APPENDIX A
Model Development

The following information describes the process involved in creating the hydrologic model that was used to evaluate conveyance and nonconveyance alternatives.

A calibrated hydrologic model using the HSPF (v.10) was developed during the Phase I Salmon Creek Basin Plan. The model describes the surface/groundwater interactions that influence flooding in the basin. This conceptual model considered the effects of weather, climate, topography, hydrostratigraphy, groundwater circulation and recharge, and surface water discharge. HSPF is a numerical program that simulates the complex hydrologic processes. This is a public domain model and was most recently updated by the U.S. Environmental Protection Agency (EPA). The Phase I model calibration results are presented in the August 2001 *Salmon Creek Basin HSPF Calibration Report* by URS. The first application of the HSPF model was to evaluate (in terms of anticipated groundwater flood stage) the effect of potential non-structural or programmatic changes in the basin. These results are discussed in Chapter 5.

Once the HSPF model provided information regarding non-structural alternatives, the next step in the analysis focused on the development of a hydraulic model to simulate flood routing flow in addition to other factors. The hydraulic analysis was conducted using the unsteady flow program Full Equation (FEQ) and its utility program FEQUTL. FEQ simulates flow and stages in stream channels, pipes, ponds, and ditches by solving mathematical equations for surface- water flow. For example, the FEQ model can estimate the stage of discharge of flow through a given stream network, providing stream surface water elevations at specific locations. Calibration of the Salmon Creek FEQ model was conducted by comparing the simulated stage to the recorded stage data at various stream gages for the storm event between 11/16/1999 - 12/31/1999.

Following the development and calibration of the FEQ model, several structural alternatives were developed to assess the effect of different storage and conveyance mechanisms for the Salmon Creek Basin. The impact (or effectiveness) of each alternative was reviewed in terms of a projected decreased flood stage as a result of the alternative's implementation.

Flood maps prepared by Thurston County and published in the Emergency Preparedness and Response Plan (ERP) show the areas flooded during the spring of 1999. The coverage was based on color infrared aerial photographs of the watershed taken during the flooding event. Comparisons of the flood mapping coverage with the model's simulated areas of flooding provided a degree of confidence about the HSPF model results.

A limiting factor in analyzing the results of the HSPF data for Salmon Creek Basin is the 2-foot contour interval of the available topographic information. In areas with higher topographic relief, this contour interval is more than adequate for a study such as this one. However, because of the unusually low slopes in the basin there is considerable uncertainty about the actual areas that would be affected by implementation of any of the non-structural or structural alternatives.

APPENDIX B
Additional tables from chapter 5

Determining Flooded Properties:

Topographic maps with a contour interval of two feet were used in conjunction with the Geographic Information System (GIS) parcel layer and aerial photographs of flood events to determine whether a given parcel is within a flood-prone area. The Thurston County contour-related flood mapping GIS layer shows areas flooded during the spring of 1999, which include a number of locations within nine subbasins. (The nine subbasins are referred to as SC2, SC6, SC7, SC9, SC10, SC11, SC12, SC13, SC14 and the groundwater recharge area [SCR]). Data for the GIS layer are from analysis of false-color infrared aerial photographs and field observations of the watershed during the groundwater-flooding event by County staff. Table 1 summarizes acreages of total flooded areas and the largest contiguous flooded area in each subbasin. These flooded areas were the result of 2 consecutive years of higher than normal precipitation.

Compared to the other subbasins, SC9, SC10, SC11 and SC13 experienced the most extensive flooding in terms of total area, with one or more locations having significantly large flooded areas.

