of Benefits, Impacts, and Cost of Proposed Driving Range Options

Criteria	Driving Range Pond Option	
	Option 1 – Fill Joes Creek Channel, Expand Driving Range Area	**Option 2 – Preserve and Enhance Joes Creek Channel, Maintain Existing Driving Range Area**
1. Joes Creek Ravine Erosion Reduction	Favorable	Favorable
2. Joes Creek Flood Peak Reduction	Favorable	Favorable
3. Impact to Stream Habitat	Unfavorable	Favorable
4. Cost	$838,000	$1,097,000

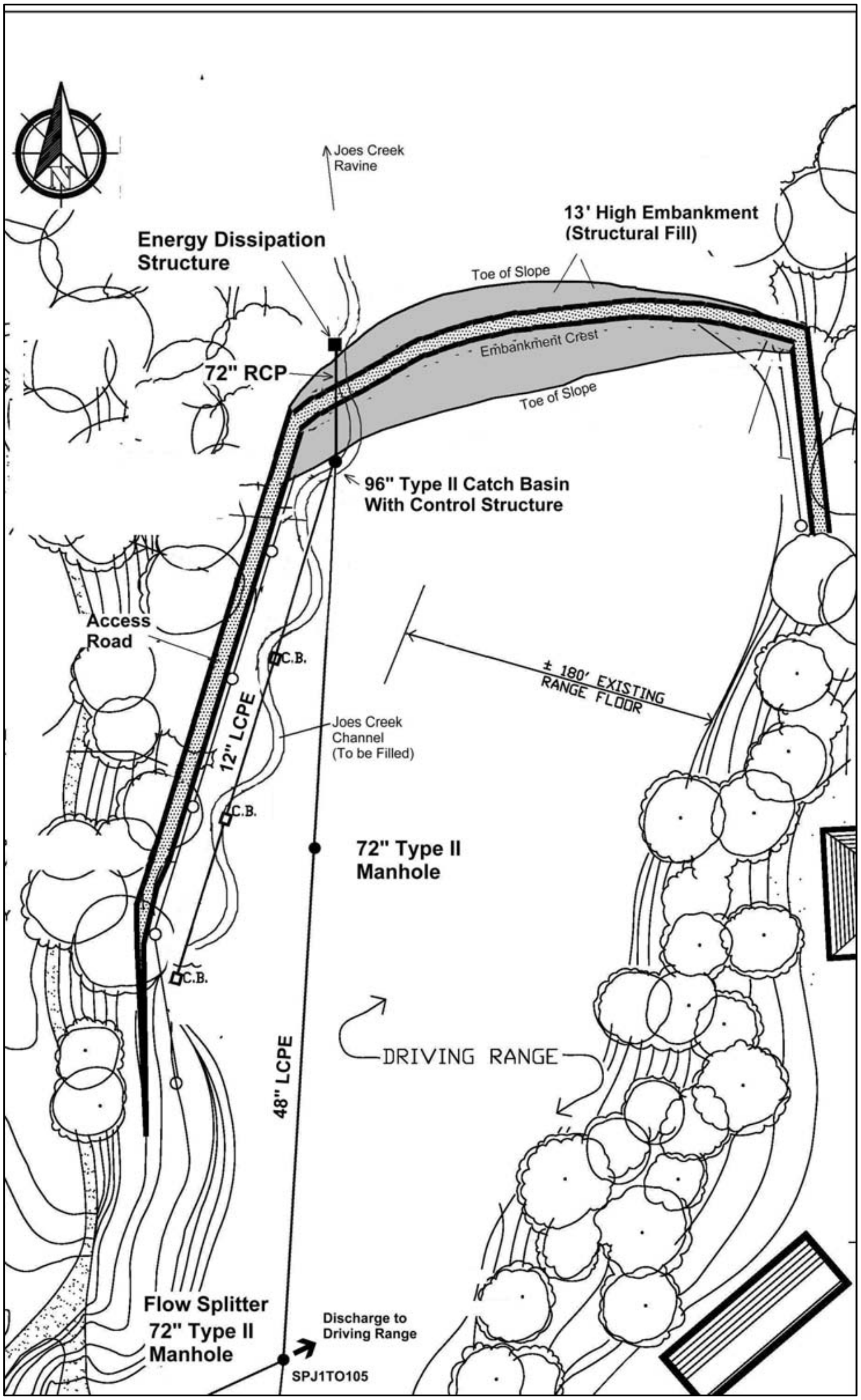

Figure 14a – Twin Lakes Golf Course Driving Range Stormwater Detention Pond, Option 1 (Conceptual Plan)

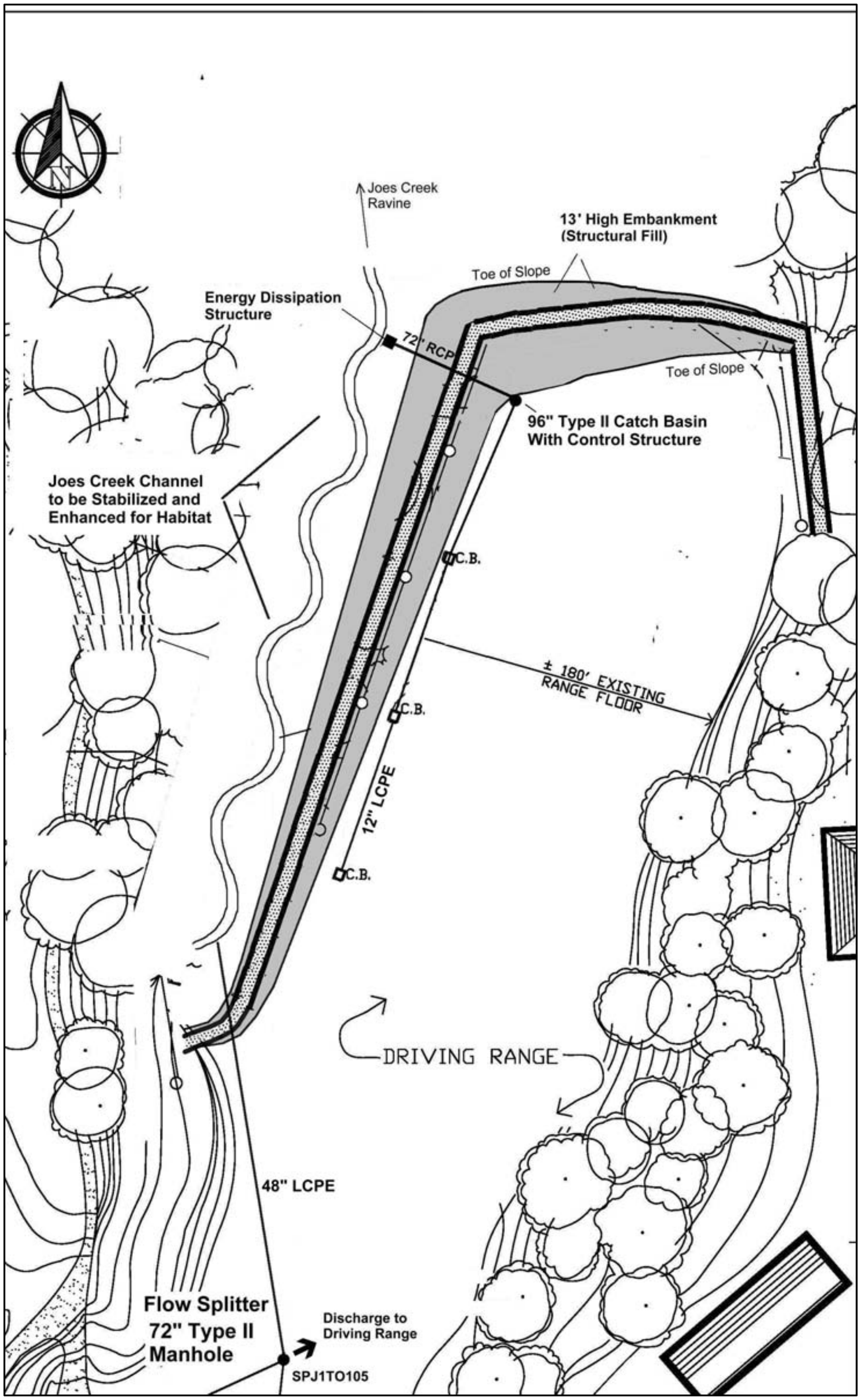

Figure 14b – Twin Lakes Golf Course Driving Range Stormwater Detention Pond, Option 2
(Conceptual Plan)

Hydrologic Performance With Proposed Mitigation Projects

Flood Peak Reduction

This section presents the hydrologic performance of the proposed Joes Creek mitigation projects. Results presented in this section were computed assuming future land use. Magnitude-frequency statistics for each simulation performed are summarized in Appendix A.

