3.3 Water Resources

Water is a valuable resource that is constantly moving and transforming as part of the hydrologic cycle. Precipitation runs off to streams and rivers and infiltrates into the ground to replenish groundwater. The groundwater ultimately discharges to surface water (freshwater and marine) through seeps and springs. In turn, surface water evaporates into the atmosphere as water vapor, forming clouds that lead to precipitation, and the cycle continues. Thus, changes to one element of the hydrologic cycle may have impacts elsewhere in the cycle.

3.3.1 Surface Water Movement, Quantity and Quality

In the context of the Thurston Highlands Development, surface water refers to rivers, streams and wetlands. Surface water is fed directly by runoff following precipitation. Some of the precipitation infiltrates into the soil. A portion of this water remains within a few feet of the surface, typically in the soil horizons developed by plants and trees. This is called “interflow”, and is usually considered as a component of runoff, since it enters nearby drainages shortly after falling as precipitation. The rest of the infiltrating water penetrates deeper into the subsurface and recharges groundwater. Relative to streams and rivers, which typically have velocities up to a few feet per second, groundwater moves very slowly, with velocities ranging from a few feet per day to a few feet in several years or longer.

Where groundwater discharges to surface water, for example a stream, the stream is said to be “gaining” over that section or reach. In other areas, the water level of the stream may be above the groundwater level. In this case, the stream is said to be “losing” over that section or reach.

Streams typically have a well-defined channel that carries the flow for most of the year, and an overbank section that carries water during high flow flood conditions. The capacity of a stream channel and overbank area is a function of the water surface level and depends upon the cross-section (wetted area and perimeter), the slope of the stream, and the hydraulic roughness, usually expressed in terms of a coefficient called Manning’s number.

AFFECTED ENVIRONMENT

The Thurston Highlands site is located in the northwest quadrant of the Nisqually Watershed, within the Thompson Creek basin. The Thompson Creek basin, approximately 16 square miles in area, is one of seven surface water basins in the Thurston County portion of the Nisqually River watershed. The Yelm Creek basin is adjacent to the Thompson Creek basin to the south and east. The principal surface water features of these two basins include Yelm Creek, Yelm Ditch, the Centralia Power Canal, and Thompson Creek (see Figure 3.3-1). Thompson Creek drains the western edge of the Yelm prairie adjacent to the Thurston Highlands site before discharging to the Nisqually River about one-half mile downstream of the Yelm Creek discharge. The Thurston Highlands site is completely within the Thompson Creek drainage basin.

Insert Figure 3.3-1. Surface Water Features

The average annual precipitation at the Thurston Highlands site is about 40 inches. Approximately one-half of the precipitation evaporates or is transpired by the existing vegetation (Pacific Groundwater Group 2008). Nearly all of the remaining precipitation infiltrates to become groundwater recharge. A small amount of runoff and interflow occur on a local scale, but at the overall scale of the site, nearly all runoff infiltrates in a short period of time. Groundwater recharge in Thurston Highlands travels to one of three receiving water bodies: vertically to the regional deep aquifer system, northward to the Nisqually River, and eastward to the nearby Thompson Creek (see Section 3.3.2).

The Thompson Creek basin includes portions of the lowland areas in the City of Yelm and adjacent areas (see Figure 3.3-1). It is an intermittent stream throughout its length, being dry for most of the year. Flow throughout the length of the creek only occurs after significant wet season precipitation events, or after a period of sustained precipitation in winter or early spring when shallow groundwater levels are high. The headwaters of Thompson Creek are primarily located in the southeastern portion of the Thurston Highlands property, and in developed areas south of SR 507. The southeast portion of the Thurston Highlands property contains numerous small wetland complexes. The Ridgeline Trough, which is the location of an historical Nisqually River channel, would also form a portion of the Thompson Creek headwaters. However, the surface water flow path from the Ridgeline Trough to Thompson Creek is blocked by the road embankment created for SR 507 (J.W. Morrissette & Associates 2006). Thompson Creek flows through undeveloped parcels, the Tahoma Valley Golf Course, areas of suburban and rural development, and finally through steep-sloped forest lands to its discharge to the Nisqually River.

From George Road to its discharge to the Nisqually River, Thompson Creek extends approximately 4 miles. The upper reaches of the creek (defined here as upstream of SR 510) are characterized by low-slopes and slow flow velocities. The bank-to-bank width of Thompson Creek varies from approximately 3 feet (in the upper reaches near George Road) to more than 20 feet near in the middle reach near SR 510. Downstream of SR 510, Thompson Creek steepens and flows through forest lands to the Nisqually River. From George Road to Tahoma Terra bridge, the average slope is 0.02 percent. Between the Tahoma Terra bridge and SR 510, the average slope is 0.17 percent, and the slope steepens to 4.3 percent from SR 510 to the Nisqually River, including a well-defined headcut. Further details of the slope and elevations are provided in Brown and Caldwell 2008. Thompson Creek also contains numerous road crossings ranging in size from a single 36-inch diameter culvert to the 15.5 feet wide by 4.5 feet high arch culvert of the Tahoma Terra Bridge. Details of crossings that were accessible for this study are provided in the *Thurston Highlands DEIS Surface Water Technical Report* (Brown and Caldwell 2008).

Thompson Creek is an intermittently-flowing creek, with the highest base flows occurring from mid-winter through early-spring. The creek is typically dry in the summer and early fall. The wintertime base flow in Thompson Creek is primarily a result of shallow groundwater (including interflow) discharge to the creek. Periodically, higher flows occur as Thompson Creek responds to local rain events. Based on studies performed by Pacific Groundwater Group (2008), the hydrology of Thompson Creek is strongly influenced by groundwater recharged over the upland areas to the west of the creek, including Thurston Highlands. The *Thurston Highlands DEIS Surface Water Technical Report* (Brown and Caldwell 2008) describes and illustrates Thompson Creek characteristics in more detail.

The section of Thompson Creek between 93rd Avenue SE and SR 510 flows over recessional outwash permeable soils. This section of the creek is dry for most of the year, and loses water to the underlying soil during periods of flow.

Flows in Thompson Creek respond to groundwater inputs and local precipitation. The creek has a history of periodic over-bank flooding. Local residents and Thurston County staff have indicated that the creek flooded in February 1996, January 1997, during the winter of 1987, and perhaps on other occasions.. Figure 3.3-2 shows the approximate area of inundation upstream of 93rd Avenue SE, during the February 1996 flood as indicated by the WSDOT aerial photography. Minor flooding has occurred at other times, but it is not known whether the observed standing water was the result of creek flooding or the presence of high groundwater.

The existing hydraulic conditions of Thompson Creek were evaluated using a HEC-RAS hydraulic model. HEC-RAS is a one-dimensional hydraulic modeling program developed by the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center (United States Army Corps of Engineers. 2006). The model uses stream geometry information (e.g., cross-section area, slope), friction, inflows and flow losses to predict water surface elevations along the creek. The model was developed from cross-section survey performed by KPFF Consulting Engineers and site observations of the creek channel material and vegetation. The model extends over a distance of approximately 16,000 feet along the creek from near George Road to SR 510. The section downstream of SR 510 was not included in the model because the steep slopes and high channel capacity suggest the potential for impacts is minimal.

The model was calibrated using flow data collected during the 2007/2008 wet season, and groundwater modeling by Pacific Groundwater Group (2008). Groundwater studies have identified two groundwater regimes (see Section 3.3.2):

- Regime A is defined where groundwater enters the shallow aquifer system, with a significant portion of the flow discharging to Thompson Creek. Regime A is absent from some areas of the Thurston Highlands site.
- Regime B occurs in deeper pre-Vashon strata. Regime B is recharged by direct infiltration to the deeper aquifer and by downward flow from Regime A. Groundwater in this regime does not contribute to the flow in Thompson Creek. This conclusion is based on observations of groundwater levels that are below the elevation of the creek, and flow directions toward the northwest, away from the creek.

Details of the groundwater model and the results of the analyses are presented in Draft EIS Section 3.3.2.

The HEC-RAS model was used to calculate approximate water surface elevations along the creek for the lowest and highest flows observed through early March 2008. The HEC-RAS model assumptions are fully described in the *Thurston Highlands DEIS Surface Water Technical Report* Brown and Caldwell (2008).

Insert Figure 3.3-2. February1996 Inundation Area

Figure 3.3-3 shows Thompson Creek flow data collected from December 29, 2007 through March 6, 2008. Flows were monitored continuously using a water depth sensor located approximately 100 feet downstream of the Tahoma Terra Bridge. The measured depths were converted to flows by applying a rating curve that was developed from instantaneous stream transect flow measurements conducted on several days across a range of flow conditions. Flows ranged from a low of 2.1 cfs to a high of 6.7 cfs. The high flow occurred at the end of a two-week period during which approximately 5.5 inches of rainfall occurred (measured at the Olympia Airport). The data monitoring program is ongoing. Additional information will be integrated into technical analyses that will be reported in the Final EIS.

