Appendix A

Groundwater Modeling to Support Revised Water Rights Mitigation Planning City of Yelm, Washington

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Submitted To:
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21-1-12322-003

APPENDIX A

GROUNDWATER MODELING TO SUPPORT REVISED WATER RIGHTS MITIGATION PLANNING
CITY OF YELM, WASHINGTON

This Technical Memorandum presents the results of groundwater modeling performed by Shannon & Wilson, Inc. (Shannon &Wilson) to support the City of Yelm's (Yelm's) water right applications and mitigation program. The purpose of this work was as follows:

- To simulate a new (2010) Baseline condition in the McAllister Groundwater Model (the model) to reflect revised groundwater pumping and water rights in the Yelm Sub-basin;
- To estimate the extent to which this new Baseline condition would affect previously predicted hydrologic impacts; and
- Simulate the first new well using the 2010 Baseline to simulate revised future groundwater pumping to meet their growing water demand.

The results of this analysis will be incorporated in Yelm's updated (2010) mitigation plan as Appendix A, to be submitted to Washington State Department of Ecology (Ecology).

SUMMARY OF CHANGES SINCE 2008 MITIGATION PLAN

This Mitigation Plan has been revised to reflect several conditions that have changed relative to the 2008 draft submittal. The primary changes reflected in this plan are:

- The model Baseline pumping was updated to reflect more current pumping conditions in the Yelm sub-basin;
- Rather than multiple phases of development, a single 1994 water right application (G2-29085) is planned at a single new well location (SW Well 1A);
- Yelm will maintain its facilities and continue its historic withdrawals at the downtown well locations;
- Water rights transfers (golf course and another pending transfer) have been modified to reflect current conditions and the proposed well located at the Nisqually Golf Course are no longer being considered;
- The growth and demand forecast have been revised to reflect currently anticipated future conditions;

- Due to the new pumping distribution and the change to a 20-year planning horizon, Yelm's demand for new water has decreased from 4,186 acre-feet per year (ac-ft/yr) (2008) to 942 ac-ft/yr (2010); and

- In 2010, 31.26 ac-ft/yr of new water right was added to Yelm's two downtown wells through exempt well consolidation work, and another pending transfer of 67 ac-ft/yr is in progress.

YELM'S FUTURE DEMAND AND WATER RIGHT REQUEST

Based on the drilling and testing results for the new (October 2010) production well (SW Well 1A), Yelm plans to update its 2008 mitigation plan to reflect the planned production from this well at lower cumulative annual (Qa) and peak instantaneous (Qi) rates than anticipated in 2008. Due to its exceptional conservation and reclaimed water programs, Yelm's current long-term demand projection for potable supply is estimated to be 1,837 ac-ft/yr, which is expected to occur in 2028. Yelm's existing water rights (after completion of the transfers) authorize total annual pumping of 894.92 ac-ft/yr at the downtown wellfield, leaving 942 ac-ft/yr of new water rights needed to serve long-range demands through 2028. Therefore, Yelm will request 942 ac-ft/yr of new water from water right application G2-29085 (priority date January 10, 1994), modified to reflect a single point of appropriation (Qa of 942 ac-ft/yr and Qi of 2,100 gallons per minute [gpm]).

MCALLISTER GROUNDWATER MODEL BACKGROUND

Figure 1 shows the model domain and Figure 2 shows the key hydrologic features of interest (also listed in Table 1). Shannon &Wilson used the 2008 Baseline version of the revised model to make the updates. The 2008 version was previously used to simulate:

- Yelm's proposed future pumping in a phased approach (up to 4,186 ac-ft/yr) (Yelm, 2008);
- The City of Olympia's (Olympia's) full build-out of the proposed McAllister Wellfield (up to 17,800 ac-ft/yr) (Olympia, 2008); and
- Several water right applications and transfers for the City of Lacey's (Lacey's) in the East Lacey and Hawks Prairie areas (Lacey, 2008).

These runs formed the basis for the individual cities mitigation plans, each submitted to Ecology between September and October 2008. The cities of Lacey and Olympia submitted updated mitigation plans to Ecology in December 2010.

In addition, a "Cumulative" modeling scenario was performed by S.S. Papadopulos and Associates, Inc. (SSPA) that simultaneously simulated the pumping for the full requested water rights for Yelm, Olympia, and Lacey using the 2008 Baseline (SSPA, 2008). This run was primarily performed to check that it is a valid approach to sum the impacts from the three cities individual runs. However, the analysis showed that the results of the cumulative and combined individual runs are generally comparable. For most water bodies, the sums of the individual run results were at least as high as those for the cumulative run. Therefore, the individual model results produced by the three cities can be added to provide a conservative estimate of cumulative impacts.

Yelm's pumping rate changes are not expected to adversely change the depletions previously identified with respect to pumping by the cities of Olympia and Lacey. Therefore, the analysis presented in this report used the Baseline conditions for Olympia and Lacey wells to show depletions associated with Yelm wells alone.

SW WELL 1A

In 2010, Yelm installed a new production well (SW Well 1A) in the Thurston Highland area of the city, approximately 1.3 miles southwest of the downtown area (Figure 3). This well is hereafter referred to as SW Well 1A. Full details of the well are included in the memorandum prepared by Golder (dated December 2010). A summary of the well construction and testing follows:

- The well was completed to a total depth of 633 feet below ground surface (bgs) (approximately 273 feet below mean sea level [MSL]) using 12-inch-diameter production casing (to 310 feet bgs) and 8-inch-diameter blank and wire-screen.
- The well consists of two primary screened sections: (1) between the depths of 369 to 437 feet bgs (-9 to -77 feet MSL), and (2) between 487 and 547 feet bgs (-127 to -187 feet MSL). The total target production interval is 147 feet, with 130 feet of screen. The well is screened in the deep, confined Tertiary undifferentiated (TQu) aquifer.
- Golder performed a step-drawdown test during September 2010 using pumping rates between 550 and 2,200 gpm. This test yielded a specific capacity of between 19 and 25 gpm per foot (gpm/ft). This equates to a transmissivity of 44,000 gallons per day per foot (5,890 square feet per day [sf/day]) and an average hydraulic conductivity of 45 feet per day (ft/day).
- Golder performed a 72-hour test during October 2010 at a constant rate of 2,100 gpm. The range in resulting transmissivities is 8,000 sf/day (for the early test time) to 5,300 sf/day (for the late-time, stable data).