Results of the analysis showed that modifying the outlets of Lakes Lorene and Jeane would reduce the frequency of flooding at lakeside residences to a recurrence interval greater than 100-years (Figures 15a and 15b). Increasing the flood discharge capacity from Twin Lakes had a negligible effect on flooding downstream of the confluence with the east branch because the west branch of Joes Creek (on which the lakes are located) accounts for very little of the total flood peak rate downstream.

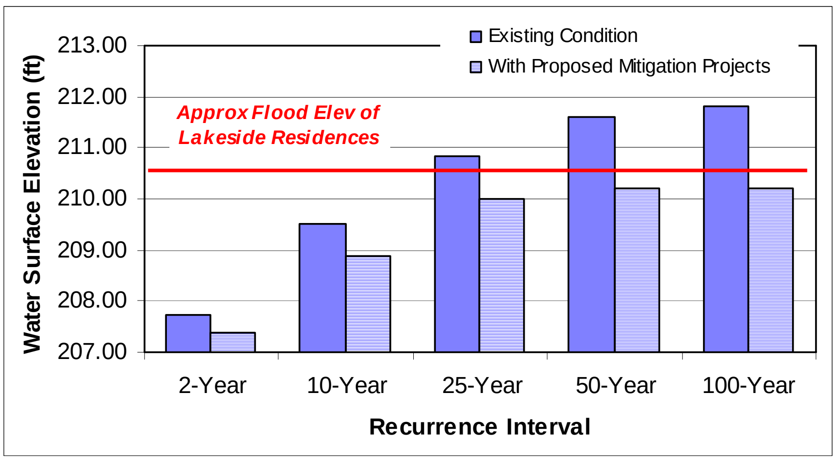

Figure 15a – Comparison of Simulated Water Surface Elevation, Existing Condition and with Proposed Mitigation Projects, Future Land Use – Lake Lorene

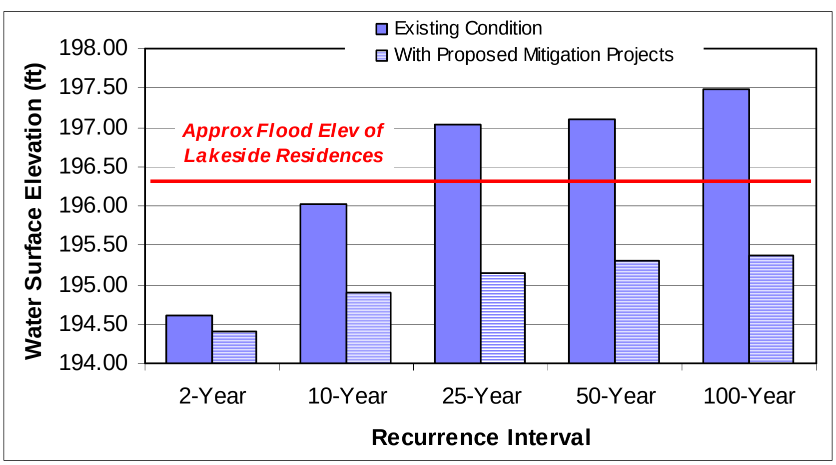

Figure 15b – Comparison of Simulated Water Surface Elevation, Existing Condition and with Proposed Mitigation Projects, Future Land Use – Lake Jeane

The simulated 100-year water surface elevation at Lake Jeane with the proposed modifications is one-foot below the flood elevation of lakeside structures. Outlet modifications were examined with the hydrologic model to determine the effectiveness of providing additional detention storage up to the flooding elevation. It was found at only a minor decrease in discharge would be provided by the additional storage and the proposed outlet configuration was deemed acceptable as is.

The proposed modifications at the Golf Course pond, in particular removing the sill at the outlet of the pedestrian underpass, resulted in a net decrease in the water surface elevation up to the 100-year recurrence interval (Figure 16). Further, the depth of flooding in the tunnel would be reduced, especially at the downstream end, where water commonly pools to a depth of 2 feet during floods.

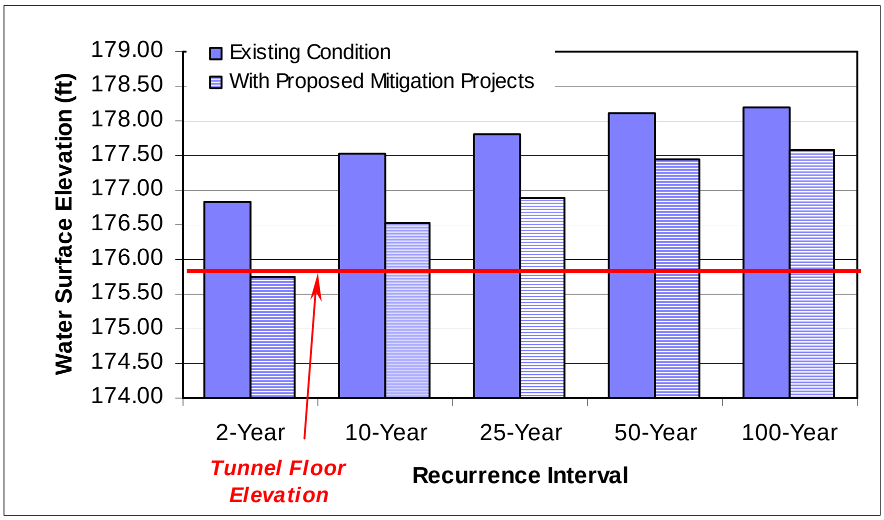

Figure 16 – Comparison of Simulated Water Surface Elevation, Existing Condition and with Proposed Mitigation Projects, Future Land Use – Golf Course Pond

Figures 17a and 17b compare the effectiveness of the proposed mitigation options at the top of the ravine and at the mouth of the stream, respectively. The driving range pond options provided approximately the same level of flood peak reduction, with peak discharge rates reduced from 12-percent to 38-percent for Option 1 versus 7-percent to 39-percent for Option 2 (measured at the mouth of Joes Creek).