Table 1: Spring 1999 Flooded Area (actual acres)

Subbasin Name	Total Flooded Area	Largest Contiguous Flooded Area
SC2	0.1	0.1
SC6	12.3	6.5
SC7	6.2	4.1
SC9	216.9	113.4
SC10	62.7	60.4
SC11	128.2	58.1
SC12	46.6	21.3
SC13	71.6	65.4
SC14	1.7	1.2
SCR	7.9	3.9
Total	**554.2**	**Not applicable**

Source: Thurston Geodata Center

Determining Future Effective Impervious Area

A full buildout condition using existing parcels with "undeveloped" land use codes was modeled for each of the non-structural alternatives. Land use data from digital mapping (Thurston County tax parcel database) was used to determine the development status for each parcel. Only the existing parcels with "undeveloped" land use codes were considered for future development. It was assumed that the current undeveloped parcels would be developed following the current Thurston County zoning code. In Table 2, the percent impervious area for the HSPF modeling is estimated from each land use code by using the data provided in Table 3.

Table 2 Estimated Effective Impervious Area Percentage by Typical Land Use Types

Zoning Code	Land Use Code or Description	% of Impervious Area
Business Park	Commercial	86%
Commercial Development	Commercial	86%
General Commercial	Commercial	86%
Neighborhood Commercial	Commercial	86%
Light Industrial	Industrial	86%
Heavy Industrial	Industrial	86%
RR 1:5	Residential, with 2-5 acres lot	4%
RR 1:2	Residential, with 1-2 acres lot	10%
SFL or SFL2	Residential, with 2-4 DU per acre	23%
SFM or Multi-Family Residential	Residential, with more than 5 DU per acre	48%

Effective impervious area (EIA) is the proportion of the total impervious area that is directly connected to the drainage network. Literature-based EIA values from previous studies conducted in or near Thurston County were used to represent the average condition (See Table 3).

Table 3: Proportion of EIA of Total Impervious Area for Typical Study Area Land Use Types

Land Use Type	Total Impervious Area %	Adjustment Factor**	Effective Impervious Area
Low-Density Residential Development, with 2-5 acres lot	10%	40%	4%
Medium-Density Residential Development, with 1-2 acres lot	20%	50%	10%
Suburban Residential Development, with 2-4 dwelling unit per acre	35%	66%	23%
High-Density Residential Development (multifamily or high density housing)	60%	80%	48%
Commercial, Industrial, Transportation	90%	90%	86%

Source: Dinicola, 1989

** The adjustment factors arise from the fact that, in a low-density residential development, only 40% of the impervious areas, on average, connect directly to stormwater conveyance systems. The other 60% represents patios, walkways, etc. which create runoff that flows to adjacent lawns or natural areas and has the opportunity to infiltrate or evaporate. In a commercial/industrial area, 90% of impervious areas drain directly into stormwater conveyance systems.

Preserving and Increasing Tree Canopy

The HSPF model was developed to assess the potential for tree cover to reduce flooding under the environmental conditions present during the spring 1999 flooding. The HSPF model simulated tree canopy interception, evaporation, infiltration, and water uptake. The model values for these parameters were derived from previous studies conducted in Thurston County. Parameter values for Salmon Creek Basin HSPF model were reviewed by the County and are tabulated in the *HSPF Model Calibration Report* (URS 2001a).