- Using a total screened length of 130 feet and a well transmissivity of 5,300 sf/day, the average hydraulic conductivity is 41 ft/day.

SW Well 1A is, by more than 100 feet, the deepest well completed in the Yelm area. In 2008, Golder evaluated the published hydraulic conductivity estimates for wells completed in the TQu aquifer within the McAllister Model domain (Golder, 2008; Figure 3-11). These data indicated a range of three orders of magnitude (from 1 to 1,000 ft/day), with a median in the range of 50 to 100 ft/day and a standard deviation of 656. The model assigns horizontal and vertical hydraulic conductivities of 75 and 0.03 ft/day, respectively, to the two deepest layers (8 and 9) that represent the TQu aquifer. Although the well test hydraulic conductivity values are lower than the modeled value, they fall just below the low end of the median range for the TQu aquifer and well within the range of one standard deviation of the hydraulic conductivity distribution for the TQu aquifer. The model is intended to simulate groundwater flow and hydrologic impacts at a basin scale. At this scale, the computed hydraulic conductivity at SW Well 1A is reasonably consistent with the hydraulic conductivity used in the model for the TQu aquifer. Because the results from the new well indicate aquifer properties are within the normal range of variability for this unit, Shannon & Wilson decided to assign the well's pumping flux to model layers 8 and 9, and use the current, calibrated hydraulic conductivity values in the regional model. Shannon & Wilson consulted with Olympia's consultant to decide on this pumping assignment.

2010 BASELINE UPDATE

Pumping Changes

For the 2010 Baseline update, Shannon &Wilson made the following changes to groundwater pumping (Table 2; Figure 4):

- Increased pumping at Yelm's two existing downtown wells (Wells 1A and 2) by a combined 31.26 ac-ft/yr. This change resulted from a "consolidation" of 26 relatively small, "exempt" wells also located in the downtown area by Ecology. Figure 3 shows the locations of these wells. The 2008 model used a series of pumping fluxes to each represent a cluster of nearby actual pumping wells. Therefore, it was necessary to reduce the modeled pumping at five of these pumping fluxes to account for the consolidation in the model. These five fluxes are all completed in the Qga aquifer; (model layer 3) and are also shown on Figure 3.
- Increased pumping from Yelm's downtown Wells 1A and 2 by 77 ac-ft/yr for the transfer of water rights from the Nisqually Golf Course well. The remaining pumping at the golf course well totaled 70 ac-ft/yr (all irrigation). The new golf course well will not be constructed as planned in 2008.

- Increase pumping from Yelm's downtown Wells 1A and 2 by 67 ac-ft/yr for Yelm's water right transfer from a pending water rights transfer. An annual pumping total of 28 ac-ft/yr remained at the transferring property to supply a planned housing development.

No other changes were made to the other modeled pumping or boundary conditions.

Revised Baseline Model Results

The 2010 Baseline was run for a total of six years, repeating monthly stress periods as in previous simulations. The model results from the final year of this simulation were used for analysis purposes.

Baseline Groundwater Level Changes

Figures 5, 6, and 7 show the revised potentiometric levels for September in the Qga (model layer 3), Qpg (model layer 5), and TQu (model layer 9) in the Yelm area. Overall, groundwater levels and flow directions are similar to those for the 2008 Baseline. The results are summarized as follows:

- Simulated groundwater levels in the Qga aquifer in the Yelm area range from 360 feet MSL near the McMonigle Farm to 220 feet MSL near where Thompson Creek enters the Nisqually River. The simulated groundwater flow direction is generally to the north-northeast in this area. Locally, some groundwater discharges from this aquifer as relatively small seeps and springs along the western edge of the Nisqually River and at numerous active production wells.
- Simulated groundwater levels in the Qpg aquifer in the Yelm area range from 340 feet MSL near the McMonigle Farm to 160 feet MSL near where Thompson Creek enters the Nisqually River. The simulated groundwater flow direction is also generally to the north-northwest in this area. Locally, some groundwater discharges from this aquifer to the Nisqually River and at several active production wells.
- Simulated groundwater levels in the TQu aquifer in the Yelm area range from 300 feet MSL near the McMonigle Farm to 140 feet MSL near where Thompson Creek enters the Nisqually River. The simulated groundwater flow direction is generally to the northwest in this area.

Baseline Groundwater Discharge Changes

The revisions to the Yelm area pumping regime resulted in changes to the Baseline discharge at all four principal hydrologic basins, some of which exceed 0.01 cubic foot per second (cfs). However, these changes are relatively small and equate to less than 0.3 percent of the overall discharge rate. Therefore, these changes do not affect the model's ability to reasonably predict the effects of future pumping.

FUTURE YELM PUMPING SIMULATION

Future Yelm Pumping

Yelm's proposed pumping for SW Well 1A was simulated using the 2010 Baseline case. Table 3 and Figure 8 present the monthly pumping totals for Yelm's two downtown wells (which remained unchanged from the 2010 Baseline case) and the new pumping for SW Well 1A. The SW Well 1A pumping was assigned to model layers 8 and 9 (TQu aquifer). The model was run for a total of six years, repeating monthly stress periods as in previous cases. The model results from the final year of this simulation are discussed in the following sections.

Modeling Results

Groundwater Level Changes

Figures 9, 10, and 11 show the simulated potentiometric levels for September in the Qga aquifer (model layer 3), the Qpg aquifer (model layer 5), and the upper portion of the TQu aquifer (model layer 8). Figures 12, 13, and 14 show the simulated changes (drawdown) in potentiometric levels in the Yelm area during September in the Qga, Qpg and TQu aquifers, respectively, compared to the 2010 Baseline.