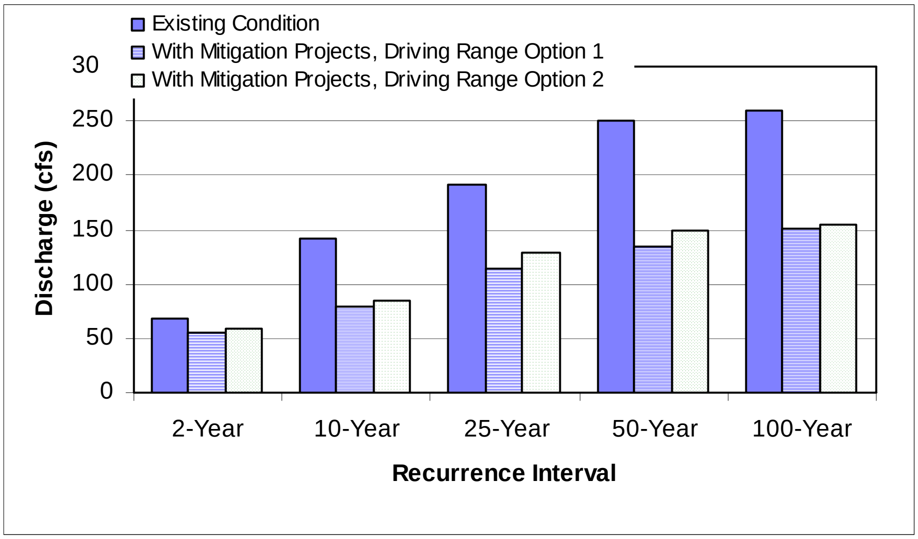

Figure 17a – Comparison of Simulated Flood Peak Discharge, Existing Condition, with Proposed Mitigation Projects and Driving Range Pond Options 1 and 2, Future Land Use Joes Creek at Top of Ravine (Upper Subbasin J2)

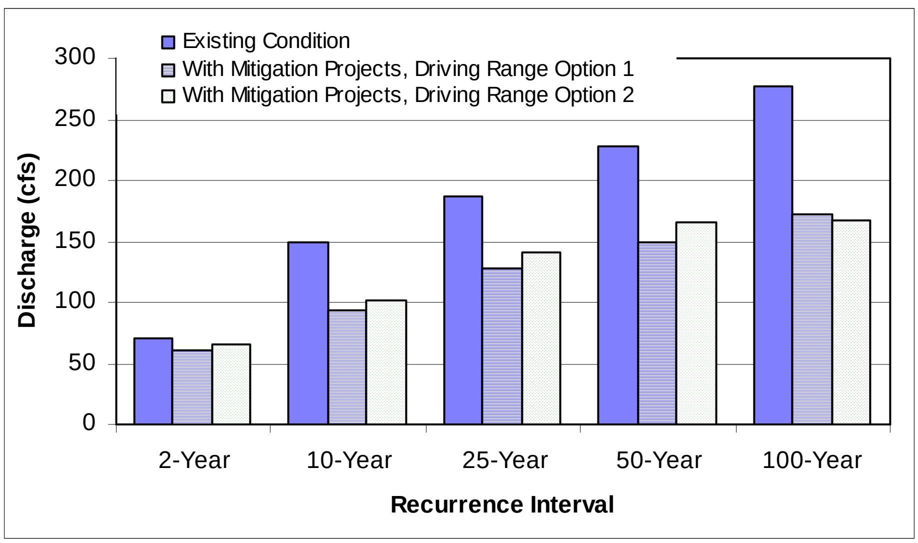

Figure 17b – Comparison of Simulated Flood Peak Discharge, Existing Condition, with Proposed Mitigation Projects and Driving Range Pond Options 1 and 2, Future Land Use Joes Creek Mouth at Puget Sound (Subbasin J1 Outlet)

Reduction in Erosive Flows

Flow duration statistics provide an indication of the relative amount of erosive work performed on the stream channel. The increase in duration of a given flow rate results in more erosive work being performed on the stream channel over time, particularly when the discharge rate exceeds the threshold for bedload movement in the receiving channel. The threshold for sediment movement is channel specific and is a function of the channel slope, cross section shape, and sediment size distribution.

As urbanization occurs in the watershed, the frequency of discharge that exceeds the historic bedload movement threshold increases. This results in greater erosive work on the stream channel leading to an expansion in the channel cross section with larger sized gravel.

Figures 18a and 18b shows that the duration of flow is reduced in the Joes Creek ravine for each of the Driving Range Pond options relative to the existing condition. Option 1 provides slightly more reduction in flow duration than Option 2 and would be expected to reduce the rate of erosion slightly more than Option 2. These results demonstrate that the proposed mitigation projects, in particular the construction of the Driving Range Stormwater Pond, would result in a lower rate of erosion in the ravine and with time, would lead to a more stable stream channel system.

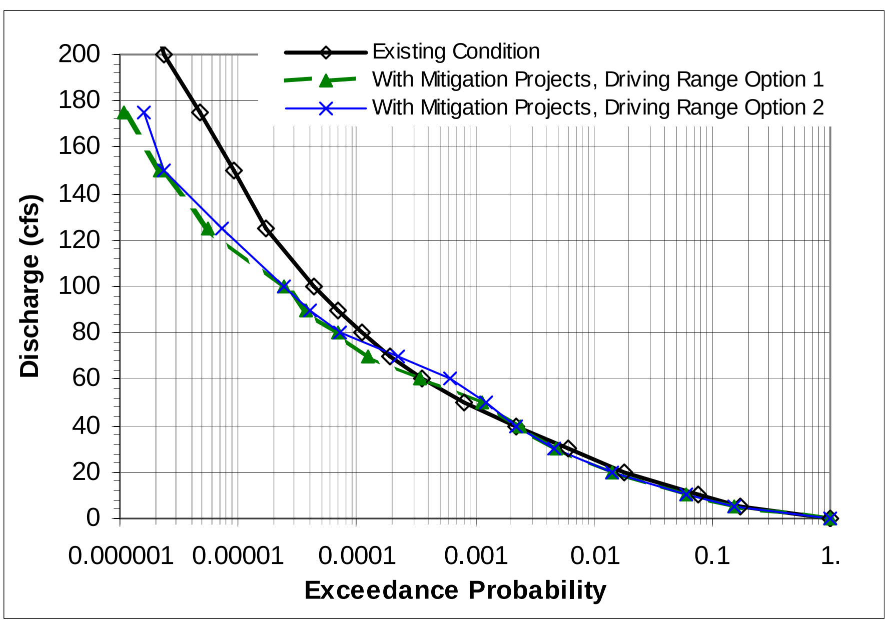

Figure 18a – Comparison of Simulated Flow Duration, Existing Condition, with Proposed Mitigation Projects and Driving Range Pond Options 1 and 2, Future Land Use Joes Creek at Top of Ravine (Upper Subbasin J2)

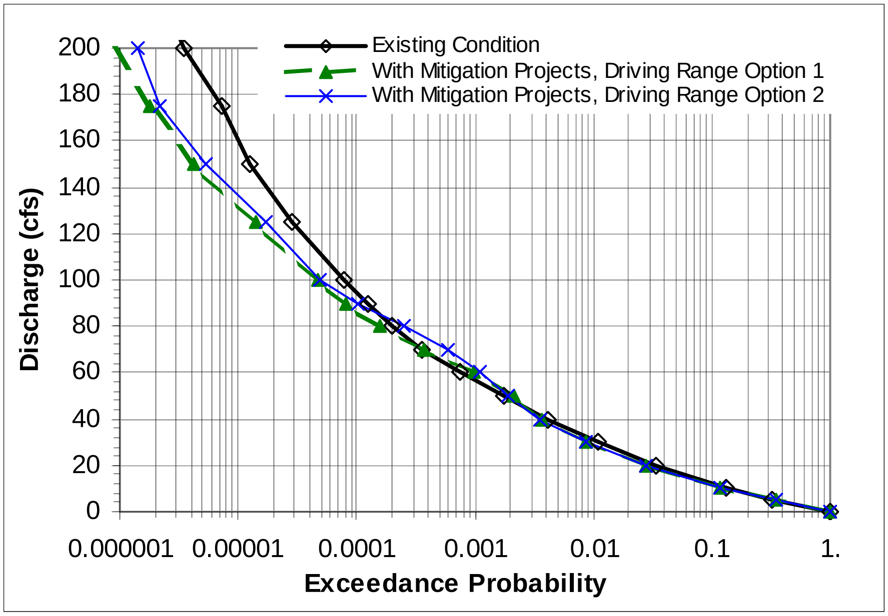

Figure 18b – Comparison of Simulated Flow Duration, Existing Condition, with Proposed Mitigation Projects and Driving Range Pond Options 1 and 2, Future Land Use
Joes Creek Mouth at Puget Sound (Subbasin J1 Outlet)

COST SUMMARY

Table 3 summarizes the cost associated with the recommended mitigation projects in the Joes Creek watershed. Cost estimates for several of the projects were taken from the City of Federal Way Gap Analysis (URS Engineers, 2001) with the remainder estimated as part of this study. These estimates were made without detailed survey, geotechnical, or habitat analyses, are for planning purposes only, and should be considered only approximate values. Appendix B contains detailed information on the development of the estimates.