Table 3.3-1 lists the computed water surface elevations along Thompson Creek for flows of 2.1 cfs and 6.7 cfs at the Tahoma Terra Bridge. Flows upstream and downstream of this location were adjusted to approximately account for gaining and losing reaches of the creek (as defined at the beginning of Section 3.3.1). Water surface elevations were approximately 0.1 to 0.4 feet higher during the high flow event. The flow widths increased by 1 to 8 feet. The range in flow depths is further illustrated for select cross-sections in Figure 3.3-4. Average wet season groundwater contribution to the flow in the creek was calculated from the groundwater model to be about 3 cfs (see Section 3.3.2), which is within the range of flows observed to early March for the 2007/2008 wet season.

Table 3.3-1. Thompson Creek simulated water surface elevations (Brown and Caldwell 2008).

			Low Flow = 2.1 cfs			High Flow = 6.7 cfs		
River Sta	Location	Bottom Elev. (ft)	Flow (cfs)	Water Surface Elev. (ft)	Top Width (ft)	Flow (cfs)	Water Surface Elev. (ft)	Top Width (ft)
160+26	near George Road SE	327.5	1.5	328.4	7.9	5.3	328.9	9.4
148+08		327.3	1.5	327.8	7.4	5.3	328.2	10.0
125+27		326.7	2.1	327.7	27.4	6.7	328.0	31.3
119+98	Tahoma Valley Golf Course	326.1	2.1	327.7	16.7	6.7	328.0	17.9
113+48	U/S Tahoma Terra Bridge	326.6	2.1	327.7	16.2	6.7	327.9	17.6
112+28	D/S Tahoma Terra Bridge	327.4	2.1	327.7	8.0	6.7	327.8	9.5
105+98		326.3	2.1	326.8	24.3	6.7	327.0	34.6
97+19		325.8	2.1	326.2	15.5	6.7	326.5	25.6
88+27	U/S Berry Valley Road	324.0	2.1	324.8	5.2	6.7	325.2	8.5
87+74	D/S Berry Valley Road	324.0	2.1	324.2	6.9	6.7	324.3	8.5
76+36		320.8	1.8	321.9	13.8	6	322.3	16.0
71+50	U/S Private Drive	320.8	1.8	321.9	107.7	6	322.2	134.7
70+81	D/S Private Drive	320.8	1.8	321.2	65.9	6	321.4	77.9
67+88	U/S 93rd Avenue SE	319.1	1.8	320.1	5.8	6	320.6	7.9
67+00	D/S 93rd Avenue SE	319.1	1.8	319.9	4.9	6	320.5	7.4
43+00	U/S 89th Avenue SE	316.3	0.01	316.3	37.9	1.5	316.5	56.2
42+40	D/S 89th Avenue SE	316.3	0.01	316.3	37.9	1.5	316.5	54.6
25+16	U/S 86th Lane	313.5	0.01	313.7	5.7	0.5	314.1	10.7
24+34	D/S 86th Lane	313.6	0.01	313.7	2.6	0.5	314.0	10.5
11+35	U/S Anderson Lane	313.2	0.01	313.2	0.6	0.5	313.4	2.8
10+57	D/S Anderson Lane	311.0	0.01	311.1	0.9	0.5	311.5	3.7
0+07	U/S SR 510	307.5	0.01	307.5	0.8	0.5	307.7	3.1

Insert Figure 3.3-3. Thompson Creek Flow Measured D/S of Tahoma Terra Bridge

Insert Figure 3.3-4. Comparison of Water Surface Elevations

To determine the range of conveyance capacities along Thompson Creek, the HEC-RAS model was run at various flow rates to determine when specific reaches of the creek would experience over-bank flooding. Figure 3.3-5 illustrates the variation in hydraulic conveyance capacity by dividing the modeled portions of the creek into low, medium and high conveyance capacities. During mid-to-late winter storm events when the local water table is high and the potential to lose water downstream of 93rd Avenue SE is dampened, the highest capacity areas (shown in green) are the least susceptible to over-bank flooding. Conversely, the lowest capacity areas (shown in red) are the most susceptible to over-bank flooding.

KPFF Consulting Engineers (2008) have identified 10 drainage basins on the Thurston Highlands site based on existing topography (Figure 3.3-6). Details of the individual basins are provided in the KPFF *Grading, Drainage and Utilities Technical Engineering Report* (2008).
There is no evidence of well-developed surface water drainage from the upland portion of the site to Thompson Creek. Over most of the upland area of the property, there is internal drainage to closed depressions and wetlands that collect local runoff and allow infiltration.

A total of 35 wetland systems were identified on the property (Coot Company 2008B). They are generally small, isolated systems within the bottoms of depressions and have no outlet. In the eastern portion of the site, there is drainage to wetlands that border Thompson Creek. Some of these may be locally connected during the wet season when groundwater elevations are high. However, these are confined within a wetland swale, and there is no evidence of a scoured stream channel. The locations of wetlands identified on the site are shown on Figure 3.4-1 in Section 3.4 of this Draft EIS.

Insert Figure 3.3-5. Thompson Creek Capacity Overview

Insert Figure 3.3-6. Project-Specific Sub-Basins

POTENTIAL IMPACTS DURING CONSTRUCTION

Full Build-Out Conceptual Land Use Alternatives

Regrading the site to meet development requirements will result in changes to existing drainage systems, and an increase in runoff since the evapotranspiration provided by the "reprod" forest cover will be removed. Water quality impacts could arise from erosion of bare ground resulting in suspended sediments in runoff. There would also be a a low risk of accidents or spills of petroleum products from construction equipment.

Phase 1 Development Concept

For Phase 1 development, potential impacts to surface water movement, quantity and quality would be similar to those identified for full build-out, though more limited in extent. The Phase 1 development area comprises approximately 28 percent of the site (351 acres of 1,240 acres, total).

No Action Alternative

Under the No Action Alternative, there would be no change from existing conditions of surface water movement, quantity and quality.

POTENTIAL DEVELOPED-CONDITION IMPACTS

Full Build-Out Conceptual Land Use Alternatives

Conversion of the site from commercial reproduction forest to urban mixed-use development would result in decreased evapotranspiration. As a result, the volume of stormwater generated for a particular storm event would increase. Stormwater infiltrated within the development will recharge groundwater. Groundwater modeling indicates that about 30 percent of the increase in recharge will discharge to Thompson Creek, with the remaining 70 percent flowing to the west or recharging the deeper aquifer system (Pacific Groundwater Group 2008).

In addition to stormwater generated by the development, the City of Yelm is also giving consideration to infiltrating reclaimed water within the Thurston Highlands development area. The concept is described in more detail in Section 3.3.3 of this Draft EIS. For the purpose of this analysis, the quantity of reclaimed water to be infiltrated was assumed to be 1.5 million gallons per day (mgd). Actual amounts could vary on a seasonal basis. For the evaluation of impacts, the groundwater modeling has assumed that the maximum quantity would be infiltrated at a single engineered facility in the area of the proposed Regional Sports Complex. For the purpose of the groundwater modeling, the dimensions of the reclaimed water infiltration facility were assumed to be 400 feet be 400 feet, representing one model grid cell. Actual dimensions would be determined based on the infiltration properties of the soil and the storage capacity (depth) of the facility.

Infiltration on the Thurston Highlands site that recharges the shallow aquifer system (Regime A) would impact the discharge to Thompson Creek. Changes in groundwater discharge to the creek are summarized in Table 3.3-2. The analyses focused on two representative water years: 1981 and 1997. The volume of precipitation in 1981 approximated the long-term average, while the precipitation in 1997 was among the highest on record.

Table 3.3-2. Change in groundwater flux to Thompson Creek.

Year	Annual Change in Thurston Highlands Recharge (cfs)	Average Change in Creek Flow (cfs)	Percentage of Recharge to Thompson Creek	Maximum Day Change in Flow (cfs)
Scenario: Full-Build Out of Thurston Highlands (referred to as Scenario 3a in groundwater modeling analysis)				
1981	1.13	0.37	32%	0.65
1997	1.29	0.43	33%	0.64
Scenario: Full Build-Out of Thurston Highlands + 1.5 mgd of reclaimed water recharge (referred to as Scenario 3b in groundwater modeling analysis)				
1981	3.45	1.08	31%	1.37
1997	3.62	1.15	32%	1.35

The effect of an increase in shallow groundwater discharge to Thompson Creek will depend upon flow in the creek. Groundwater modeling shows that the groundwater flux to the creek is not sensitive to the water level in the creek. The creek cross-section is typically narrower at the stream bed than at the top of the stream channel bank. Thus, for the same increase in groundwater discharge to the creek, there will be a greater rise in the water level when the flow is low, with a low water level, than when the flow is high. This effect becomes more pronounced once the creek goes overbank and the cross-sectional area available for flow greatly increases.