- The simulated groundwater flow direction in all three aquifers generally remains the same as for the 2010 Baseline case (Figures 9, 10, and 11).
- In the Qga aquifer, the predicted maximum decrease in potentiometric level is 0.3 foot, generally centered on the SW Well 1A (Figure 12).
- In the Qpg aquifer, the maximum predicted decrease in potentiometric level is 0.8 foot, also centered on the SW Well 1A (Figure 13).
- In the TQu aquifer, the maximum predicted drawdown resulting from the new pumping is 6.0 feet (Figure 14). Groundwater levels are predicted to be drawn down by approximately 1 foot at a distance of 2.5 miles from SW Well 1A.

The model averages the groundwater level (and therefore, drawdown) across the model cell in which a pumping well is located. In the model, the cell in which SW Well1A is located has dimensions of 100 feet by 100 feet. Consequently, the model does not accurately predict the drawdown in, or very close to, a well which is essentially a point (a diameter of only 10 inches) rather than a substantial area. However, this does not affect the model's ability to reasonably predict drawdown from new pumping at distances from the new pumping well.

Groundwater Discharge Changes

Table 4 shows the predicted changes in groundwater discharge (depletions) to the main hydrologic features compared to the 2010 Baseline. Figures 15 through 18 show the predicted monthly depletions for the four main features (the Nisqually River at River Mile [RM] 4.3, the Deschutes River at Tumwater, McAllister Creek at Medicine Creek and Woodland Creek at Henderson Inlet).

Nisqually River Valley. The groundwater discharge to the Nisqually River upstream from RM 4.3 includes discharge directly to the river, seepage from Kalama Springs in the middle valley area, and discharge from Yelm Creek near RM 21.8 where the Centralia Canal re-enters the river.

The model predicts that the SW Well 1A pumping will decrease the discharge to the Nisqually River at RM 4.3 by up to 0.32 cfs, with the greatest depletion occurring in August (Figure 15). Although the river is not closed to further appropriations at RM 4.3, the river is closed between June 1 and November 15 at RM 21.8 (Washington Administrative Code [WAC] 173-511; Ecology, 1988a). The predicted depletion range for the river reach upstream of RM 21.8 (defined by the modeled Upper Nisqually river reach) is 0.08 to 0.11 cfs. However, the river depletions at RM 4.3 and RM 21.8 are not predicted to exceed one percent of the respective Baseline discharges during any month.

Deschutes River Valley. The groundwater discharge to Deschutes River upstream from Tumwater includes discharge directly to the river, seepage from Silver Springs in the upper valley area, and discharge from Spurgeon Creek.

The model predicts that the SW Well 1A pumping will decrease the discharge to the Deschutes River by up to 0.24 cfs, with the greatest depletion occurring in February and March (Figure 16). The predicted depletion during the closure period (April 15 to November 1; WAC 173-513; Ecology, 1988b) ranges from 0.15 to 0.19 cfs. The depletion is predicted to exceed one percent of the Baseline discharge only during September and October.

McAllister Valley. The groundwater discharge to McAllister Creek upstream from the confluence with Medicine Creek includes discharge directly to the creek, seepage from numerous, relatively small springs located along the western valley bluff, and (principally) discharge from the pool and wetland area fed principally by McAllister and Abbot Springs. McAllister Creek and Lake St. Clair (which is an entire closed lake) are closed year-round to consumptive appropriations (WAC 173.511; Ecology, 1988a).

The model predicts that the proposed SW Well 1A pumping will decrease the discharge to McAllister Creek by up to 0.21 cfs, with the greatest depletion occurring in August and September (Figure 17). The depletion to the creek is not expected to exceed one percent of the Baseline discharge during any month. The model also predicts that the new pumping will not result in discharge depletion for Lake St. Clair above 0.01 cfs during any month.

Woodland Creek Basin. The groundwater discharge to Woodland Creek upstream from Henderson Inlet includes discharge directly to the creek and drainage from the tri-lakes (Long, Hicks, and Pattison) and the inter-lake wetland areas. These three lakes and Woodland Creek are closed year-round to consumptive appropriations (WAC 173-513; Ecology, 1988b).

The model predicts that the SW Well 1A pumping will decrease the discharge to the Woodland Creek Basin year-round by 0.02 cfs (Figure 18). The depletion is expected to exceed one percent of the Baseline discharge only during October.

SUMMARY AND CONCLUSIONS

Model Updates for 2010

The primary objective of this modeling analysis was to simulate Yelm's future groundwater pumping using its existing two downtown wells (Wells 1A and 2) and the new SW Well 1A, which is located west of the downtown area, to meet future demand. To achieve this, it was necessary for Shannon & Wilson to update the 2008 version of the model. This involved updating the baseline conditions in the model to reflect new pumping conditions in the Yelm sub-basin. These changes included revising Yelm's downtown pumping to more accurately reflect changes to a pending local water right transfer and Ecology's consolidation of 26 exempt wells.

The results indicated that groundwater levels in the Yelm area increased by up to one foot compared to 2008 conditions. These changes also resulted in increased Baseline discharge to Yelm Creek and the Upper Nisqually River reach.

Yelm's Future Pumping

The 2010 Baseline model was used to simulate Yelm's future pumping to meet demand through 2028. This involved continuing to use the two downtown Yelm wells (Wells 1A and 2) at the same rates as in the Baseline case (totaling 895 ac-ft/yr) and the new SW Well 1A (totaling 942 ac-ft/yr) for a annual total of 1,837 ac-ft/yr. The combined simulated peak monthly rate was

1,902 gpm (in August), which equates to a peak operational rate of approximately 2,400 gpm. The new well pumping flux was assigned to the TQu aquifer (layers 8 and 9).

The simulation results indicate the following:

- Groundwater levels in the Yelm area will decline by no more than one foot in the Qga and Qpg aquifers in the Yelm area. Although groundwater levels in the TQu aquifer will decline by up to 6 feet near the SW Well 1A, the drawdown will not exceed one foot at a distance of more than 2.5 miles from the well. The new pumping will not significantly affect the regional groundwater flow direction in the main aquifers.
- The groundwater discharge to the Nisqually River at RM 4.3 and 21.8 will decrease by up to 0.32 and 0.11 cfs (both in August), respectively. The depletions to the Nisqually River will not exceed one percent of the Baseline discharge rate during any month at either station. The new pumping will decrease discharge to Yelm Creek by up to 0.06 cfs.
- The groundwater discharge to the Deschutes River at Tumwater will decrease by between 0.15 and 0.24 cfs (in February). Most of this depletion will occur in the upper river reach. Only during September and October will the depletions exceed one percent of the Baseline discharge rate to the river.
- The groundwater discharge to the McAllister Valley will decrease by between 0.14 and 0.21 cfs (in August and September). The depletions to the creek will not exceed one percent of the Baseline discharge rate during any month.
- The groundwater discharge to Woodland Creek will decrease by 0.02 cfs year-round. All of this depletion will occur at the tri-lakes and the inter-lake wetland areas. Only during October will the depletions exceed one percent of the Baseline discharge rate to the creek.