Table 3 – Summary of Mitigation Project Costs

Tetra Tech/KCM Project No.	Project Name	Estimated Cost
JOE-1	Lake Jeane Outlet Improvement	$1,039,500*
JOE-4	Lake Lorene Outlet Channel Improvement	$238,500*
JOE-13	Twin Lakes Golf Course Pond Outlet Improvement	$528,500*
--	Twin Lakes Golf Course Driving Range Detention Pond, Option 1	$838,000
--	Twin Lakes Golf Course Driving Range Detention Pond, Option 2	$1,097,000

* Costs taken from the City of Federal Way, Gap Analysis, URS Engineers, 2001

HYDROLOGIC PERFORMANCE OF STRUCTURES IN THE COLD CREEK WATERSHED

INTRODUCTION

This section presents the results of a hydrologic analysis of Easter Lake in the Cold Creek watershed. Modification of the Easter Lake outlet to reduce the likelihood of flooding at structures surrounding the lake was simulated using the HSPF model. These modifications were originally developed as part of the City of Federal Way Comprehensive Surface Water Management Plan[1]. Impacts of these modifications in terms of increasing the potential of downstream flooding and erosion are also presented.

EXISTING FLOODING PROBLEMS

Easter Lake is located at the headwaters of Cold Creek, a small urban tributary to Puget Sound in Federal Way. Flooding surrounding the lake occurs due to restrictions in the outlet channel and an undersized driveway culvert located 400 feet downstream of the lake outlet.

Analysis of Easter Lake was performed using the HSPF hydrologic and SWMM EXTRAN hydraulic models. Figure 19 shows the water surface profile of the Easter Lake outlet channel during a winter flood that resulted in a 100-year water surface elevation at the lake. The profile shows that a high point at the lake outlet and a restrictive culvert downstream limits the discharge capacity resulting in elevated lake water surface during floods.

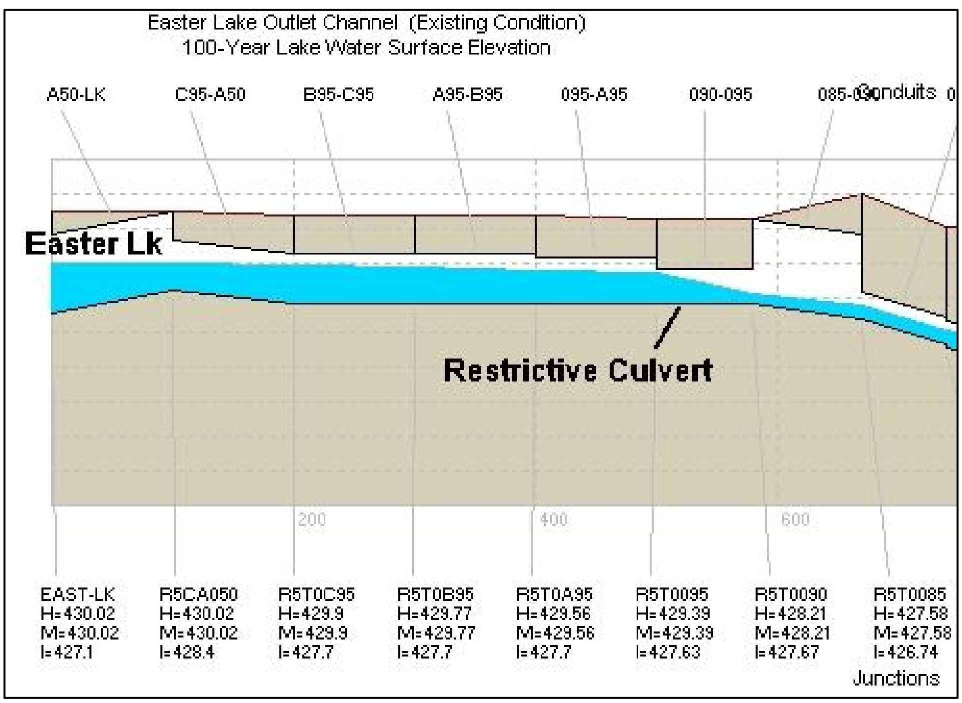

Figure 19 - Easter Lake Existing Outlet Channel, 100-year Water Surface Elevation (Computed using SWMM EXTRAN model)

MITIGATION PROJECT DESCRIPTION

The mitigation project proposed in the Comprehensive Surface Water Management Plan would replace the existing 24-inch driveway culvert in the outlet channel with a 36-inch culvert. In addition, the high point at the lake outlet would be widened by several feet and lowered by 0.7 feet to provide a control invert elevation of 427.7 feet. With this proposed outlet configuration, the 100-year lake water surface elevation was computed to be 429.1 feet, which is below the 430.0-foot water surface elevation where structural flooding occurs. Figure 20 shows the water surface profile of the Easter Lake outlet channel with the proposed modifications during a flood that resulted in a 100-year water surface elevation at the lake.

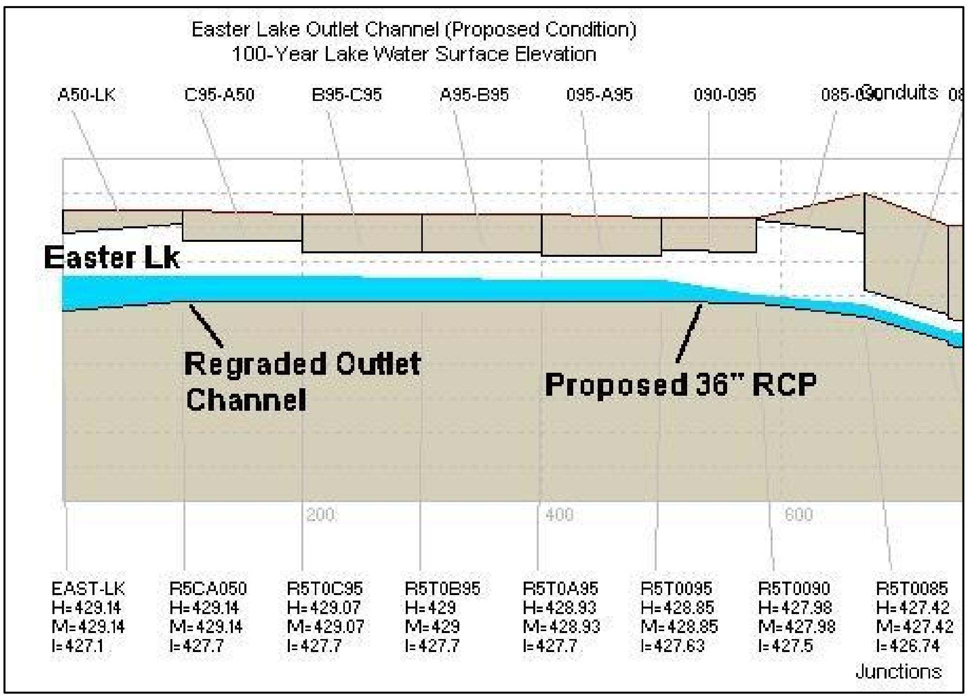

Figure 20 - Easter Lake Proposed Outlet Channel, 100-year Water Surface Elevation
(Computed using SWMM EXTRAN model)

HYDROLOGIC PERFORMANCE WITH PROPOSED MITIGATION PROJECT

The proposed Easter Lake outlet modifications (culvert replacement and channel grading) were analyzed separately to determine the relative contribution of flood reduction benefits and potential impacts to downstream discharge rates. In the figures that follow, the proposed modifications are labeled as Easter Lake Outlet Option 1 and Easter Lake Outlet 2, and are defined as follows:

> *Easter Lake Outlet Option 1*: replace the existing 24-inch driveway culvert in the outlet channel with a 36-inch culvert.