Table 4: Percentage of Land Covers for Study Area Existing Conditions

Subbasin Name	With Current Tree Canopy			Minimum of 35% Tree Canopy			Minimum of 65% Tree Canopy		
	Impervious	Grass/ Lawn	Tree Canopy	Impervious	Grass/ Lawn	Tree Canopy	Impervious	Grass/ Lawn	Tree Canopy
SC1	4.6%	48.7%	46.7%	4.6%	48.7%	46.7%	4.6%	30.4%	65.0%
SC2	3.7%	51.0%	45.3%	3.7%	51.0%	45.3%	3.7%	31.3%	65.0%
SC3	5.5%	56.7%	37.8%	5.5%	56.7%	37.8%	5.5%	29.5%	65.0%
SC4	14.7%	42.5%	42.8%	14.7%	42.5%	42.8%	14.7%	20.3%	65.0%
SC5	5.8%	86.0%	8.2%	5.8%	59.2%	35.0%	5.8%	29.2%	65.0%
SC6	8.1%	69.3%	22.6%	8.1%	56.8%	35.0%	8.1%	26.9%	65.0%
SC7	3.3%	51.4%	45.3%	3.3%	51.4%	45.3%	3.3%	31.7%	65.0%
SC8	5.3%	42.9%	51.8%	5.3%	42.9%	51.8%	5.3%	29.7%	65.0%
SC9	7.4%	70.4%	22.2%	7.4%	57.6%	35.0%	7.4%	27.6%	65.0%
SC10	5.5%	67.3%	27.2%	5.5%	59.5%	35.0%	5.5%	29.5%	65.0%
SC11	7.9%	40.1%	52.0%	7.9%	40.1%	52.0%	7.9%	27.1%	65.0%
SC12	13.8%	55.1%	31.1%	13.8%	51.2%	35.0%	13.8%	21.2%	65.0%
SC13	14.3%	72.1%	13.6%	14.3%	50.7%	35.0%	14.3%	20.7%	65.0%
SC14	7.6%	92.4%	0.0%	7.6%	57.4%	35.0%	7.6%	27.4%	65.0%
Total Watershed	6.9%	54.8%	38.2%	6.9%	50.9%	42.2%	6.9%	28.1%	65.0%

Source: URS Tech Memo, 2002a

Table 5: Percentage of Various Land Covers for Study Area Full Build-out Conditions

Subbasin Name	With Current TreeCanopy			Minimum of 35% Tree Canopy			Minimum of 65% Tree Canopy		
	Impervious	Grass/ Lawn	Tree Canopy	Impervious	Grass/ Lawn	Tree Canopy	Impervious	Grass/ Lawn	Tree Canopy
SC1	5.8%	47.5%	46.7%	5.8%	47.5%	46.7%	5.8%	29.2%	65.0%
SC2	5.1%	49.6%	45.3%	5.1%	49.6%	45.3%	5.1%	29.9%	65.0%
SC3	19.6%	47.9%	32.6%	19.6%	45.4%	35.0%	19.6%	15.4%	65.0%
SC4	43.1%	23.0%	33.9%	43.1%	21.9%	35.0%	35.0%	0.0%	65.0%
SC5	6.2%	85.5%	8.2%	6.2%	58.8%	35.0%	6.2%	28.8%	65.0%
SC6	9.4%	68.1%	22.6%	9.4%	55.6%	35.0%	9.4%	25.6%	65.0%
SC7	8.5%	46.8%	44.7%	8.5%	46.8%	44.7%	8.5%	26.5%	65.0%
SC8	6.9%	41.7%	51.4%	6.9%	41.7%	51.4%	6.9%	28.1%	65.0%
SC9	9.4%	68.4%	22.2%	9.4%	55.6%	35.0%	9.4%	25.6%	65.0%
SC10	29.2%	43.6%	27.2%	29.2%	35.8%	35.0%	29.2%	5.8%	65.0%
SC11	19.3%	33.1%	47.6%	19.3%	33.1%	47.6%	19.3%	15.7%	65.0%
SC12	42.3%	31.6%	26.1%	42.3%	22.7%	35.0%	35.0%	0.0%	65.0%
SC13	25.0%	61.3%	13.7%	25.0%	40.0%	35.0%	25.0%	10.0%	65.0%
SC14	56.8%	43.2%	0.0%	56.8%	8.2%	35.0%	35.0%	0.0%	65.0%
Total Watershed	16.2%	47.2%	36.6%	16.2%	42.5%	41.2%	15.0%	20.0%	65.0%

Source: URS Tech Memo, 2002a

APPENDIX C
Hazard Mitigation Grant Program and Community Development Block Grant Program

In 2002, Thurston County had an opportunity to refine property statistics when grant funds became available through the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Grant Program. Created in 1998, this federal program is designed to help individuals, states and local governments lessen the impact of disasters and minimize the hardships that may result from future disasters. The program attempts to prevent the recurring "damage-rebuild-damage-again" cycle that, in the past, often limited the effectiveness of disaster recovery efforts. The federal government made Hazard Mitigation money available because of the 2001 Nisqually Earthquake. Although the earthquake triggered the federal expenditures, a certain percent of the federal money was dedicated to non-earthquake related projects, such as flood-relief. Thurston County applied for a hazard mitigation grant to mitigate flooding in Salmon Creek Basin.