REFERENCES

Golder Associates Inc. (Golder), 2010, SW Yelm Well No.1A: Prepared for the City of Yelm: December.

Lacey, City of, 2008, Comprehensive Water Rights Mitigation Plan, Phase I: September.

Olympia, City of, 2008, McAllister Wellfield Mitigation Plan: September.

S.S. Papadopulos and Associates, Inc. (SSPA), 2008, McAllister wellfield model: comprehensive pumping scenario for cities of Olympia, Lacey and Yelm: Technical Memorandum from Michael Riley to Rich Hoey, City of Olympia: July 3.

Washington State Department of Ecology (Ecology), 1988a, Instream Resources Protection Program – Nisqually River Basin, Water Resources Inventory Area (WRIA) 11: Chapter 173-511 WAC, June.

Washington State Department of Ecology (Ecology), 1988b, Instream Resources Protection Program – Deschutes River Basin, Water Resources Inventory Area (WRIA) 13: Chapter 173-513 WAC, June.

Yelm, City of, 2008, Water Right Mitigation Plan: October.

LIST OF ENCLOSURES

TABLE 1
MODEL BOUNDARY REACHES

Zone No.	Boundary Feature	Comments
1	U. McAllister Valley Springs	Tributary to McAllister Creek. Excludes McAllister Spring.
2	Lake St. Clair	
3	McAllister Creek	
4	M. Deschutes River	Between Macintosh and Offutt lakes.
5	McAllister Valley bluff springs	Tributary to McAllister Creek.
6	L. Nisqually River – River Mile (RM) 4.3 to Puget Sound	Reach below minimum in stream flow point.
7	Up-gradient boundary	
8	Budd Inlet	
9	M. Nisqually River – from zone 22 to zone 33 (new U. Nisqually)	
10	Eaton Creek	Tributary to Lake St. Clair.
11	Spurgeon Creek	Tributary to Deschutes River.
12	Puget Sound	
14	L. Deschutes River	Downstream from new M. Deschutes reach.
15	McAllister Spring	Tributary to McAllister Creek.
16	Hicks Lake	Tributary to Woodland Creek.
17	Long Lake	
18	Pattison Lake	
19	Long-Pattison wetland area	
20	First 5,000 feet of Nisqually above RM 4.3	
21	Second 5,000 feet of Nisqually above RM 4.3	
22	Third 5,000 feet of Nisqually above RM 4.3	
23	U. Deschutes River	Upstream from new M. Deschutes reach.
24	Hicks-Pattison wetland area	Tributary to Woodland Creek.
25	Woodard Creek	
26	Woodland Creek	Starts at the outlet from Long Lake.
31	Kalama Creek Springs	Tributary to Nisqually River.
32,34	Yelm Creek	Tributary to Nisqually River.
33	U. Nisqually River	Upstream from Thompson Creek inflow. Previously included in Zone 9.
35	Silver Spring and Creek	Tributary to Deschutes River.

TABLE 2
2008 AND 2010 BASELINE GROUNDWATER PUMPING FOR THE YELM AREA

	Downtown Yelm Wells 1A and 2		Proposed New Nisqually GC Well		Total Yelm Pumping		Other Local Pumping	
Phase	**Annul (afy)**	**Peak Monthly (gpm)**	**Annul (afy)**	**Peak Monthly (gpm)**	**Annul (afy)**	**Peak Monthly (gpm)**	**Annual (afy)**	**Peak Monthly (gpm)**
2008 Baseline	719.66	747	232.61	242	952.27	989	199.8	150
2010 Baseline	894.92	928	0	0	894.92	928	98	171