> *Easter Lake Outlet Option 2*: replace the existing 24-inch driveway culvert in the outlet channel with a 36-inch culvert. In addition, the high point at the lake outlet would be widened by several feet and lowered by 0.7 feet to provide a control invert elevation of 427.7 feet.

Modifying the Easter Lake outlet by replacing the 24-inch culvert in the outlet channel (Option 1) would reduce the frequency of flooding at lakeside residences from approximately a 50-year recurrence interval to a recurrence interval greater than 100-years (Figure 21). Grading the outlet channel in addition to the culvert replacement further reduces the water surface elevation during floods, with the 100-year reduced to approximately one-foot below the flood elevation.

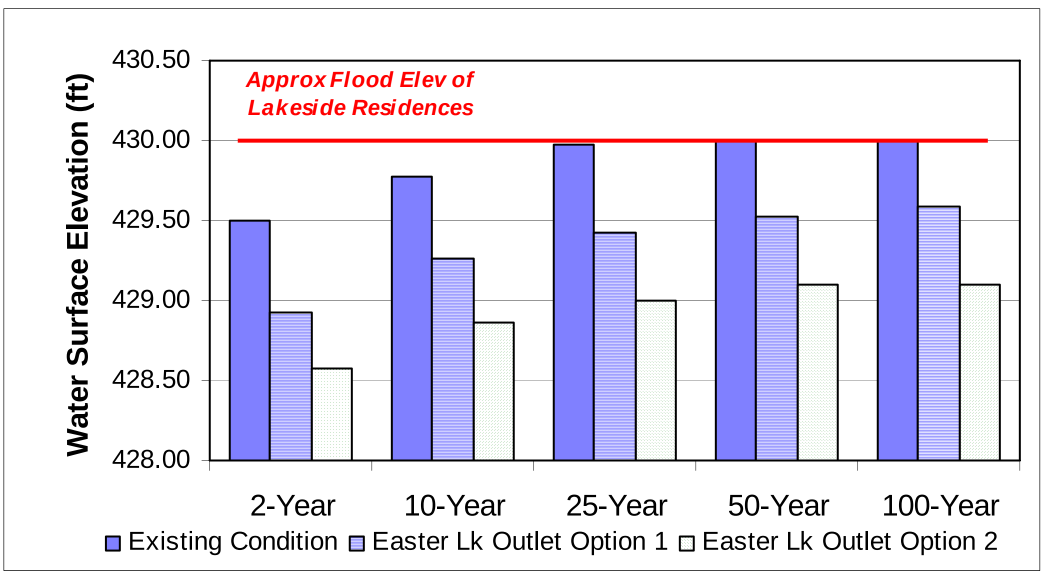

Figure 21 – Comparison of Simulated Water Surface Elevation, Existing Condition and with Proposed Mitigation Project, Existing Land Use – Easter Lake

While modifying the lake outlet would reduce flooding surrounding the lake, the discharge rate from the lake would be increased slightly. Figures 22a and 22b compare the peak discharge rates at the Cold Creek ravine under existing and proposed conditions. The proposed lake modifications resulted in a negligible increase in peak discharge rate downstream at the ravine. The reason for this is that the discharge rate from the lake is small relative to flows entering from areas downstream and the flood peak from the lake is lagged relative to the downstream peaks.

The proposed modifications also had negligible effect on the flow duration computed at the Cold Creek ravine. Figures 23a and 23b show that the proposed modifications resulted in a negligible increase in the flow duration downstream of the lake. This indicates that there would be a negligible increase in the rate of channel erosion downstream associated with the Easter Lake improvements.

The Federal Way Comprehensive Surface Water Management Plan recommended that berms be constructed at the north shore of Easter Lake to protect structures from flooding in addition to the outlet modifications previously described. It is not clear whether the berms would be required to prevent flooding due to uncertainty in the elevation at which flooding of structures occurs in this area. A detailed survey of the area should be performed to determine the elevation where structures flood and subsequently a decision made as to whether berms are needed and the height and location of such berm(s).

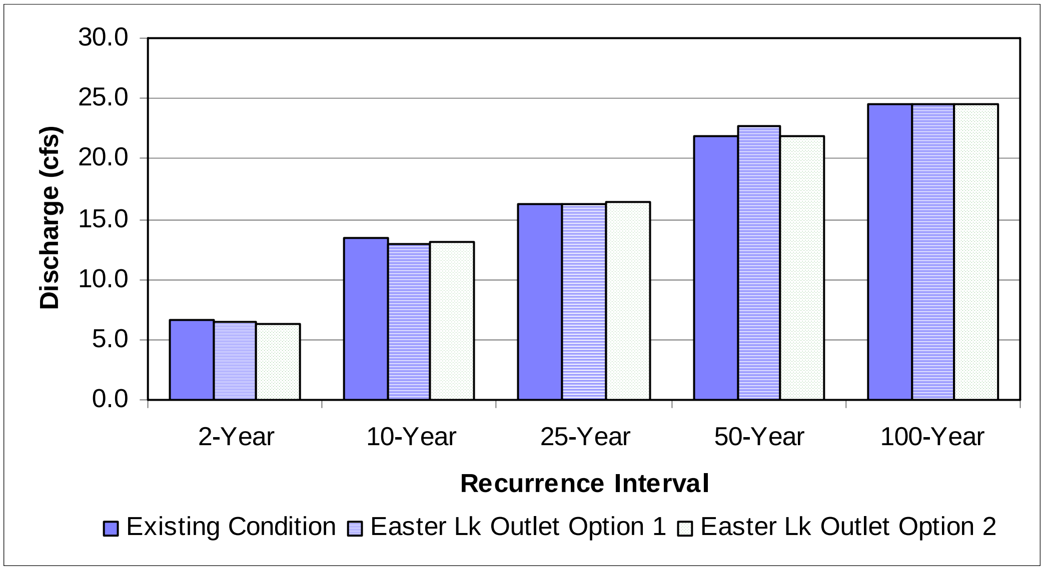

Figure 22a – Comparison of Simulated Flood Peak Discharge, Existing Condition and with Proposed Mitigation Project, Existing Land Use
Cold Creek Ravine (Upper Subbasin C5)

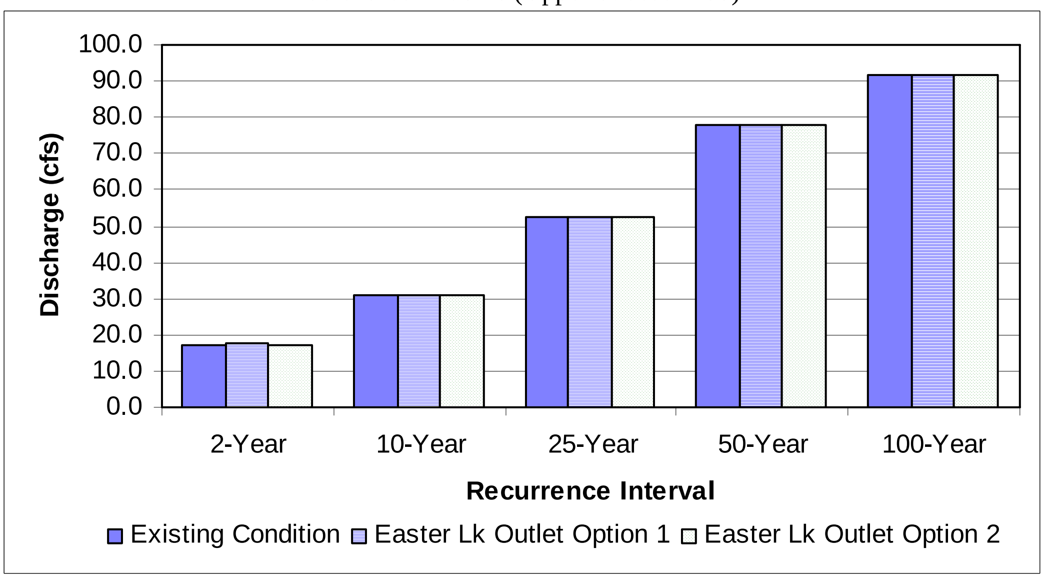

Figure 22b – Comparison of Simulated Flood Peak Discharge, Existing Condition and with Proposed Mitigation Projects, Existing Land Use
Cold Creek at Puget Sound (Subbasin C1 Outlet)