A total of approximately 100 properties were identified that either reported flood-damage or were shown on groundwater flood maps and/or photos as being inundated. Property owners were mailed questionnaires seeking their participation in the hazard mitigation grant program. Twenty property owners responded to the initial mailing. These property owners were sent a second mailing with a questionnaire asking them to provide an itemized costs list of their flood damage/flood fighting expenditures. Items included home rehabilitation costs; property devaluation; dislocation costs such as hotels; bottled-water; porta-potties; generators; sand-bags, and lost wages due to time away from work. To determine grant eligibility, County staff developed a cost-benefit model that assumed the following:

- The life of the proposed mitigation project was 100 years;
- The recurrence interval of the flood event was 20 years;
- The amount of damage sustained and flood fighting cost were assumed to occur per flood event; and
- Property devaluation was assumed to be a one-time cost.

Using these assumptions, a flood event would recur five-times over the life of the project; therefore, the damage prevented cost, would be the per event cost multiplied five-times, plus the one-time property devaluation. If it could be demonstrated that the damage prevented cost were less than or equal to the project mitigation cost, the project would meet or exceed a cost-to-benefit ratio of 1:1 and be eligible for grant funding. Using this formula, ten of twenty properties were identified as potentially eligible for grant funding. Thurston County submitted these properties in a Hazard Mitigation Grant Application to the state's Department of Emergency Management (DEM) for consideration.

DEM used the FEMA cost-benefit analysis model and found that none of the applicants met the required 1:1 cost/ benefit ratio required for grant eligibility (in other words, for every $1 spent there would be $1 of benefit). FEMA's model is far more conservative and assumes the following:

- The life of the project is a mortgage cycle (or thirty-years);
- The recurrence interval was twenty years; and
- The amount of damage sustained was the per event cost.

Using the County's formula, the flood-event would have occurred five-time over the life of the project. Using the FEMA model the flood-event would have occurred only once; therefore, the FEMA model significantly reduced the cost-benefit ratio.

A second grant program known as the Community Development Block Grant provided funds for senior low-income citizens that suffered flood damage; the stipulation being that the applicant be senior low-income and the property must have been damaged during the 1996 floods. Two of the final ten applicants were eligible for funding under this program; in the end, only one of the two took advantage of the program.

Most property owners that reported flood damage did not meet the cost benefit ratio necessary to qualify for federal funding. This does not negate the fact that these properties were damaged and their owners experienced financial and emotional hardship. All properties in Salmon Creek Basin are eligible for flood insurance, and this remains a viable option for property owners.

APPENDIX D
Cost Estimates for Conveyance Alternatives

ALTERNATIVE COST ASSUMPTIONS

Construction costs were obtained from RS Means Site Work & Landscape Cost Data 2000 and from professional experience. As stated in the alternative discussion, it was assumed that any portion of an alternative that is along a road must be a pipe. Portions along natural land could be either pipe or ditch. Costs were estimated for both.

Pipe Cost Assumptions

- Pipe invert would be an average of 8 feet deep.
- Saw cut asphalt, 6" thick, $3/foot.
- Excavation, bulk, bank, $3/cubic yard.
- Grading for topsoil, 6" deep, 500' haul at $1/square yard.
- Compaction, $1/cubic yard.
- Pipe was storm drainage, corrugated galvanized metal, coated, $77.50/foot for 36" pipe and $42/foot for 24" pipe
- Backfill, $1/cubic yard
- Replace roadway (if applicable), 5" thick pavement, 6" thick gravel base, 12 feet wide, $41/foot
- Manholes $8/foot when along a road. No manholes were included if pipe was on natural land.
- Siphons were assumed to be $10,000 each based on professional experience. Siphons were included in cost when a pipe was not deep enough to safely clear a known existing structure, such as a road or gas line.
- Costs for tees and bends were obtained from RS Means.
- Costs did not include navigating around existing utilities or driveways.