Notes:
afy = acre-feet per year
gpm = gallons per minute

TABLE 3
SIMULATED YELM MONTHLY PUMPING

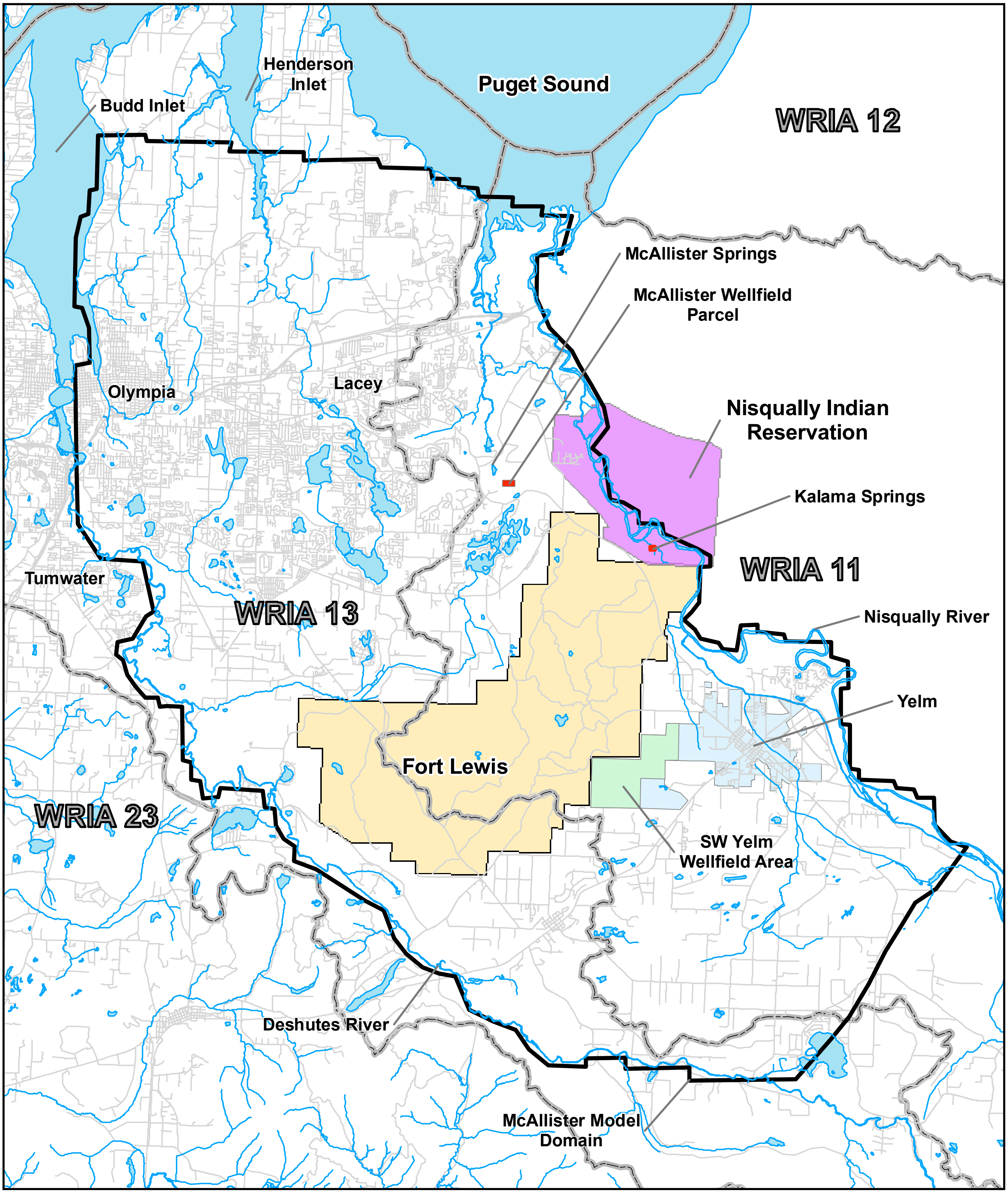
Month	Monthly Pumping Rates			
	Yelm Downtown Wells (gpm)	SW Yelm Well A (gpm)	Total (gpm)	Total (afm)
Oct	483	508	991	135.6
Nov	392	413	805	106.7
Dec	429	452	881	120.5
Jan	428	451	879	120.4
Feb	377	397	774	95.7
Mar	423	445	868	118.8
Apr	432	455	887	117.5
May	522	551	1,073	147.0
Jun	691	727	1,422	188.0
Jul	902	950	1,852	253.6
Aug	928	974	1,902	260.5
Sep	635	668	1,303	172.7
Total				1,837.0

Notes:
afm = acre-feet per month
gpm = gallons per minute

TABLE 4
PREDICTED CHANGES IN GROUNDWATER DISCHARGE VERSUS BASELINE FOR FUTURE YELM PUMPING

Hydrologic Area/Feature	Highest Seasonal Discharge Change			Summer Discharge Change	
	cfs	%	month(s)	cfs	%
Nisqually Valley					
- Yelm Creek	-0.06	-2.6	Apr	-0.05	56[(1)]
- Upper reach	-0.11	-0.5	Aug	-0.11	-0.5
- Kalama Creek Spring	-0.02	-0.5	Jul-Aug	-0.02	-0.5
- Middle reach	-0.06	-0.4	Aug	-0.06	-0.4
- Lower reach	-0.09	-0.4	Aug-Sep	-0.09	-0.4
Nisqually River at RM 4.3	**-0.32**	**-0.5**	**Aug**	**-0.32**	**-0.5**
Deschutes Valley					
- Upper reach	-0.15	-0.5	Feb	-0.11	-1.0
- Middle reach	-0.03	-1.6	Jul	-0.03	-1.6
- Silver Creek/Spring	-0.01	-1.1	Sep	-0.01	-1.1
- Lower reach/Spurgeon Creek	-0.06	-0.2	Feb	-0.04	-0.4
Deschutes River at Tumwater	**-0.24**	**-0.3**	**Feb-Mar**	**-0.19**	**-0.9**
McAllister Valley					
- McAllister Spring	-0.12	-0.3	Aug-Sep	-0.12	-0.3
- Other upper valley springs	-0.09	-0.3	Aug-Sep	-0.09	-0.3
- McAllister Creek	<0.01	-	-	<0.01	-
- Valley-bluff springs	<0.01	-	-	<0.01	-
- Lake St. Clair	<0.01	-	-	<0.01	-
McAllister Creek at Medicine Creek	**-0.21**	**-0.3**	**Aug-Sep**	**-0.21**	**-0.3**
Woodland Creek Basin					
- Long-Hicks-Pattison lakes	-0.02	-2.8	Aug	-0.02	-2.8
- Woodland Creek	<0.01	-	-	<0.01	-
Woodland Creek at Henderson Inlet	**-0.02**	**-1.7**	**Oct**	**-0.02**	**-0.9**

Notes:
1 Baseline discharge rate (June) for Yelm Creek is 0.09 cfs.
cfs = cubic feet per second
RM = River Mile



LEGEND

- McAllister Model Domain
- WRIA Boundary
- SW Yelm Wellfield
- City of Yelm
- Nisqually Indian Reservation
- Fort Lewis

0 15000

Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Source:
Golder Associates, Inc.

This figure was originally produced in color. Reproduction in black and white may result in a loss of information.