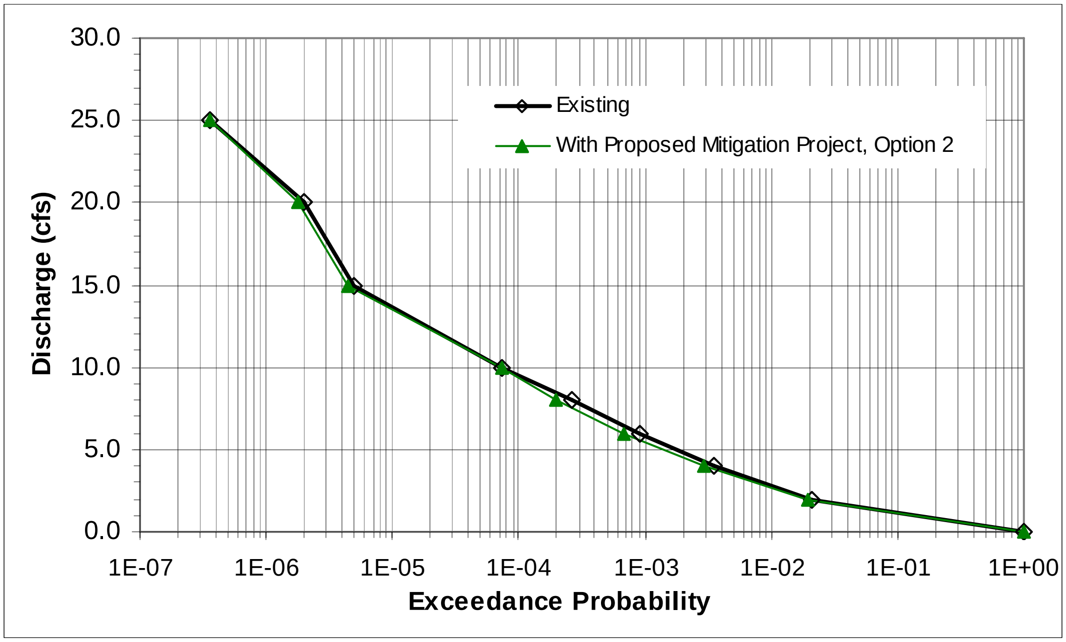

Figure 23a – Comparison of Simulated Flow Duration, Existing Condition and with Proposed Mitigation Project, Existing Land Use
Cold Creek Ravine (Upper Subbasin C5)

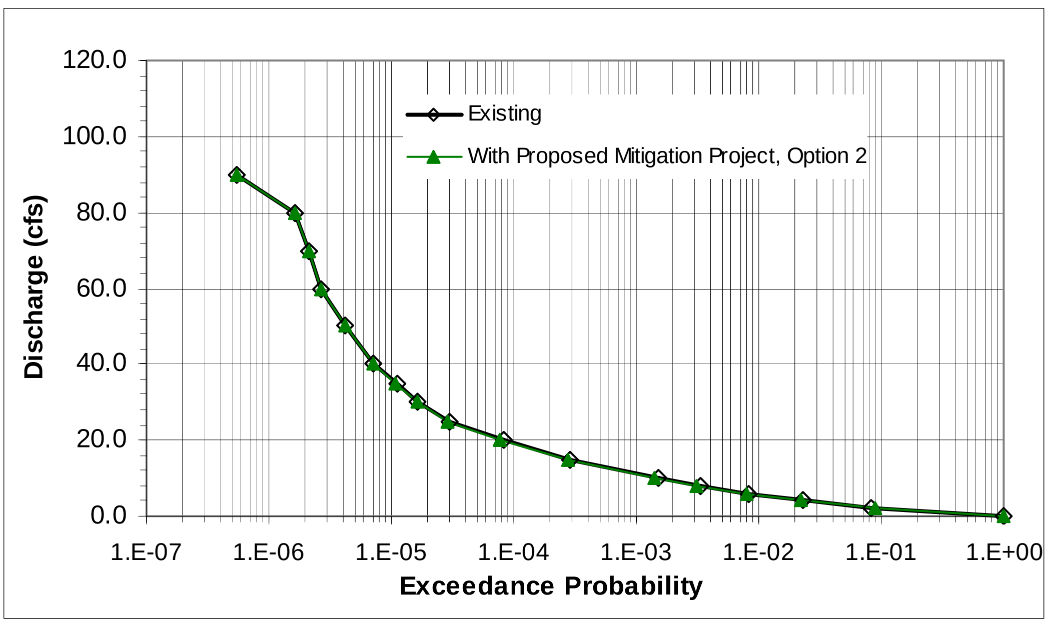

Figure 23b – Comparison of Simulated Flow Duration, Existing Condition and with Proposed Mitigation Projects, Existing Land Use
Cold Creek at Puget Sound (Subbasin C1 Outlet)

COST SUMMARY

Table 4 summarizes the costs associated with the recommended mitigation projects analyzed in the Cold Creek watershed. These estimates were made without detailed survey, geotechnical, or habitat analyses, are for planning purposes only, and should be considered only approximate values. Appendix B contains detailed information on the development of the estimates.

Table 4 – Summary of Mitigation Project Costs

Tetra Tech/KCM Project No.	Project Name	Estimated Cost*
EAS-1	Easter Lake Outlet Channel Improvement	$151,700

* Costs taken from the City of Federal Way, Gap Analysis, URS Engineers, 2001

SUMMARY AND CONCLUSIONS

In 1996, an engineering analysis was performed by Tetra Tech/KCM, Inc[1] as part of a Comprehensive Surface Water Management Plan for the City of Federal Way and included recommendations to reduce the flooding potential near Twin Lakes and Easter Lake. The Tetra Tech/KCM report recommended increasing the discharge capacity of each lake to reduce the frequency of flooding of lakeside structures. In addition, stormwater detention was recommended downstream of Twin Lakes at an existing pond at the Twin Lakes golf course to mitigate the stormwater detention lost by increasing the discharge capacity at the upstream lakes.

The projects originally proposed for Twin and Easter Lakes by Tetra Tech/KCM were analyzed as part of the current study using the HSPF hydrologic model. The continuous-flow, rainfall-runoff algorithms in HSPF provided improved estimates of runoff and lake water levels, and a better assessment of the proposed mitigation projects. These improved assessments were possible because of the capability of the HSPF model to analyze the runoff produced by long-duration storms and sequences of storms that commonly occur in western Washington.

JOES CREEK AND TWIN LAKES

Results of the HSPF analysis indicate that the size of the existing outlet structures at Lake Lorene, and Lake Jeane restrict lake discharges and would result in flooding of lakeside residences and structures at a 25-year recurrence interval. Downstream, the Twin Lakes Golf Course pond was predicted to flood nearly every year on average and several times per year in some years.

Increasing the flood discharge capacity from Twin Lakes would reduce the frequency of flooding of lakeside structures beyond the 100-year recurrence interval. The proposed modifications include replacing an undersized culvert in the outlet channel of Lake Lorene and replacing the outlet pipes at Lake Jeane. Increasing the flood discharge capacity from Twin Lakes had a negligible effect on flooding downstream of the confluence with the east branch because the West Branch of Joes Creek (on which the lakes are located) accounts for very little of the total flood peak rate.

According to the 1990 Hylebos and Lower Puget Sound Basin Plan[5], increased runoff associated with upstream urbanization has increased the rate of erosion in the Joes Creek ravine. High flows, in past years, have also caused channel incision and lateral erosion that have undermined the system of poles that support the netting used to contain golf balls on the driving range, which is a concern to the Twin Lakes Homeowners Association. To reduce the potential for downstream flood and erosion damage, a regional detention pond is proposed at the Twin Lakes Driving Range to mitigate the increased flood flows resulting from the proposed lake outlet modifications and to mitigate increased runoff associated with existing upstream urbanization.