The additional groundwater flux into Thompson Creek would affect flow rates and water surface levels. To assess the potential magnitude of the changes, the increases in groundwater fluxes (Table 3.3-2) were added to observed flows from the 2007/2008 wet season and input to HEC-RAS simulations. Table 3.3-3 lists the combinations of existing flow conditions and different potential future flow additions that were considered. The simulations focus on examining the difference in water surface elevations associated with the 1997 water year. While the groundwater modeling results for 1981 and 1997 did not show a substantial difference in the additional recharge flux, the results for the 1997 climate conditions are carried forward into the surface water modeling analysis because the fluxes were larger; therefore, using these results is more conservative.

In the discussion that follows, the average change in creek flow is identified as "Average 1997," and the maximum day change in flow is identified as "Maximum 1997." Two locations are presented in tables as representative of conditions along the creek. The first location is upstream of the Tahoma Terra Bridge ("U/S Tahoma Terra Bridge"), which represents conditions adjacent to the Thurston Highlands Master Planned Community. The second location is upstream of the 86th Lane crossing, which the modeling indicates as the location of the greatest increase in water level of Thompson Creek resulting form the additional groundwater fluxes. Complete details of fluxes, stream flows and water level changes are presented in the *Thurston Highlands Surface Water Technical Report (*Brown and Caldwell 2008). The "Existing Conditions" flows are the lowest and highest observed flows at the Tahoma Terra Bridge gauge. The "Additional Flux" flows were produced from MODFLOW groundwater simulations using the water year 1997 precipitation and recharge estimates as model inputs.

For the Final EIS, the surface water impacts analysis will be extended to include the potential change in flood stage associated with increased groundwater flows to Thompson Creek. For the FEIS analysis, the results of long-term hydrologic simulations (using HSPF) will be integrated with the existing HEC-RAS hydraulic model to estimate how historical floods (e.g., the January 12, 1997 flood) would have been affected by full build-out of the Thurston Highlands Preferred Alternative.

Table 3.3-3 summarizes the HEC-RAS modeling results for the four "1997" average and maximum groundwater flux changes listed in Table 3.3-2. The water surface rise upstream of the Tahoma Terra Bridge ranges from negligible to 0.1 foot. Upstream of 86th Lane, the water surface rise is between 0.2 foot and 0.6 foot. Note that the greatest water level increases occur with the lower flows. This is because of the stream channel geometry influence on the relationship between flow, stream depth, and stream width as discussed above. In sections on the creek with shallow side slopes, the increase in the width of the creek ranges up to 15 feet. Complete details are presented in the *Thurston Highlands Surface Water Technical Report* (Brown and Caldwell 2008).

Table 3.3-3. Thompson Creek water rise with additional groundwater fluxes: Thurston Highlands full build-out Preferred Alternative.

Scenario	**Existing Conditions**		**Additional Flux**		**Water Rise (feet)**	
		Flow (cfs)		**Flow (cfs)**	**Upstream TahomaTerra Bridge**	**Upstream 86th Lane**
3a	Low Flow	2.1	Average 1997	0.43	0.0	0.3
3b	High Flow	6.7	Maximum 1997	0.64	0.0	0.2
3a	Low Flow	2.1	Average 1997 + Reclaimed Water	1.15	0.1	0.6
3b	High Flow	6.7	Maximum 1997 + Reclaimed Water	1.35	0.1	0.3

Since Thompson Creek discharges to the Nisqually River, the increase in flows in Thompson Creek will result in an increase in the discharge to the River. However, the increases will be negligible compared with the flow in the River; there would be no observable impact.

Studies have shown that runoff from urban areas frequently has impaired water quality. Common pollutants and some potential sources are tabulated below (Washington Department of Ecology 2006).

Table 3.3-4. Common pollutants in stormwater and some potential sources.[1]

Pollutant	Potential Sources
Lead	Motor oil, transmission bearings, gasoline[2]
Zinc	Motor oil, galvanized roofing, tire wear, down spouts
Cadmium	Tire wear, metal plating, batteries
Copper	Brake linings, thrust bearings, bushings
Chromium	Metal plating, rocker arms, crank shafts, brake linings, yellow lane strip paint
Arsenic	Smelters, fossil fuel combustion, natural occurrence
Bacterial/Viral Agents	Domestic animals, septic systems, animal and manure transport
Oil & Grease	Motor vehicles, illegal disposal of used oil
Organic Toxins	Pesticides, combustion products, petroleum products, paints & preservatives, plasticizers, solvents
Sediments	Construction sites, stream channel erosion, poorly vegetated lands, slope failure, vehicular deposition
Nutrients	Sediments, fertilizers, domestic animals, septic systems, vegetative matter
Heat	Pavement runoff, loss of shading along streams
Oxygen Demanding Organics	Vegetative matter, petroleum products

Reference Guidance for UIC Wells that Manage Stormwater Department of Ecology December 2006 Publication No. 05-10-067 Table 4.1.

[1]Adapted from a number of sources: Novotny, V. and G. Chesters (1981). *Handbook of Nonpoint Pollution.* Van Nostrand Reinhold Company, New York, p. 322. Galvin D. and R. Moore (1982). *Toxicants in Urban Runoff*, METRO Toxicant Program, Report #2. METRO, Seattle, pp 3-89 - 3-92. PTI Environmental Services (1991). *Pollutants of Concern in Puget Sound. Puget Sound Estuary Program*, U.S. EPA, Seattle, pp 47-51. URS *et al*. (1988). City of Puyallup, Stormwater Management Program. Technical Memorandum WQ-1: Stormwater Quality Issues. Table 1.

[2]Although lead is no longer an additive to gasoline, it is still present in the environment in trace amounts, and the remaining lead on the ground can be picked up by stormwater runoff.

Phase 1 Development Concept

Phase 1 of the Thurston Highlands project would develop approximately 351 acres of the project site and increase the amount of groundwater recharge within Thurston Highlands and groundwater flux to Thompson Creek. The hydrogeological modeling analysis estimated the increase in groundwater recharge and groundwater flux to Thompson Creek for the following scenarios:

- Scenario 2a: Thurston Highlands Phase 1 development concept, with nearby land uses unchanged.
- Scenario 2b: Thurston Highlands Phase 1 development (Scenario 2a) with an additional 1.5 mgd of reclaimed water infiltrated onsite.

♦ Scenario 2c: Thurston Highlands Phase 1 development with full build-out of Tahoma Terra. No reclaimed water and no additional development in UGA.

Together these scenarios were developed to isolate the effects of Thurston Highlands Phase 1 and the effect of the on-going development of Tahoma Terra. Table 3.3-5 lists the "average" and "maximum day" change in groundwater flux to Thompson Creek for each of these scenarios.

Table 3.3-5. Thurston Highlands Phase 1 change in groundwater flux to Thompson Creek.

Year[1]	**Annual Change in Thurston Highlands Recharge (cfs)**	**Average Change in Creek Flow (cfs)**	**Percentage of Recharge to Thompson Creek**	**Maximum Day Change in Flow (cfs)**
Scenario 2a: Thurston Highlands Phase 1; all other land uses unchanged				
1981	0.31	0.09	28%	0.13
1997	0.37	0.10	27%	0.14
Scenario 2b: Thurston Highlands Phase 1 + 1.5 mgd of reclaimed water infiltrated onsite; all other land uses unchanged				
1981	2.63	0.78	29%	0.83
1997	2.69	0.79	29%	0.83
Scenario 2c: Thurston Highlands Phase 1 + full build-out of Tahoma Terra; no reclaimed water and no additional development within the UGA				
1981	0.43	0.16	37%	0.35
1997	0.50	0.19	37%	0.34

1. The hydrogeological modeling analysis focused on conditions during water years 1981 and 1997. Precipitation amounts during 1981 approximate the long-term average conditions, while 1997 is among the wettest years on record.

The changes in water surface levels in Thompson Creek were assessed using the HEC-RAS hydraulic model. Table 3.3-5 lists the combinations of existing flow conditions and different potential future flow additions that were considered. The Final EIS will include an evaluation of the impacts of increased groundwater recharge on the magnitude of flood events.

Table 3.3-6 summarizes the HEC-RAS modeling results for the six "1997" average and maximum groundwater flux changes listed in Table 3.3-5. The water surface rise upstream of the Tahoma Terra Bridge would be negligible for all of the scenarios considered. Upstream of 86th Lane, the water surface rise would range from negligible to 0.5 foot. Note that the greatest water level increases would occur with the lower flows. This is because of the stream channel geometry influence on the relationship between flow, stream depth, and stream width as discussed above. In sections of the creek that have shallow side slopes, the increase in the width of the creek would range up to 12 feet. See additional detail presented in the *Thurston Highlands Surface Water Technical Report* (Brown and Caldwell 2008).

Table 3.3-6. Thompson Creek water level rise with additional groundwater fluxes: Thurston Highlands Phase 1 development concept.