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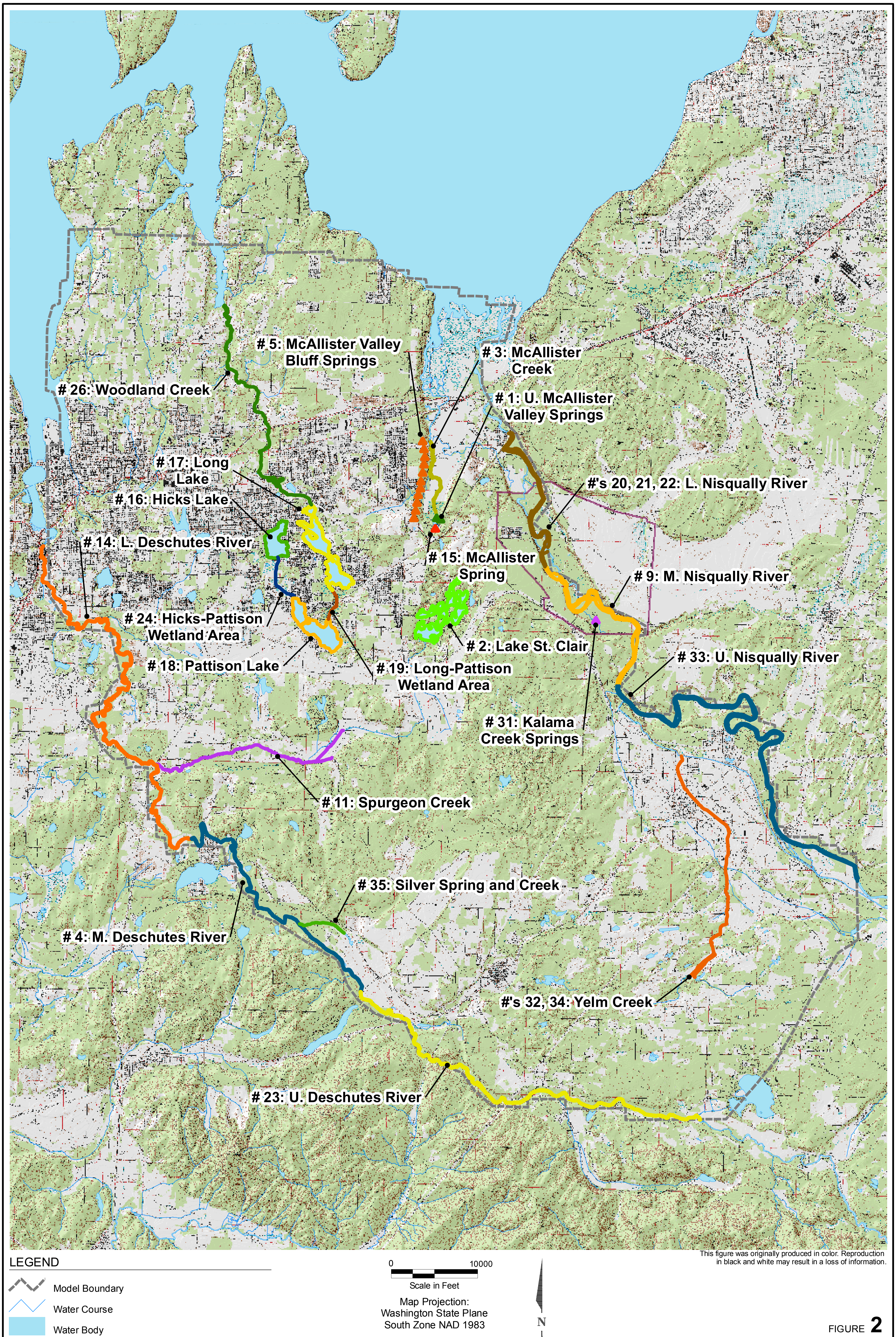
FIGURE 1

MAJOR FEATURES OF THE MCALLISTER GROUNDWATER MODEL



Map Projection: Washington State Plane South Zone NAD 1983

Source: USGS,NHD, Golder Associates, Inc.

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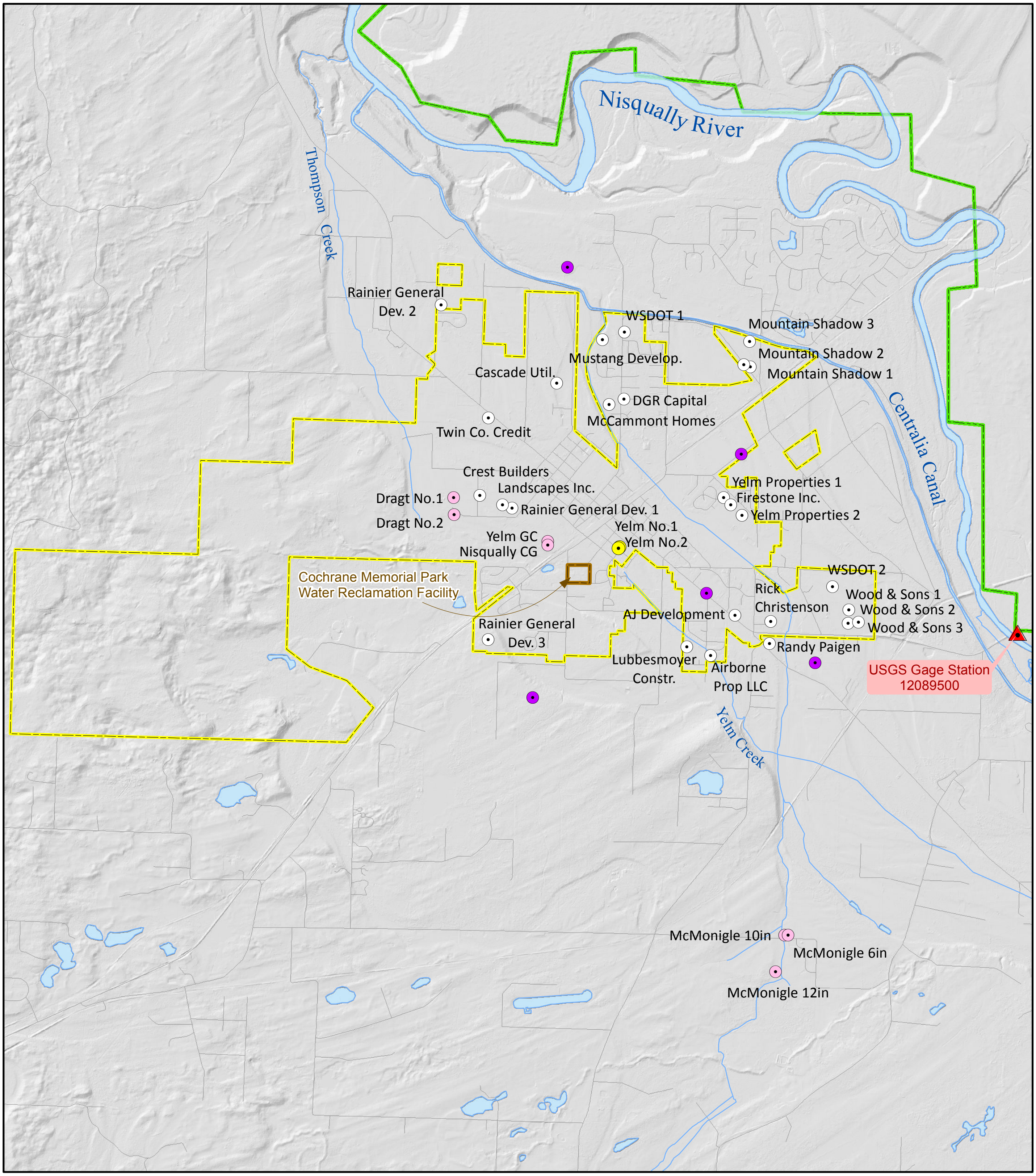
FIGURE 2