The Twin Lakes Golf Course and Homeowners Association have been amenable to the development of a regional stormwater detention pond at the driving range provided that the area occupied by the pond is available for use as a driving range for the majority of the year. A stormwater pond at the driving range was not addressed as part of the Tetra Tech/KCM study and is proposed in this report for the first time. The potential stormwater detention volume at the driving range is considerably larger than at the Golf Course Stormwater Pond proposed in the 1996 KCM/Tetra-Tech report. Thus, the performance of a stormwater pond located at the driving range was examined in lieu of providing flood storage at the Golf Course Pond.

Two driving range stormwater detention pond options were analyzed as part of this study. The first option includes an embankment with a maximum height of 13-feet constructed along the northern end of the driving range with a maximum flood storage capacity of 16.6 acre-feet (723,000 cu ft). Under this option, the existing open channel that conveys Joes Creek along the western boundary of the driving range would be filled expanding the driving range area with the creek piped beneath the pond/driving range.

The second option includes an embankment with a maximum height of 13 feet constructed along the northern and western sides of the driving range with a flood storage capacity of 12.5 acre feet (544,000 cu-ft). For this option, Joes Creek would remain in an open channel reconstructed to minimize the erosion potential and enhance fish habitat.

An analysis of flood reduction benefits showed comparable performance for each pond option. Ten-year recurrence interval flood peaks in the ravine downstream of the project would be reduced by 44-percent for Option 1 and 41-percent for the Option 2 configuration. A flow duration analysis, which provides a relative measure of the amount of erosive work performed on the stream channel, showed a reduction in flow duration for each option. This indicates that the proposed driving range stormwater pond options would reduce the rate of erosion in the Joes Creek ravine, which would benefit downstream fish habitat.

COLD CREEK AND EASTER LAKE

Results of the hydrologic and hydraulic analysis of Easter Lake in the Cold Creek watershed showed that lakeside structures currently flood at approximately a 50-year recurrence interval. A 24-inch culvert located at the lake outlet restricts the lake discharge capacity. Hydrologic/hydraulic model simulations showed that increasing the discharge capacity of Easter Lake by replacing the culvert with a 36-inch diameter pipe reduced the frequency of structural flooding beyond the 100-year recurrence interval. The Tetra Tech/KCM report also recommended grading the outlet channel from the lake in addition to replacing the culvert. It was found that grading the outlet channel in combination with the culvert replacement further reduced the 100-year water surface elevation by 0.5 feet. Increasing the discharge rate from the Lake would not increase the flooding or erosion potential downstream because the discharge from the lake represents a small fraction of the total discharge entering the Cold Creek ravine downstream. Thus, no projects are proposed downstream to provide mitigation for increased flows from Easter Lake.

REFERENCES

1. City of Federal Way Department of Public Works, Comprehensive Surface Water Management Plan, KCM/Tetra-Tech, May 1996

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APPENDICES

APPENDIX A – MAGNITUDE-FREQUENCY ESTIMATES

Table A-1 Joes Creek Watershed, Flood-Frequency Values, Lake Lorene (Subbasin J8) Water Surface Elevation (ft)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
1. Existing Land Use, Existing Condition	207.60	209.25	210.46	211.14	211.40
2. Future Land Use, Existing Condition	207.74	209.51	210.82	211.61	211.80
3. Future Condition, Increase Q from Lorene and Jeanne	207.39	208.87	210.00	210.20	210.22

Flood Elevation: 210.5 ft

Table A-2 Joes Creek Watershed, Flood-Frequency Values, Lake Jeane (Subbasin J7) Water Surface Elevation (ft)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
1. Existing Land Use, Existing Condition	194.50	195.88	196.86	196.96	197.36
2. Future Land Use, Existing Condition	194.61	196.03	197.03	197.10	197.49
3. Future Condition, Increase Q from Lorene and Jeanne	194.41	194.90	195.14	195.31	195.37

Flood Elevation: 196.3 ft

Table A-3 Joes Creek Watershed, Flood-Frequency Values, Golf Course Pond (Subbasin J6) Water Surface Elevation (ft)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
1. Existing Land Use, Existing Condition	176.83	177.54	177.80	178.10	178.20
2. Future Land Use, Existing Condition	176.83	177.54	177.80	178.10	178.20
3. Future Condition, Increase Q from Lorene and Jeanne, Remove Ped Underpass Restrict	176.37	177.56	177.92	178.40	178.47
4. Same as 3, Replace Golf Course Pond Outlet Pipes	175.75	176.54	176.88	177.44	177.58

Pedestrian Underpass Floor Elevation: 175.83 ft

Table A-4 Joes Creek Watershed, Flood-Frequency Values, Driving Range Pond Water Surface Elevation (ft)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
5. Same as 4, Pond Option 1, 16.7 Ac-Ft Pond	157.82	165.71	166.73	166.92	167.07
5. Same as 4, Pond Option 2, 12.5 Ac-Ft Pond	157.40	164.43	166.73	166.91	166.97

Pond Overflow Elevation: 166.0 ft

Table A-5 Joes Creek Watershed, Flood-Frequency Values,
SW 340th St Detention Pond (Subbasin J20) Water Surface Elevation (ft)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
All Scenarios	385.05	386.79	388.08	388.38	388.95

Pond Overflow Elevation: 391.0 ft

Table A-6 Joes Creek Watershed, Flood-Frequency Values,
Lake Lorene (Subbasin J8) Discharge (cfs)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
1. Existing Land Use, Existing Condition	16.6	22.5	25.4	26.7	27.2
2. Future Land Use, Existing Condition	17.4	23.1	26.1	27.6	28.0
3. Future Condition, Increase Q from Lorene and Jeanne	18.5	27.8	39.9	48.9	49.8

Table A-7 Joes Creek Watershed, Flood-Frequency Values,
Lake Jeane (Subbasin J7) Discharge (cfs)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
1. Existing Land Use, Existing Condition	14.2	19.6	22.7	23.0	24.0
2. Future Land Use, Existing Condition	14.7	20.1	23.2	23.3	24.4
3. Future Condition, Increase Q from Lorene and Jeanne	14.5	30.7	40.3	47.8	51.4

Table A-8 Joes Creek Watershed, Flood-Frequency Values,
Golf Course Pond (Subbasin J6) Discharge (cfs)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
1. Existing Land Use, Existing Condition	51.6	111.5	144.5	184.5	200.1
2. Future Land Use, Existing Condition	52.1	111.9	145.1	184.6	200.1
3. Future Condition, Increase Q from Lorene and Jeanne, Remove Ped Underpass Restrict	50.2	114.3	142.9	184.8	191.4
4. Same as 3, Replace Golf Course Pond Outlet Pipes	52.6	114.8	143.0	181.0	191.3

Table A-9 Joes Creek Watershed, Flood-Frequency Values,
Head of Joes Creek Ravine, Top of Subbasin J2, Discharge (cfs)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
1. Existing Land Use, Existing Condition	68.2	141.8	190.5	250.0	258.7
2. Future Land Use, Existing Condition	68.7	142.2	191.4	250.0	259.0
3. Future Condition, Increase Q from Lorene and Jeanne, Remove Ped Underpass Restrict	68.3	144.4	186.3	246.7	257.7
4. Same as 3, Replace Golf Course Pond Outlet Pipes	70.1	149.1	184.6	238.8	257.6
5. Same as 4, Include 16.7 ac-ft pond, Fill Joes Creek, Driving Range Option 1	54.7	79.1	114.1	134.7	151.5
6. Same as 4, Include 12.5 ac-ft pond, Joes Creek Open Channel, Driving Range Option 2	59.0	84.5	128.4	148.8	154.3