Scenario	Existing Conditions		Additional Flux		Water Rise (feet)	
		Flow (cfs)		Flow (cfs)	Upstream TahomaTerra Bridge	Upstream 86th Lane
2a	Low Flow	2.1	Average 1997	0.10	0.0	0.2
2a	High Flow	6.7	Maximum 1997	0.14	0.0	0.0
2b	Low Flow	2.1	Average 1997 + Reclaimed Water	0.79	0.0	0.5
2b	High Flow	6.7	Maximum 1997 + Reclaimed Water	0.83	0.0	0.2
2c	Low Flow	2.1	Average 1997	0.19	0.0	0.2
2c	High Flow	6.7	Maximum 1997	0.34	0.0	0.1

No Action Alternative

There would be no change in surface water runoff conditions if the No Action Alternative were selected. Since access to the site is not physically restricted by fencing, there is a potential for uncontrolled activities such as dumping that could lead to water quality degradation.

MITIGATION MEASURES

Incorporated Plan Features. Potential mitigation measures to reduce the impact of stormwater generated by the Thurston Highlands development are summarized in Draft EIS Section 3.19.4.

Applicable Regulations. Regulations applicable to design of the stormwater system are described in Draft EIS Section 3.19.4. Permits for grading activities will require submission of Erosion and Sediment Control (ESC) and Spill Prevention Control and Cleanup (SPCC) plans. Compliance with these plans will minimize the potential for water quality impacts. Work in or modifications to wetlands would require permits from the Department of Ecology, and in some cases from the U.S. Army Corps of Engineers. Compliance with these regulations is discussed in Draft EIS Section 3.4.

Other Possible Mitigation Measures. Mitigation alternatives for the increased volume of stormwater that would be generated on the Thurston Highlands site, and increased peak flows, are based on the following strategies:

♦ Reduce runoff using Low Impact Development (LID) technologies that promote natural retention, evapotranspiration and infiltration.

- Reduce peak flows using retention/detention facilities.

Concepts for design of the Thurston Highlands stormwater management system are described in the Draft EIS Section 3.19.4.

As noted above, development of Thurston Highlands will result in an increase in the volume of water to be infiltrated on the site, with the potential to increase the discharge of groundwater to Thompson Creek. The following strategies have been identified to mitigate the increased flows in Thompson Creek:

- Reduce the quantity of stormwater that needs to be infiltrated
- Infiltrate stormwater in an area where recharge does not report to Thompson Creek
- Store stormwater during the wet season for use during the dry season and/or until the timing of recharge would have a minimal impact on Thompson Creek
- Improve the conveyance capacity of Thompson Creek so that it can handle increased flows without an increase in flooding
- Add storage to Thompson Creek.

These strategies are discussed in further detail below.

The quantity of stormwater to be infiltrated could be reduced by enhancing evapotranspiration within the development. This could be accomplished by maintaining as much of the existing forest cover as possible, and by enhancing transpiration by select plantings. However, evapotranspiration is highest in the summer months, which is not the period when stormwater generation is greatest. This alternative is therefore considered to have limited mitigation potential.

Infiltration of stormwater in areas where recharge does not report to Thompson Creek has the potential to significantly reduce groundwater discharge to Thompson Creek. Groundwater modeling analyses for this mitigation alternative are discussed in Section 3.3.2. Without mitigation, the increase in groundwater flow to Thompson Creek could be up to 0.64 cfs. By limiting the areas where infiltration would be located, there is the potential to limit the increase to near zero.

The impacts of increased groundwater flow to Thompson Creek would be most significant during the wet season when groundwater discharge to the creek is naturally higher. Storing stormwater in the wet season for use or infiltration during the dry season would therefore reduce the impact on Thompson Creek. The average annualized increase in flows and volumes are shown in Table 3.3-7 for median (1981) and wet (1997) water years.

Table 3.3-7. Annualized average increases in Thompson Creek flow and volume with Thurston Highlands Phase 1 and full build-out.

Scenario	Water Year	Annualized average flow increase (cfs)	Annualized average flow volume (acre-ft)
Thurston Highlands Phase 1	1981	0.088	63
	1997	0.100	72
Thurston Highlands full build-out	1981	0.368	266
	1987	0.427	309

To store the complete stormwater volume for Phase 1 would require ponds with an average depth of 10 feet and total area of 6 to 7 acres. For full build-out, total required pond area would increase to about 30 acres. Ponds would need to be lined to prevent uncontrolled infiltration of the stored water into the subsurface. Depending on the size of the ponds, extensive grading of the existing topography may be required. The most suitable location for the ponds would be in the relatively level area that is proposed for the Regional Sports Complex; however, the ponds would reduce the area that to be developed for the sports complex.

Stormwater detention ponds would reach their maximum capacity in spring, and would be empty by the end of summer. If the stored water were to be used for irrigation, a water right may be required. In order to obtain aesthetic and recreational benefit during the summer months, some water could be retained. This would require an increase in the pond area or depth to allow for "dead" storage volume. This mitigation alternative may have application in conjunction with other measures, but because of the area that would have to be dedicated to the ponds, it is unlikely to be appropriate for full mitigation of increased groundwater flows to Thompson Creek.

As an alternative or complement to ponds, soils could be amended with compost to a depth of 10 to 12 inches to improve moisture retention in areas to be landscaped. Compostable material could be obtained during clearing operations by grinding wood waste and stumps. Soil moisture retained during the wet season would be evapotranspired by plants in the drier months.

The conveyance capacity of Thompson Creek could be improved by a variety of approaches, depending upon what is the limiting factor. If the channel conditions are limiting, the cross-section could be increased, or the friction characteristics could be improved by cleaning out the channel. If channel crossings, such as undersized culverts, are controlling the flow, they could be replaced with structures with a greater conveyance capacity. It appears that the section of the creek in the vicinity of 89th Avenue SE has among the lowest hydraulic capacity. However, the lands adjacent to this section of the creek are privately-owned, and the topographic survey of this section of creek channel is incomplete.

The storage capacity within the creek could be increased to reduce hydrograph peaks during flood events. This reduction would offset the increase in groundwater discharge to the creek.

The impacts from reclaimed water infiltration could be mitigated by reducing the amount infiltrated, and/or by limiting the time of infiltration so that the increase in groundwater flux to Thompson Creek would occur at a time when flow in the creek would be low. As part of the City's 2008 *Sewer System Plan* update, alternate sites for reclaimed water infiltration will also be examined.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

No significant unavoidable adverse impacts to surface water movement, quantity or quality would be anticipated.

3.3.2 Groundwater Movement, Quantity and Quality

Groundwater occupies subsurface pore space in soils and rocks. The groundwater level or elevation is the level to which water rises in a well constructed in the water-bearing formation. Soils that are permeable, such as sands and gravels, allow the free flow of groundwater, and are called aquifers. By contrast, soils that restrict the flow of groundwater, such as silts and clays, are called aquitards. Aquifers are classified as being either confined or unconfined. A confined aquifer has aquitards above and below, and a water level that rises above the top of the aquifer. An unconfined aquifer has a water level that is within the aquifer. As a result, the section of the aquifer that is above the water level (or water table as it is also called), is only partially saturated. This zone of partial saturation is also known as the vadose zone.

By installing monitoring wells at various locations within an aquifer, the hydraulic heads relative to a datum, usually sea level, can be determined. Groundwater flows from areas of high hydraulic head to areas of low hydraulic head. If contours (called equipotentials) are drawn through points of equal hydraulic head, the groundwater flow direction is generally in the direction of steepest slope. The slope between two points divided by the distance between the points is the hydraulic gradient. The ability of aquifer material to transmit water is called the permeability, or hydraulic conductivity. The quantity or flux of water that flows through a section of aquifer is a function of the hydraulic gradient, the hydraulic conductivity and the cross-sectional area of the aquifer.

Recharge to a groundwater system occurs from the natural infiltration of precipitation into the subsurface. Man-made systems such as irrigation, stormwater infiltration ponds and injection wells can also contribute water to the groundwater. Discharge of groundwater occurs from springs and seeps. Some of these are visible, for example at the base of slopes. Elsewhere, springs and seeps occur into the beds of lakes, streams and rivers and can only be detected by careful observation of flows or by small changes in water temperature of chemistry.

The geology and groundwater occurrence in the south Pierce County and north Thurston County area has been studied by federal and state agencies (Drost 1998, USDA 1990, Washington Division of Geology and Earth Resources 2001), and more recently by consultants to local cities to understand and quantify the sustainable groundwater resource (Golder Associates 2005; Golder Associates 2006; Golder Associates 2007; Noble and Wallace, 1966; and Robinson & Noble, Inc., 2001). Investigations of geology, groundwater and surface water related to development of the Thurston Highlands site have been performed and are summarized in this Draft EIS. Supporting technical reports (Brown and Caldwell 2008, Coot Company 2008B, KPFF Consulting Engineers 2008, and Pacific Groundwater Group 2008) are also available for review.