MCALLISTER MODEL WATER KEY HYDROLOGIC FEATURES

Path: T:\Project\21-1112322_CityofYelm\AV_mxd\Figure3.mxd Date: 2/15/2011



LEGEND

Change In Modeled Potentiometric Level (ft)
Model Domain
City of Yelm
Water Course
Water Body
Private Well
Modeled Private Well
Fluxes Reduced for 2010 Consolidation
City of Yelm Well
Consolidated Exempt Well
Road

0 4,000
Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

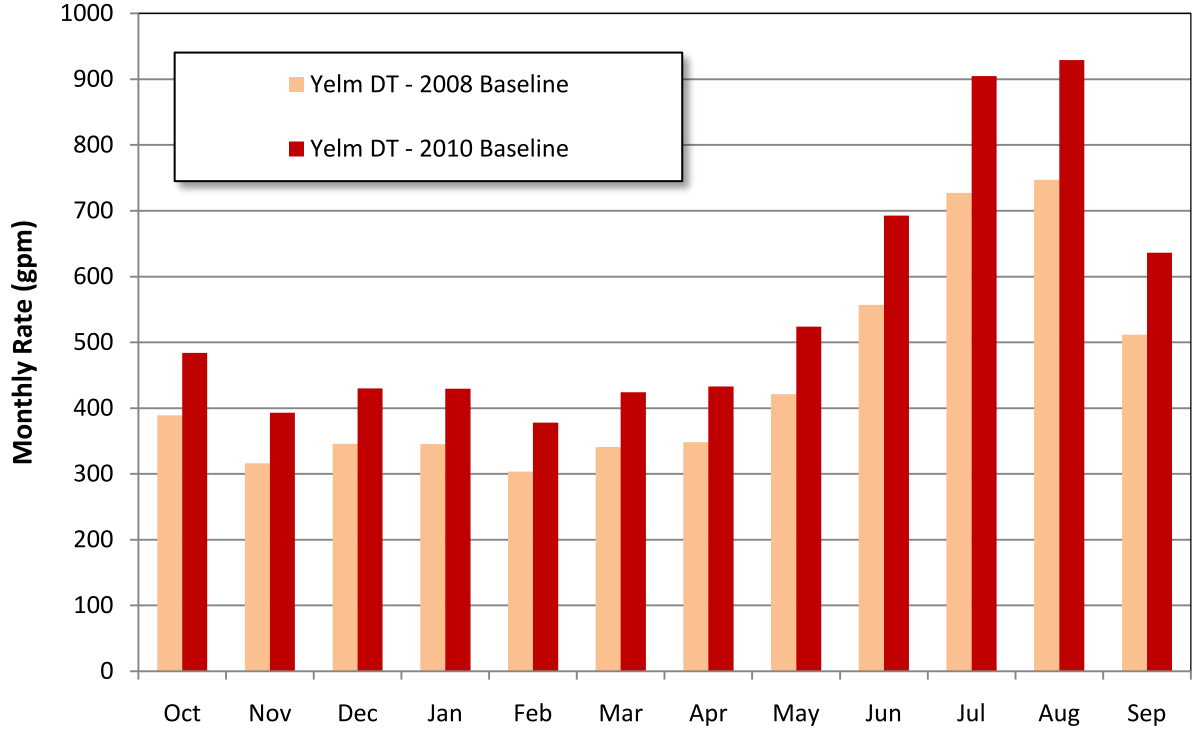
Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