Table A-10 Joes Creek Watershed, Flood-Frequency Values,
Joes Creek Mouth at Puget Sound, Subbasin J1, Discharge (cfs)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
1. Existing Land Use, Existing Condition	69.5	148.4	186.7	227.5	277.0
2. Future Land Use, Existing Condition	70.2	148.6	187.1	227.7	277.0
3. Future Condition, Increase Q from Lorene and Jeanne, Remove Ped Underpass Restrict	69.3	151.9	195.2	237.1	276.7
4. Same as 3, Replace Golf Course Pond Outlet Pipes	71.0	152.4	195.4	237.0	276.4
5. Same as 4, Include 16.7 ac-ft pond, Fill Joes Creek, Driving Range Option 1	61.5	93.4	127.9	148.6	172.8
6. Same as 4, Include 12.5 ac-ft pond, Joes Creek Open, Driving Range Option 2	65.2	100.9	141.4	165.9	167.8

Table A-11 Joes Creek Watershed, Flood-Frequency Values,
SW 340th St Detention Pond, Inflow and Outflow (Subbasin J20), Discharge (cfs)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
Pond Inflow, All Scenarios	12.5	27.4	39.4	51.2	58.7
Pond Outflow, All Scenarios	3.7	7.3	9.3	9.9	11.0

Table A-12 Joes Creek Watershed, Flood-Frequency Values,
North Shore Flow Diversion to Tacoma, Subbasin J23 Discharge (cfs)

Scenario	Recurrence Interval (Years)				
	2	10	25	50	100
Discharge to Joes Creek, All Scenarios	4.1	10.1	14.8	16.0	16.3
Diversion to City of Tacoma, All Scenarios	0.0	0.0	1.8	8.3	11.1

Table A-13 Cold Creek Watershed, Flood-Frequency Values,
Easter Lake Water Surface Elevation (ft)

Subbasin	Scenario	Recurrence Interval (Years)				
		2	10	25	50	100
C9	Existing Condition	429.50	429.77	429.97	430.00	430.00
C9	With Proposed Easter Lake Project Option 1, Replace 24” Culvert	428.92	429.26	429.43	429.52	429.59
C9	With Proposed Easter Lake Project Option 2, Replace 24” Culvert and Grade Channel Outlet	428.58	428.86	429.00	429.10	429.10

Easter Lake Flood Elevation: 430.0 ft

Table A-14 Cold Creek Watershed, Flood-Frequency Values, Discharge (cfs)

Subbasin	Scenario	Recurrence Interval (Years)				
		2	10	25	50	100
C9	Existing Condition	2.4	4.3	5.3	5.3	5.3
C9	With Proposed Easter Lake Project, Option 1	2.1	3.4	4.2	4.7	5.5
C9	With Proposed Easter Lake Project, Option 2	2.0	3.9	5.3	6.4	6.4
C6	Existing Condition	6.6	13.4	16.3	21.8	24.6
C6	With Proposed Easter Lake Project, Option 1	6.5	12.9	16.2	22.8	24.6
C6	With Proposed Easter Lake Project, Option 2	6.4	13.0	16.4	21.9	24.6
C1	Existing Condition	17.2	30.7	52.3	77.9	91.9
C1	With Proposed Easter Lake Project, Option 1	17.4	31.2	52.6	77.9	92.0
C1	With Proposed Easter Lake Project, Option 2	17.2	30.7	52.5	77.9	91.6

APPENDIX B – COST ESTIMATES

City of Federal Way

Project: **Stormwater Detention Pond at Twin Lakes Driving Range, Option 1**
Fill Joes Creek, Expand Driving Range Footprint

March 24, 2003

Item No.	Standard Item No.	Item Description	Approx. Quantity	Unit Meas.	Estimated Unit Price	Amount
1		Flow Splitter Structure	1	EA	$25,000	$25,000
2	35.00	Flow Control Structure	1	EA	$50,000	$50,000
3	33.10	Manhole Type 2, 72-inch, extra depth	1	EA	$12,000	$12,000
4	29.10	Culvert, LCPE, 48"	520	LF	$80	$41,600
5	75.00	Reinfoced Concrete Pipe Cradle	52	CY	$50	$2,600
6	29.02	72" Concrete Culvert	65	LF	$400	$26,000
7	19.00	Gabion Overflow Spillway	100	SY	$54	$5,431
8	29.04	Culvert, LCPE, 12"	300	LF	$21	$6,210
9	29.24	CB Type I	3	Each	$1,258	$3,773
10	43.50	Energy Dissipation Structure	1	EA	$30,000	$30,000
11	12.00	Unsuitable Excavation Including Haul	800	CY	$15	$12,000
12	15.00	Access Road	900	LF	$25	$22,500
13	17.00	Embankment Material/Construction	3,000	CY	$30	$90,000
14	45.00	Seeding, Fertilizing and Mulching	2	AC	$5,000	$10,000
15	16.50	Construction Dewatering	1	LS	$20,000	$20,000
16	72.00	Replace Pavement	600	SY	$17	$10,344
17	52.00	Site Restoration	1	LS	$20,000	$20,000
18	2.00	Temporary Erosion/Sedimentation Control	1	LS	$20,000	$20,000
19	1.00	Mobilization (10%)	1	LS	$40,746	$40,746
				SUBTOTAL		$448,204
		Items Yet to be Defined at 10%				$44,820
				SUBTOTAL		$493,024
	63.0	Sales Tax at 8.9 %				$43,879
				SUBTOTAL		$536,903
	64.0	Construction Contingencies at 20%				$107,381
				SUBTOTAL		$644,284
	65.0	Design and Construction Management at 30%				$193,285
			TOTAL PROJECT COSTS			**$837,569**

<u>*Notes:*</u>
Estimate does not include: permitting, mitigation costs, easements and property acquisitions.

City of Federal Way

Project: **Stormwater Detention Pond at Twin Lakes Driving Range, Option 2**
Retain and Enhance Joes Creek Stream Channel

March 24, 2003

Item No.	Standard Item No.	Item Description	Approx. Quantity	Unit Meas.	Estimated Unit Price	Amount
1		Flow Splitter Structure	1	EA	$25,000	$25,000
2	50.00	Channel Stabilization, Habitat Enhancement	380	LF	$150	$57,000
3	35.00	Flow Control Structure	1	EA	$50,000	$50,000
4	75.00	Reinfoced Concrete Pipe Cradle	52	CY	$50	$2,600
5	29.02	72" Concrete Culvert	65	LF	$400	$26,000
6	29.10	Culvert, LCPE, 48"	240	LF	$80	$19,200
7	19.00	Gabion Overflow Spillway	100	SY	$54	$5,431
8	29.04	Culvert, LCPE, 12"	300	LF	$21	$6,210
9	29.24	CB Type I	3	Each	$1,258	$3,773
10	43.50	Energy Dissipation Structure	1	EA	$30,000	$30,000
11	12.00	Unsuitable Excavation Including Haul	1,700	CY	$15	$25,500
12	15.00	Access Road	900	LF	$25	$22,500
13	17.00	Embankment Material/Construction	6,000	CY	$30	$180,000
14	45.00	Seeding, Fertilizing and Mulching	2	AC	$5,000	$10,000
15	16.50	Construction Dewatering	1	LS	$20,000	$20,000
16	72.00	Replace Pavement	600	SY	$17	$10,344
17	52.00	Site Restoration	1	LS	$20,000	$20,000
18	2.00	Temporary Erosion/Sedimentation Control	1	LS	$20,000	$20,000
19	1.00	Mobilization (10%)	1	LS	$53,356	$53,356
				SUBTOTAL		$586,914
		Items Yet to be Defined at 10%				$58,691
				SUBTOTAL		$645,605
	63.0	Sales Tax at 8.9 %				$57,459
				SUBTOTAL		$703,064
	64.0	Construction Contingencies at 20%				$140,613
				SUBTOTAL		$843,677
	65.0	Design and Construction Management at 30%				$253,103
			TOTAL PROJECT COSTS			**$1,096,780**

Notes:
Estimate does not include: permitting, mitigation costs, easements and property acquisitions.