AFFECTED ENVIRONMENT

<u>Regional and Site Groundwater Units</u>

Drost (1998) described hydrogeologic conditions in northern Thurston County, and these data have been extrapolated to Yelm for the purpose of this study. Drost (1998) divided the most recent glacial deposits into three geohydrologic units summarized in the *Infiltration Effects Assessment* (Pacific Groundwater Group 2008) Table 3: Qvr (recent alluvium, Vashon recessional outwash and end moraine − Qvm), Qvt (Vashon glacial till), and Qva (Vashon advance outwash). *Draft Infiltration Effects Assessment* Table 4 summarizes the geologic units as interpreted at the Highlands. More detailed descriptions of the three primary Vashon geohydrologic units are discussed below.

Recessional Outwash and Moraine (Qvr). Alluvium was deposited as the glaciers retreated to the north (recessional outwash). This outwash comprises the youngest Vashon glacial material. It commonly occurs at the ground surface (e.g., Yelm Prairie), and overlies Qvt. The prairie has been described as a "kame terrace," indicating deposition between a glacier and an adjacent valley wall (the uplands area). Where saturated and sufficiently thick, the Qvr deposits in Thurston County comprise the shallowest aquifer used by small, private wells and some larger wells. Recessional outwash sands and gravels are described as permeable and allowing rapid infiltration. Qvr is mapped by the Washington Division of Geology and Earth Resources (2001) as outcropping in a small area on the central east edge of the Thurston Highlands and south of the Tahoma Terra development in the headwaters of Thompson Creek. Analyses of hydrogeologic properties of the Qvr were not generated for this investigation. However, infiltration capacity estimates are provided in the *Soil Survey of Thurston County* (USDA 1990) for soils that developed on the Qvr, as well as in the *Grading, Drainage, and Utilities Technical Engineering Report* prepared for the project (KPFF 2008).

Till (Qvt). Drost (1998) indicates that Qvt is present and continuous in the Yelm area. It is exposed at the surface in west Yelm, and in small northeastern areas of the Thurston Highlands site. Where not exposed, Qvt commonly underlies Qvr deposits. Thickness may vary from less than 25 feet to more than 100 feet (south of Yelm). Data collected during the Thurston Highlands field investigation suggest that the areas at the margins of the Vashon glaciation like the Highlands do not have substantial Qvt strata. Moraine and outwash deposits would be expected to form between glacial lobes and may not be laterally continuous in this area near the margins of the most recent ice. Till may occur as pods or lenses in some areas of the moraine deposits. It is usually relatively impermeable and limits, but does not eliminate, downward groundwater flow (i.e., it is aquitard material). Nonetheless, it can be highly variable, exhibiting a range in permeability and thickness. Drost (1998) reports vertical hydraulic conductivity of the Qvt to be 0.01 to 0.002 feet per day, whereas Golder Associates (2005) models a value of 3 feet per day. The hydraulic conductivity of the Qvt at the Highlands was not evaluated for this project.

Advance Outwash (Qva). Qva in the area consists of relatively permeable sands and gravels, creating an important water supply aquifer for both private and municipal wells. Although exposures of Qva are not mapped in Yelm by the Washington Division of Geology and Earth Resources (2001), Drost (1998) interprets that Qva is continuous and varies in thickness between less than 25 feet to more than 50 feet northwest of Yelm. The Qvt often creates a confining layer above this aquifer; however, where the Qvt is absent, the Qvr and Qva are connected, and the shallowest aquifer is unusually thick. The Washington Division of Geology and Earth Resources (2001) does not map Qva outcrops within the Highlands or near-vicinity. Geologic interpretation in this study does not indicate exposures within the site except in a very small area in the Thompson Creek headwaters area. However, if Qva occurs at depth, analyses of soil texture for the Thurston Highlands project suggest that hydraulic conductivity of the Qva is on the order of 200 to 500 feet per day. These estimates are within the range of 6.8 to 130,000 feet per day (median: 150 feet per day) estimated by Drost (1998).

Pre-Vashon Deposits. A series of glacial and non-glacial deposits underlie the Vashon glacial sequence. The Kitsap Formation (Qf) is a regional aquitard stratigraphically beneath the Qva. Some deeper units that would be below the Kitsap Formation can create important aquifers that are used in Thurston County and the Yelm area for water supply (e.g., the Qc and

Tqu aquifers). These units are sufficiently deep (a few hundred feet) to have little effect on surface infiltration facilities, and therefore were not investigated in the *Thurston Highlands Draft Infiltration Effects Assessment*. Golder Associates (2005) focused on a pre-Vashon aquifer in Thurston Highlands. Golder Associates (2006) presents results from aquifer testing of the deeper aquifer unit. Golder Associates (2007) summarizes results of recent groundwater modeling that also focused on deeper aquifer units.

At the Thurston Highlands site, groundwater flow appears to be laterally continuous between the Vashon advance outwash aquifer beneath the uplands portion of the site, and the recessional outwash and moraine aquifer that extends below the Yelm Prairie. This system is referred to collectively as the "shallow aquifer." The aquifers in the pre-Vashon sediments are referred to as the "deep aquifer(s)." For most of the area, the shallow aquifer is unconfined. However, the Vashon till unit locally forms a confining unit above the advance outwash.

Investigations

Thurston Highlands site investigation work to-date includes the construction of 12 piezometers, 7 stilling wells, and 4 temporary staff gages. Aquifer characteristics were estimated using field and laboratory techniques. An additional seven borings were drilled in March 2008 and five of these were converted to piezometer installations. The locations of the piezometers and stilling wells are shown on Figure 3.1-1. Water level observations have been collected since June 2007 using a manual water level probe. In addition, pressure transducers with data loggers were installed in six piezometers on November 15, 2007 and have provided continuous data on water levels since that time. Water level observations by others have been collected and aggregated into a database to provide a comprehensive picture of spatial and temporal variations in groundwater elevations. The *Draft Infiltation Effects Assessement* (Pacific Groundwater Group 2008) contains logs of the investigation drilling, aggregated water level observations, and laboratory test results.

Recharge

According to regional groundwater studies by Golder Associates (2003), recharge to the shallow groundwater system in the Yelm area is primarily through infiltration of precipitation. Recharge also occurs as seepage from surface water, septic systems, reclaimed water infiltration (e.g., Cochrane Park), and irrigation return flow. Annual groundwater recharge from precipitation was estimated by Golder Associates (2003) to range between 1.9 and 2.1 feet per year.

The Thurston Highlands site receives an annual average of about 40 inches of precipitation. Under existing conditions, about half of the precipitation evaporates or is transpired by existing forest vegetation (Brown and Caldwell 2008). Nearly all of the remainder infiltrates to become groundwater recharge. A small amount of runoff and interflow occurs locally, but at the scale of the site, nearly all runoff infiltrates in a short period of time. For the existing conditions, total recharge equals about 1.8 feet per year. The recharge initially flows vertically downward through the variably saturated moraine deposits, with lateral movement only occurring in saturated zones, which become more common with depth.

In addition to stormwater, consideration is being given to infiltrating up to 1.5 million gallons per day (mgd) of reclaimed water form the City of Yelm waste water treatment process (see Draft EIS Section 3.3.3). The optimum location of infiltration facilities has not yet been determined. For the purpose of this analysis, it was assumed that reclaimed water would be infiltrated at a maximum rate of 1.5 mgd.

Groundwater Flow

Groundwater sub-basins may roughly follow surface water watershed boundaries; however, sigificant variances can occur. The location of the groundwater divide between the Deschutes and the Nisqually basins was not identified in this study but is presumed to be off-site to the west and probably near the western boundary of the Thurston Highlands site. Inferring from other work (e.g., Robinson & Noble 2001), shallow groundwater on the prairie flows generally north towards the Nisqually River. Groundwater in the deep aquifers flows more northwesterly (Golder 2007).

Laterally-moving groundwater follows flow paths of varying length until discharge to Thompson Creek or the Nisqually River, or until it is extracted from the system by vegetation or pumping wells. The discharge location of groundwater on the different flow paths is used to define two groundwater flow regimes (Figure 3.3-7).

- Regime A is defined where groundwater enters the shallow aquifer system, with a significant portion of the flow discharging to Thompson Creek. Regime A is absent from some areas of the Thurston Highlands site.
- Regime B occurs in deeper pre-Vashon strata. Regime B is recharged by direct infiltration to the deeper aquifer and by downward flow from Regime A. Groundwater in this regime does not contribute to the flow in Thompson Creek. This conclusion is based on observations of groundwater levels that are below the elevation of the creek, and flow directions toward the northwest, away from the creek.

A schematic of the Thurston Highlands hydrological system is shown in Figure 3.3-8. For existing conditions, infiltration is equal to precipitation minus natural evapotranspiration, since there is no significant runoff from the site area. Build-out of the development will mimic the natural conditions by collecting and infiltrating stormwater. In addition, reclaimed water may also be infiltrated. Infiltrated water will move downward through the unsaturated zone to groundwater. Depending on the location of the infiltration facility, the infiltrating water will enter either the shallow or the deep aquifer system. Groundwater in the shallow system may discharge to Thompson Creek, flow laterally to discharge to the Nisqually River, or recharge the deep groundwater system by leakage through the aquitard, or by downward flow where the aquitard is absent. In the deep groundwater system, lateral flow is to the north-northwest, away from Thompson Creek (PGG 2008).