Ditch Cost Assumptions

- Ditch invert would be an average of 5 feet deep.
- Shape assumed was a 1-foot bottom with 2:1 side slopes.
- Excavation is structural at $50/cubic yard
- Grading and compaction as shown above
- Costs did not include navigating around existing utilities or driveways.

Channel Clearing Cost Assumptions

- Entire 14,550' long channel (28' wide) is cleared and grubbed.
- 10' center of channel corridor is not hydroseeded, planted with trees, or irrigated
- Trees are planted 10-foot on center

- Wood chip mulch is 3-foot diameter, 3-inches deep for each tree.
- Waterline installation assumes water source within 2,000 feet.
- Costs did not include site access or land acquisition.

Horizontal Directional Drilling Cost Preliminary Assumptions

Feasibility-level costs have yet to be determined. The following preliminary costs will need to be refined based on additional work to optimize pipe size and type of drill rig required.

- Assumes drilling twin 4,200-foot pipelines at a cost of approximately $110 per foot.
- Mobilization and demobilization of the horizontal directional drilling rig ($120,000) would only be paid if schedule constraints prevented use of a rig based on the West Coast.
- Cost for drilling would be about 2 ½ times greater if a pipe diameter larger than 12" is utilized.
- Slotted stainless steel pipe would be approximately $92.00 per foot. It may be possible to drill a 14" diameter hole and then pull back slotted PVC pipe at a much lower cost. These details will need to be worked out, if this alternative is selected for further investigation.
- A remotely actuated valve is contemplated that only opens when groundwater reaches a pre-determined level. As a conservative measure this valve would be set to fail closed, thereby limiting the risk of dewatering wetlands and near-surface wells. $6,000 is allotted for each valve and sensor.

The total costs for each alternative included an assumed contingency of 30% of construction costs and an additional 30% of construction costs for engineering, administration, and legal factors.

Summary Chart

Alternative	**Cost**
Rhondo Pond to Littlerock Road 2	$4,361,920
93JR	$651,248
Rhondo Pond to Jones Road	$1,428,104
- All Pipe	$2,026,488
Rhondo Pond to Littlerock Road 1	$2,996,608
- All Pipe	$3,591,800
Rhondo Pond to Fish Trap Creek	$1,261,464
- All Pipe	$1,856,656
East Basin	$676,336
Hopkins Ditch Clearing	$1,150,745
Conceptual	
HDD	$2,734,080

Rhondo Pond to Littlerock Road 2 Alternative

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's)	17,000.00	$160.00	$2,720,000
Tees	3	$970.00	$2,910
Bends	4	$665.00	$2,660
SUBTOTAL			**$2,726,200**
Contingency (30% of construction)	30%		$817,860
Engineering Administration & Legal (30% of construction)	30%		$817,860
TOTAL			**$4,361,920**

93JR Alternative

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's)	2,540.00	$160.00	$406,400
SUBTOTAL			**$407,030**
Contingency (30% of construction)	30%		$122,109
Engineering Administration & Legal (30% of construction)	30%		$122,109
TOTAL			**$651,248**

Rhondo Pond to Jones Road Alternative

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's)	3480	$160.00	$556,800
Pipe (land)	1400	$108.00	$151,200
Ditch	5000	$34.00	$170,000
Tees	2	$970.00	$1,940
Bends	3	$665.00	$1,995
Siphon	1	$10,000.00	$10,000
SUBTOTAL			**$892,565**
Contingency (30% of construction)	30%		$267,770
Engineering Administration & Legal (30% of construction)	30%		$267,770
TOTAL			**$1,428,104**