Groundwater Model

The objectives of groundwater modeling were to:

- Develop a quantitative model to simulate and understand hydrogeologic conditions at the site in three dimensions.
- Estimate effects of possible future development on Thompson Creek flow.
- Evaluate possible mitigating conditions and measures.

Insert Figure 3.3-7. Groundwater Flow

Insert Figure 3.3-8.
Thurston Highlands Precipitation, Evapotranspiration, and Infiltration Schematic

The groundwater flow model was constructed using Modflow-Surfact (Hydrogeologic, Inc., 1996) with the Streamflow Routing and River Packages (Prudic 1989), and input/output management with Groundwater Vistas (Environmental Simulations, Inc. 2000−2007). This software is based on the Modflow program originally developed by the USGS (McDonald and Harbaugh 1988). The project model incorporated the regional hydrogeologic concepts defined by Drost (1998). A previously-constructed Modflow model for Thurston County (Drost, 1999), and a later modification ("Olympia model") for the City of Lacey McAllister Springs area (CDM, 2002a, CDM, 2002b and Golder, 2006) was used as a starting base for the groundwater model construction.

The Modflow model consists of eight layers representing hydrogeologic units from the recessional outwash and alluvium to the Tertiary (Tqu) aquifers at the base. The model domain covers approximately 20 miles from east to west, and 13 miles north to south (Figure 3.3-9). The western boundary is defined by the Deschutes River and the eastern boundary by the Nisqually River. The southern boundary is mainly defined by bedrock, and is simulated as a no-flow boundary. The northern boundary and southeastern boundary are defined by constant head cells. The initial hydraulic properties used were the same as the Olympia model. In order to determine the discharges along Thompson Creek, the creek was divided into a number of segments as shown in Figure 3.3-10. Complete details of the model are provided in the Draft *Infiltration Effects Assessment* (Pacific Groundwater Group 2008).

Analyses were performed for existing conditions, for which it is estimated the Thurston Highlands site was comprised of 86 percent forest cover. Hydrologic properties were adjusted to obtain calibration to observed groundwater elevations for the Thurston Highlands area, consistent with generally accepted modeling practices. Stormwater recharge for developed conditions was calculated using the analyses by KPFF (2008) of monthly stormwater generation rates. The change in recharge was applied over the sub-basin where the stormwater originated. For model analyses that considered development in areas beyond Thurston Highlands, existing conditions were based on interpretation of land use from aerial photos. Future land use full build-out was assumed in accordance with the existing zoning map in the City of Yelm Comprehensive Plan (2006). The effect of a change in land use on recharge was estimated using the HSPF model (Brown and Caldwell 2008). For consistency with the site area, the change in recharge was used. By following this approach of using the change in recharge for modeling future conditions, the discharges to Thompson Creek also represented changes.

In order to cover a range of climatic conditions, two water years representing median (1981) and wettest (1997) annual precipitation amounts were used from the record period 1955 to 1999 available for the Olympia Airport. Calibrated-model groundwater heads showed good calibration with observed heads. The model shows that the creek is gaining (i.e., groundwater level is above the stream level and therefore groundwater is discharging into the creek) to about Segment 10. From Segment 10 to Segment 13 the creek becomes a losing stream (i.e., the groundwater level is below the stream level and therefore water is draining out of the creek and recharging groundwater). The creek becomes gaining again as it drops in elevation to its discharge to the Nisqually River. This simulated behavior is consistent with observations that the stream is frequently flowing as far as 86th Lane, and then becomes dry to the SR 510 crossing and below.

Insert Figure 3.3-9. Model Area

Insert Figure 3.3-10. Thompson Creek Segmentation

POTENTIAL IMPACTS DURING CONSTRUCTION

During construction, existing “reprod” forest cover will be removed. As a result, evapotranspiration will be reduced, and the volume of runoff will increase. Since the proposal is to infiltrate all runoff onsite, recharge to groundwater will increase. Construction conditions were not explicitly modeled. However, since the project will be developed sequentially, including clearing of forested areas, the impacts will be less than following project full build-out.

Full Build-Out Conceptual Land Use Alternatives

Impacts during construction could result from the increase in stormwater infiltration and recharge to groundwater. This could produce an increase in fluxes to Thompson Creek and an increase in recharge of the deeper aquifer systems. In addition, groundwater elevations could rise along the creek, resulting in an increase in the high groundwater hazard area.

Phase 1 Development Concept

Construction impacts for the Phase 1 development would be similar to those described above for full build-out, though over approximately 28 percent of the site.

No Action Alternative

For the No Action Alternative, there would be no change from existing conditions of evapotranspiration, infiltration, or surface water runoff.

POTENTIAL DEVELOPED-CONDITION IMPACTS

Full Build-Out Conceptual Land Use Alternatives

Direct impacts could result from the increase in stormwater infiltration and recharge to groundwater. This could produce an increase in fluxes to Thompson Creek and an increase in recharge of the deeper aquifer systems. To evaluate these impacts, two scenarios have been analyzed using the groundwater model:

- Scenario 3a: Thurston Highlands full build-out (2030), with all other conditions unchanged.
- Scenario 3b: Scenario 3a with reclaimed water infiltration.

The groundwater model indicates that the shallow groundwater system would transmit about 30 percent of the increased recharge (with or without reclaimed water infiltration) to Thompson Creek with the headwater creek segments receiving most of the increased base flow. Infiltration of 1.5 mgd reclaimed water in the future Regional Sports Complex area would approximately triple the total change in recharge (0.73 mgd stormwater in Water Year 1981, and 2.2 mgd stormwater and reclaimed water in Water Year 1981). Using the annual water volumes discharging to Thompson Creek, the model predicts an approximate tripling of the change in discharge to Thompson Creek with infiltration of reclaimed water, compared with the change in discharge without infiltration of reclaimed water. Most of the additional creek flow would be added in creek segments in the headwaters, and would occur mostly in the wet season. For the purpose of the groundwater modeling, the dimensions of the reclaimed water infiltration facility were assumed to be 400 feet be 400 feet, representing one model grid cell. Actual dimensions would be determined based on the infiltration properties of the soil and the storage capacity (depth) of the facility. Infiltration of 1.5 mgd reclaimed water into the hypothetical 400-foot by

400-foot area would create a groundwater mound at least 10 feet high below the infiltration area.

The change in flux downward from the till towards deeper aquifers would increase by up to 0.0036 mgd with the increase in recharge from stormwater. This flux increase would nearly double if an additional 1.5 mgd of reclaimed water were infiltrated on the Thurston Highlands site.

For stormwater infiltration alone, the model predicts that maximum groundwater head increases adjacent to Thompson Creek would range from zero (Segment 13) to about 1-foot (Segment 5) and average about 0.3 feet. With the additional infiltration of 1.5 mgd reclaimed water, the model predicts that maximum groundwater head increases adjacent to Thompson Creek would range from zero (Segment 13) to about 3 feet (Segment 5) and would average about 0.8-feet. For scenarios with and without reclaimed water infiltration, the largest head change is predicted to occur in the Thompson Creek headwaters area.

A relationship between flooded area and groundwater head was developed for the closest high groundwater hazard area, which is just downstream of Tahoma Terra in creek Segment 10 (Table 3.3-8). The model-predicted groundwater head increase in the example high groundwater hazard area (HGWHA) ranges from 0.080 feet for stormwater only to 0.13 feet for stormwater and 1.5 mgd of reclaimed water. Using these model results and the relationship in Table 3.3-8, the rising heads would equate to about a 5 percent and 8 percent increase in the size of the high groundwater hazard area. However, the relationship between groundwater rise and the area of groundwater flooding would be unique for each flood area.

Table 3.3-8. Effects of raising groundwater levels on extent of high groundwater hazard areas (Thompson Creek Segment 10).

Modeled Increased Groundwater Elevation (feet)	**Estimated Increase in HGWHA (%)**
0	0
0.5	30
1.0	50
1.5	70

The volume of stormwater that would be generated and infiltrated for the Preferred Alternative would be less than for Traditional Development, but more than with the Urban Village Alternative. Average annual flows for the alternatives for the representative median and wet years are summarized below in Table 3.3-9.

Table 3.3-9. Infiltration amounts for existing conditions and the conceptual land use alternatives (personal communication with Ben Enfield, P.E., KPFF, May 14, 2008).

	Average annual infiltration recharge (mgd)	
	Median Water Year 1981	Wet Water Year 1997
Existing Conditions	1.921	3.041
Preferred Alternative	2.610	3.813
Traditional Development	2.622	3.826
Urban Village	2.531	3.725

It is anticipated that about 30 percent of the increase in stormwater due to development will report to Thompson Creek for any of the conceptual land use alternatives.

Based on the groundwater model, indirect impacts to groundwater from Thurston Highlands development would be limited. Particle tracking in the model shows the increased recharge moving downward through the moraine, recessional outwash and till and then flowing northward in the advance outwash. In addition to the northward gradient, there is a vertical gradient within the advance outwash. Thus, some of the increased recharge would flow downward into deeper aquifers and move off-site under the influence of the regional groundwater system. Groundwater head increases in these deeper and more remote areas would be small and generally beneficial for stream and river base flows.

Phase 1 Development Concept

For the Phase 1 development concept, the following scenarios have been analyzed using the groundwater model:

- Scenario 2a: Thurston Highlands Phase 1 development concept, with all other conditions unchanged.
- Scenario 2b: Scenario 2a with reclaimed water infiltration
- Scenario 2c: Scenario 2a with Thurston Highlands Phase 1 development concept, plus fully-built Tahoma Terra. Existing conditions elsewhere in the UGA (2012).

The groundwater model indicates that the shallow groundwater system would transmit about 30 percent of the increased recharge (with or without reclaimed water infiltration) to Thompson Creek with the headwater creek segments receiving most of the increased base flow. Infiltration of 1.5 mgd reclaimed water in the future Regional Sports Complex area would increase the total change in recharge by a factor of about six (0.27 mgd stormwater in Water Year 1981, and 1.7 mgd stormwater and reclaimed water in Water Year 1981). Using the annual water volumes discharging to Thompson Creek, the model predicts an increase by a factor of about five in the change in discharge to Thompson Creek with infiltration of reclaimed water, compared with the change in discharge without infiltration of reclaimed water. Most of the additional creek flow would be added in creek segments in the headwaters areas and would mostly occur in the wet season. The effects of infiltrating 1.5 mgd of reclaimed water would be the same as described for the Thurston Highlands full build-out scenario.

The change in flux downward from the till toward deeper aquifers would increase by up to 0.0036 mgd with the increase in recharge from stormwater. This flux increase would nearly double with the additional infiltration of 1.5 mgd of reclaimed water.

For Phase 1 stormwater infiltration alone, the model predicts that maximum groundwater head increases adjacent to Thompson Creek would range from zero (Segment 13) to about 0.5 foot (Segment 5) and average about 0.1 feet. With the additional infiltration of 1.5 mgd reclaimed water, the model predicts that maximum groundwater head increases adjacent to Thompson Creek would range from zero (Segment 13) to about 2 feet (Segment 5) and average about 0.6 feet. For scenarios with and without reclaimed water infiltration, the largest head change would occur in the Thompson Creek headwaters area.

A relationship between flooded area and groundwater head was developed for the closest high groundwater hazard area, which is just downstream of Tahoma Terra in Thompson Creek

Segment 10 (Table 3.3-10). The model-predicted groundwater head increase in the example high groundwater hazard area ranges from 0.06 feet with Phase 1 stormwater only to 0.07 feet for stormwater and 1.5 mgd of reclaimed water infiltration. Using these model results and the relationship in Table 3.3-10, the rising heads would equate to about a 4 percent increase in the size of the high groundwater hazard area. However, the relationship between groundwater rise and the area of groundwater flooding would be unique for each flood area.

No Action Alternative

No impacts to groundwater movement, quantity or quality would be expected with the No Action Alternative. Runoff and recharge conditions would not change from existing conditions. Therefore, there would be no change to shallow groundwater flow to Thompson Creek.

MITIGATION MEASURES

Incorporated Plan Features. All of the conceptual land use alternatives considered incorporate stormwater infiltration throughout Thurston Highlands site using existing depressions or constructed facilities. However, as noted below, mitigation of the increased flow to Thompson Creek may require infiltration to be restricted to certain areas of the site. The development will be constructed in phases giving an opportunity to evaluate and, if necessary, improve the performance of the stormwater infiltration systems, and a potential reclaimed water infiltration system.

Applicable Regulations. The Federal Safe Drinking Water Act requires that all federally-defined public water systems (Group A systems) using groundwater as their source implement a wellhead protection program. Group A systems include all public water systems which serve 25 or more persons or 15 or more connections. The Washington Administrative Code addressing requirements for Group A public water systems (WAC 246-290) includes mandatory wellhead protection measures for all Group A public water systems in the State using wells or springs. Guidance on Wellhead protection requirements is provided in the Washington State Department of Health Wellhead Protection Program Guidance Document (2005).

The City of Yelm has enacted a Critical Areas Code to implement the goals, policies, guidelines, and requirements of the Yelm Comprehensive Plan and the Growth Management Act, Chapter 36.70A RCW (City of Yelm Critical Areas Code 2005). The entire City of Yelm and its Urban Growth Area are identified as a highly susceptible Critical Aquifer Recharge Area (Section 14.08.110). This section of the Code defines the performance standards for the Critical Aquifer Recharge Area including underground tanks, vehicle servicing and repair, and the use of reclaimed water for surface percolation or direct recharge. The Code also addresses Frequently Flooded Areas (Section 14.08.120), including high groundwater flood hazard areas. Requirements include delineation of the base flood elevation and a limitation on development with 50 feet of the outer edge of the high groundwater flood hazard area or two feet above the base flood elevation.

Use of reclaimed water for surface percolation must meet the groundwater recharge criteria given in Chapter 90.46.080(1) and Chapter 90.46.010(10) RCW. Standards for reclaimed water have been jointly developed by the Department of Health and the Department of Ecology (Washington Department of Ecology 1997). The City's wastewater treatment process generates effluent that meets meets Class A standards in accordance with State regulations. The City currently infiltrates reclaimed water within Cochrane Park. Reclaimed water for infiltration within Thurston Highlands (if any) would meet State requirements.

Potential water quality impacts to groundwater from infiltrating stormwater and/or reclaimed water would be minimized by treatment of the water prior to infiltration. For stormwater, the treatment requirements defined in Ecology's 2005 SWMWW would be implemented. These requirements were formulated to reduce suspended solids, oil and grease, and phosphates.

Other Possible Mitigation Measures. In order to minimize the increase in groundwater discharge to Thompson Creek, stormwater infiltration facilities could be located in areas where the groundwater flow does not report to the headwaters of Thompson Creek. This would result in an increase in fluxes to the lower aquifer and/or the shallow aquifer system discharging to the Nisqually River. The most suitable areas for infiltration are where the till is thin or absent, and/or locations distant from Thompson Creek. This mitigation option would require capturing stormwater from some site drainage basins and conveying it using a pumping system and force main to the selected areas for infiltration. In order to investigate this mitigation option, the groundwater model was run with stormwater recharge limited to sub-basin F for the Phase 1 and full build-out scenarios. Without mitigation, the increase in groundwater flow to Thompson Creek would be approximately 30 percent of the recharge. By limiting the area where infiltration would occur, this mitigation option has the potential to minimize the impact on stream flow in Thompson Creek to near zero.

Impacts to Thompson Creek from stormwater infiltration could be minimized by extraction of groundwater by wells. Pumping could occur on the site or in the near vicinity and benefits would be greatest if the water was used in areas where return flows would have minimum effects on Thompson Creek. Theoretically, full-implementation of this option would have the potential to effectively mitigate impacts to Thompson Creek, whereas a partial implementation could provide more limited reduction in the potential impact.

The impact on groundwater discharge to Thompson Creek from infiltration of reclaimed water on the site could be minimized or eliminated by controlling the location, amount and timing of infiltration. As noted above for stormwater, location of the infiltration facility where the groundwater flow does not report to Thompson Creek would be beneficial. The potential impacts to Thompson Creek would be most significant during the wet season. Therefore, restricting infiltration to periods when groundwater discharge to Thompson Creek is naturally low would significantly reduce the potential impacts, and may have a beneficial effect of maintaining flow in the creek and associated wetlands for longer periods. This option would require, however, that the City have an alternate reclaimed water infiltration site that could accommodate 100 percent of the requirements for discharge.

Public outreach programs could be used to educate residents on limiting the use of fertilizers and garden chemicals, and cleanup and disposal of pet wastes.

Significant Unavoidable Adverse Impacts

Identified groundwater impacts are either not adverse or not significant (for example, the rise in the groundwater level under infiltration areas), or are avoidable by mitigation (such as the increase in groundwater flux to Thompson Creek).

3.3.3 Public and Private Water Systems

AFFECTED ENVIRONMENT

Potable Water. The City of Yelm provides potable water to its residents and others within its water service area through the operation of a municipal water system. The present water service area is comprised of those properties within the City limits, including the Thurston Highlands site, properties within the City's Urban Growth Area, and an area north of the Centralia power canal that Yelm has historically provided potable water. The water system area is approximately 9.7 square miles and includes a number of existing, independent water systems that are located adjacent to or inside the Yelm water service area.

To provide potable water to its customers, Yelm withdraws water from a well field located in the central business district, treats the water, stores it in two 500,000-gallon water tanks, and distributes it to water customers through a system of water mains and service lines. Water to serve the existing Yelm water system is pumped from an aquifer located in an recessional outwash (Qvr) deposit located in the Yelm Creek sub-basin of the Nisqually River watershed.