Rhondo Pond to Jones Road - All Pipe

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's)	3,480	$160.00	$556,800
Pipe (land)	6,400	$108.00	$691,200
Tees	2	$970.00	$1,940
Bends	9	$665.00	$5,985
Siphon	1	$10,000.00	$10,000
SUBTOTAL			**$1,266,555**
Contingency (30% of construction)	30%		$379,967
Engineering Administration & Legal (30% of construction)	30%		$379,967
TOTAL			**$2,026,488**

Rhondo Pond to Littlerock Road 1 Alternative

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's)	8820	$160.00	$1,411,200
Pipe (land)	2640	$108.00	$285,120
Ditch	5000	$34.00	$170,000
Tees	2	$970.00	$1,940
Bends	6	$665.00	$3,990
SUBTOTAL			**$1,872,880**
Contingency (30% of construction)	30%		$561,864
Engineering Administration & Legal (30% of construction)	30%		$561,864
TOTAL			**$2,996,608**

Rhondo Pond to Littlerock Road 1

Alternative - All Pipe

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's)	8,820	$160.00	$1,411,200
Pipe (land)	7,640	$108.00	$825,120
Tees	2	$970.00	$1,940
Bends	9	$665.00	$5,985
SUBTOTAL			**$2,244,875**
Contingency (30% of construction)	30%		$673,463
Engineering Administration & Legal (30% of construction)	30%		$673,463
TOTAL			**$3,591,800**

Rhondo Pond to Fish Trap Creek Alternative

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's)	1000	$160.00	$160,000
Pipe (land)	4190	$108.00	$452,520
Ditch	5000	$34.00	$170,000
Tees	2	$970.00	$1,940
Bends	5	$665.00	$3,325
SUBTOTAL			**$788,415**
Contingency (30% of construction)	30%		$236,525
Engineering Administration & Legal (30% of construction)	30%		$236,525
TOTAL			**$1,261,464**

Rhondo Pond to Fishtrap Creek Alternative - All Pipe

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's)	1000	$160.00	$160,000
Pipe (land)	9190	$108.00	$992,520
Tees	2	$970.00	$1,940
Bends	8	$665.00	$5,320
SUBTOTAL			**$1,160,410**
Contingency (30% of construction)	30%		$348,123
Engineering Administration & Legal (30% of construction)	30%		$348,123
TOTAL			**$1,856,656**

East Basin Alternative

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$630.00	$630
Pipe (road, w/ MH's, 24")	3270	$125.00	$408,750
Bends	9	$370.00	$3,330
Siphon	1	$10,000.00	$10,000
SUBTOTAL			**$422,710**
Contingency (30% of construction)	30%		$126,813
Engineering Administration & Legal (30% of construction)	30%		$126,813
TOTAL			**$676,336**

Hopkins Ditch Clearing

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$34,350.00	$34,350
Clearing and Grubbing (acre)	9.35	$4,500.00	$52,075
Temporary Erosion/Sediment Control	1	$3,000.00	$3,000
Herbicide Application (acre)	9.35	$2,400.00	$22,400
Hydroseed (acre)	5.6	$1,000.00	$5,600
5 Gallon Trees (each installed)	2,600	$100	$260,000
Wood Chip Mulch (cy)	170	$35	$5,950
Irrigation (sf)	261,900	$1	$261,900
2" Waterline (lf)	2,000	$12	$24,000
3-year Plant Maintenance	1	$60,000	$60,000
SUBTOTAL			**$719.215**
Contingency (30% of construction)	30%		$215,765
Engineering Administration & Legal (30% of construction)	30%		$215,765
TOTAL			**$1,150,745**

HDD Preliminary Concept

Item	Amount	Unit Cost	Cost
Mob/Demob	1	$120,000.00	$120,000
Directional Drilling	8400	$110.00	$924,000
12" Slotted Stainless Pipe	8400	$92.00	$772,800
Remotely Actuated Valve and Sensor	2	6000	12,000
SUBTOTAL			**$1,708,800**
Contingency (30% of construction)	30%		$512,640
Engineering Administration & Legal (30% of construction)	30%		$512,640
Preliminary TOTAL			**$2,734,080**

APPENDIX E
Maps