The City of Yelm currently does not have sufficient water rights to serve the entire water service area. Water right applications for additional rights sufficient to serve future growth in the City of Yelm and its Urban Growth Area were made to the Washington Department of Ecology in 1994 to withdraw water from the area of the Thurston Highlands site and from the deeper aquifer located in the advance outwash deposits (Qva).

Since that time, the City has participated in the Watershed Planning Process for the Nisqually Water Resource Inventory Area (WRIA 11) pursuant to the Watershed Planning Act adopted by the Legislature in 1998. The Nisqually Tribe was the lead agency and the Nisqually Watershed Plan was first adopted in the State when it was approved by Pierce, Thurston, and Lewis Counties in April 2004.

The Watershed Planning Unit began implementation of the plan in November 2005, with key recommendations including sub-basin processing of water right applications and additional efforts in water conservation, reuse, and reclamation. A final Detailed Implementation Plan was completed in April 2007 which outlined the methodology and process for reviewing new water rights applications and transfers in the watershed as well as the system to review mitigation plans.

Development of the Thurston Highlands Master Planned Community is dependent upon the City obtaining additional water rights through the issuance of new rights or the transfer of existing water rights to the City. The current City of Yelm *Water System Plan* notes this requirement for the Thurston Highlands site, as well as for the Tahoma Terra Master Planned Community.

There are other public and private water systems as well as individual wells located within and adjacent to Yelm's water service area, as identified in the adopted *Yelm Water System Plan*.

Reclaimed Water. The City of Yelm was the first sewer system in the State of Washington to produce Class A reclaimed water pursuant to Chapter 90.46 RCW, the Reclaimed Water Act of 1992. It encouraged the beneficial use of reclaimed water to use water resources in the best interest of present and future generations. The Act encouraged reuse of reclaimed water provided that it is used for direct, beneficial purposes such as crop and turf irrigation, and/or commercial and industrial uses.

In 1993, the City of Yelm began to pursue reclaimed reuse with 100 percent upland discharge in order to eliminate wastewater discharge directly into the Nisqually River. This activity was initiated after the start of construction of the City's new Septic Tank Effluent Pump (STEP) sewer system in 1992.

In order to gain public support for reclaimed water reuse, and to encourage the construction of water reclamation facilities, the Washington State Legislature directed the Departments of Ecology and Health to establish "pilot projects" for those cities that were interested in pioneering reclamation projects in Washington State. Yelm became a pilot project program, but finding a direct, beneficial use for reclaimed water during winter months when there was no demand for irrigation was a deterrent to completion of the program. An outcome of the pilot project program working with the Departments of Ecology and Health, however, was that the Legislature amended Chapter 90.46 RCW in 1995 to provide for the non-consumptive use of reclaimed water through infiltration, wetland discharges, and stream flow augmentation.

In the summer of 1999, the City of Yelm completed construction of its reclaimed water project. The City currently treats 100 percent of the its wastewater to Class A reclaimed water standards, and has the most extensive Class A water reclamation facility and distribution system in Washington State. Reclaimed water is currently used for irrigation at schools, parks, churches, homes, streetscapes, for construction purposes, and for school bus washing. Additionally, the City uses reclaimed water to support a constructed wetland park and aquifer recharge facility at Cochrane Memorial Park.

The City of Yelm's reclaimed water system is so successful that the demand for reclaimed water often exceeds the supply during the summer irrigation months, prompting the construction of a 500,000 gallon reclaimed water tank in 2005 to provide storage to meet peak demands.

Because wastewater is generated and treated throughout the year, and because demand for consumptive uses of reclaimed water is minimal during the winter months as irrigation is by far the predominant use of reclaimed water, non-consumptive uses are required for 100 percent upland discharge.

Aquifer recharge through infiltration is one method of the non-consumptive discharge of reclaimed water that the City of Yelm asked Thurston Highlands to explore as part of the Environmental Impact Statement to determine whether it would be possible to infiltrate reclaimed water within the project site during winter months when the production of reclaimed water exceeds the demand for upland discharge. As projections for build-out of Thurston Highlands and the City's Urban Growth Area indicated that approximately 1.5 million gallons per day of reclaimed water would be produced, this planning number was used to model potential impacts as a worst-case scenario. This analysis is presented in the *Thurston Highlands Infiltration Effects Assessment* (Pacific Groundwater Group 2008) and the *Surface Water Evaluation of Thompson Creek* (Brown and Caldwell 2008), summarized in Draft EIS Sections 3.3.1 and 3.3.2.

The City is currently preparing a *Reclaimed Water Plan* for adoption to guide development of the Reclaimed Water Facility. Alternative sites are being considered for their merits and impacts as infiltration facilities for Class A reclaimed water from the City's wastewater treatment and reuse/discharge system (Parametrix, March 2007). No conclusion had been reached at the time of this writing as to whether discharge of reclaimed water within Thurston Highlands is a preferred alternative. Other locations are available for reclaimed water infiltration if, for environmental, operational, or other reasons, Thurston Highlands is not the preferred alternative for reclaimed water discharge.

POTENTIAL IMPACTS DURING CONSTRUCTION

Full Build-Out Conceptual Land Use Alternatives

Well drilling creates the potential for contaminants to enter the aquifer from the surface of the ground or other, more shallow, water-bearing strata. Deep, water supply well drilling is not a direct element of the Thurston Highlands Master Planned Community proposal.

Construction activities create the potential for fuel and chemical spills that could potentially reach existing public and private water systems if a spill were to occur within the critical aquifer recharge area.

Phase 1 Development Concept

Potential impacts during construction within the Phase 1 development area would be similar to those possible under full build-out of any of the conceptual land use alternatives, though on a more limited scale. The Phase 1 development area constitutes approximately 28 percent of the site.

No Action Alternative

Under the No Action Alternative, the Thurston Highlands property would not be developed, and no potable water system would be constructed on the site.

POTENTIAL DEVELOPED-CONDITION IMPACTS

Full Build-Out Conceptual Land Use Alternatives

Any potential direct impacts to public or private water systems from development of the Thurston Highlands Master Planned Community relate to the City's acquisition of additional water rights sufficient to serve the proposed development and development elsewhere within the City's Urban Growth Area. There are no major differences in direct impacts between any of the conceptual land use alternatives analyzed.

At full build-out, the Thurston Highlands Master Planned Community could include a number of land uses that have the potential to impact public and private water systems within the critical aquifer recharge area. Land uses such as service stations, print shops, and dry cleaners that use and store petroleum or chemicals; the large Regional Sports Complex that may require the application of fertilizers, herbicides, and pesticides; and stormwater runoff from residential, commercial, and recreational land uses could all potentially contaminate the aquifer used by public and private water systems. The risk of contamination from these sources is considered extremely low. For example, the existing water source for the City of Yelm is a shallow aquifer in the center of the Central Business District.

The withdrawal of additional water from the regional aquifer by the City of Yelm to expand its water system to serve Thurston Highlands as well as other anticipated growth within the City's water service area has the potential to impact other public and private water systems if the additional withdrawal would impact the static water level in the wells used by other water systems.

Phase 1 Development Concept

Potential impacts to public and private water systems attributable to development within the Thurston Highlands Phase 1 area would be similar to those described for the full build-out scenario, though more limited in scope. The Phase 1 development concept would generate approximately 20 percent of the total anticipated number of homes within the Master Planned Community, and approximately 20 percent of the total resident population that would require potable water supply.

No Action Alternative

The No Action Alternative would not require any additional potable water to serve the property, and therefore would have no impacts on public or private water systems.

Mitigation Measures

Incorporated Plan Features. Erosion and Sedimentation Control (ESC) and Spill Prevention Control and Clean-up (SPCC) Plans would be in-place and implemented at all times during construction activities on the site.

Applicable Regulations. The City of Yelm has adopted a Critical Areas Code pursuant to the requirements of the Growth Management Act that regulates development within critical aquifer recharge areas to protect groundwater drinking sources. The Code currently prohibits certain high-risk land uses and establishes standards for other land uses to protect the aquifer from contamination from petroleum and chemicals. The Critical Areas Code is updated periodically to ensure that the most current protection standards are adopted, and would likely be updated several times during the course of the Thurston Highlands development. The Master Planned Community would be subject to the requirements for development within a critical aquifer recharge area as provided in the most current version of the Yelm Critical Areas Code.

The Washington Department of Ecology, as part of its review of new water rights applications, considers the water rights of other water systems and the impact that additional groundwater withdrawal may have on public and private water systems that could potentially be affected by the approval of new water rights. A request by the City of Yelm to the Washington Department of Ecology to review and act on the City's pending application would include groundwater modeling consistent with the policies of the *Nisqually Watershed Plan and Detailed Implementation Plan*. The request would also include a detailed mitigation plan, if impacts were indicated to other water rights holders or to in-stream flows in the Nisqually River or Deschutes River.

Significant Unavoidable Adverse Impacts

No significant adverse impacts to public or private water supplies are anticipated that could not be avoided or mitigated.