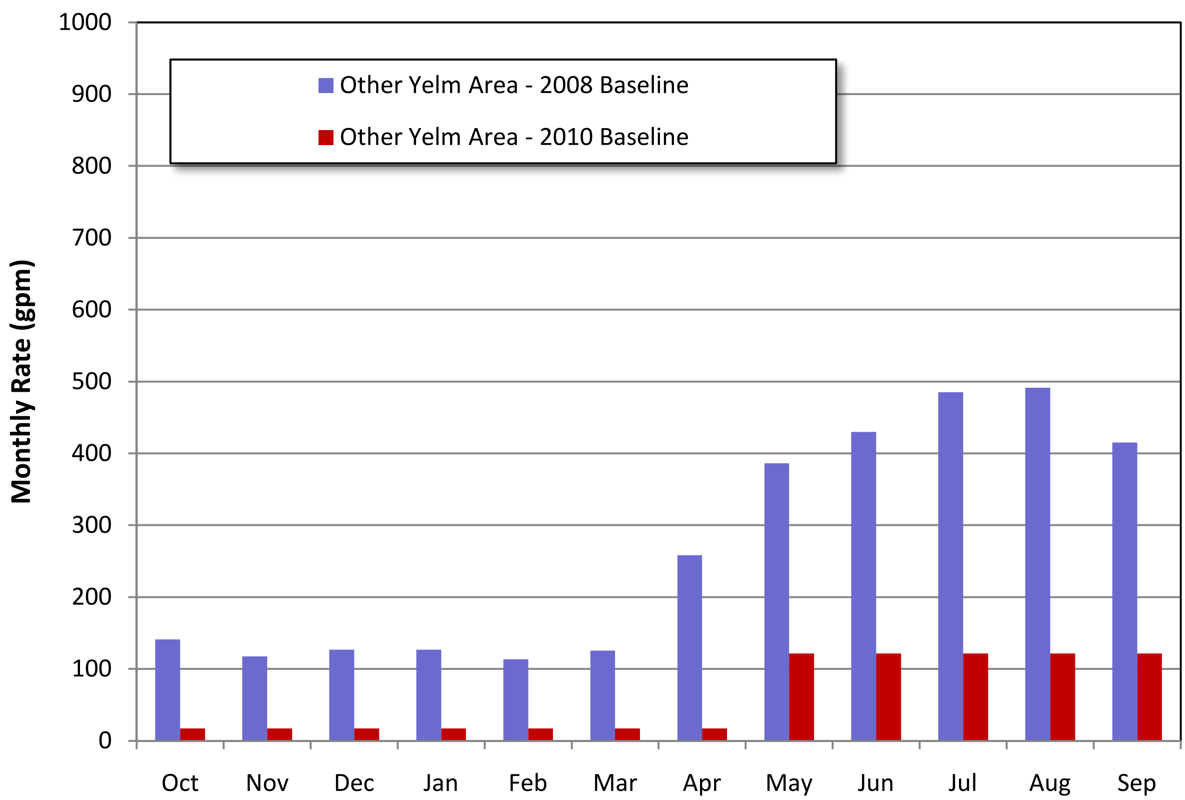
Source:
PSLC, Golder Associates, Inc.

N E S W

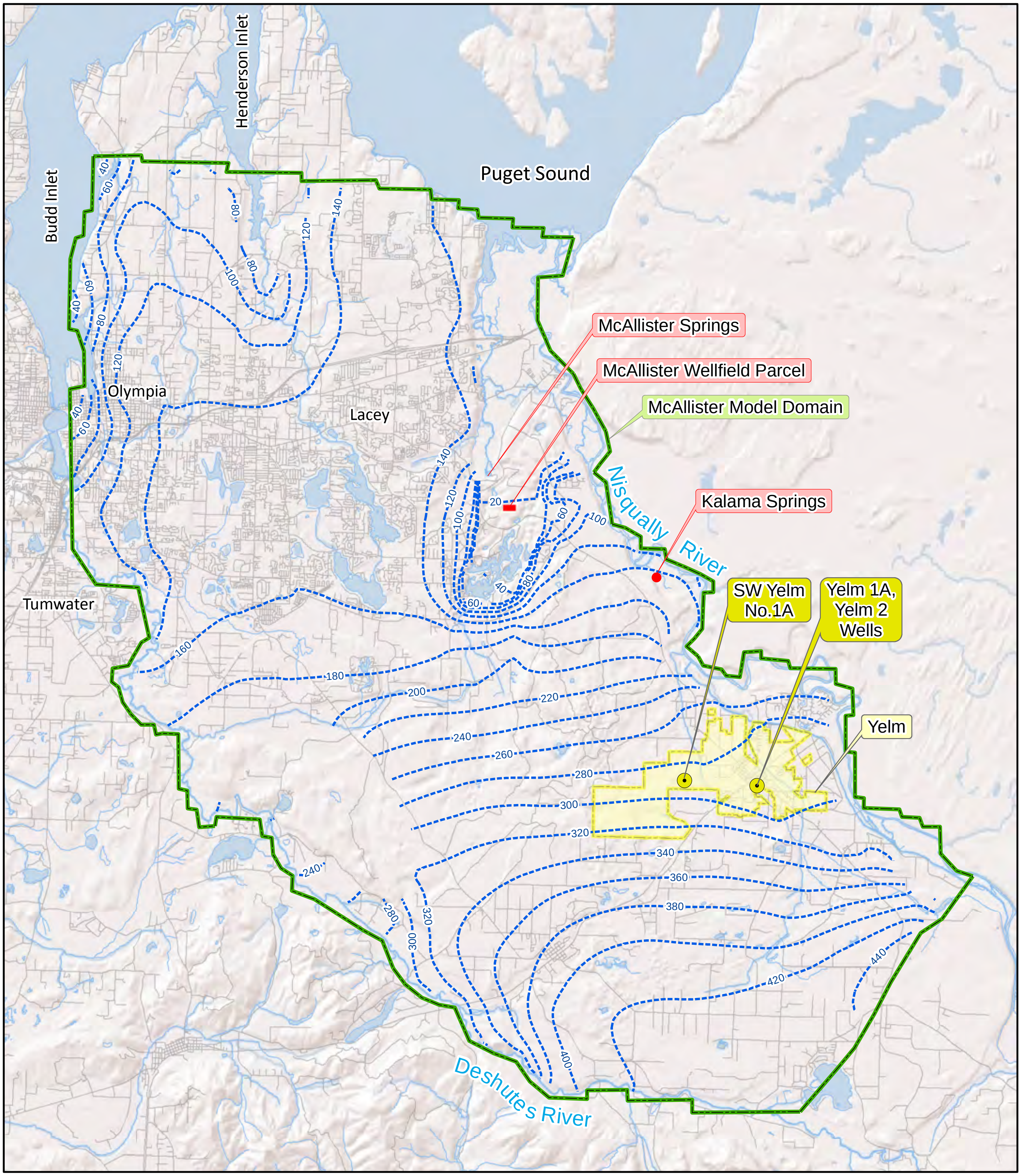
FIGURE **3**

LOCATION OF CONSOLIDATED EXEMPT WELLS IN THE DOWNTOWN YELM AREA





City of Yelm – 2010 Water Rights Mitigation Plan	SIMULATED PUMPING FOR DOWNTOWN YELM WELLS – 2008 AND 2010 BASELINE CASES			
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	Project No: 21-1-12322.003	Date: 11/23/10	Drawn by: SDT Checked by: LMW	**FIG 4**



LEGEND

- Drawdown (ft msl)
- Model Domain
- City of Yelm
- City of Yelm Well
- Road
- Water Course
- Water Body

0 15,000

Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

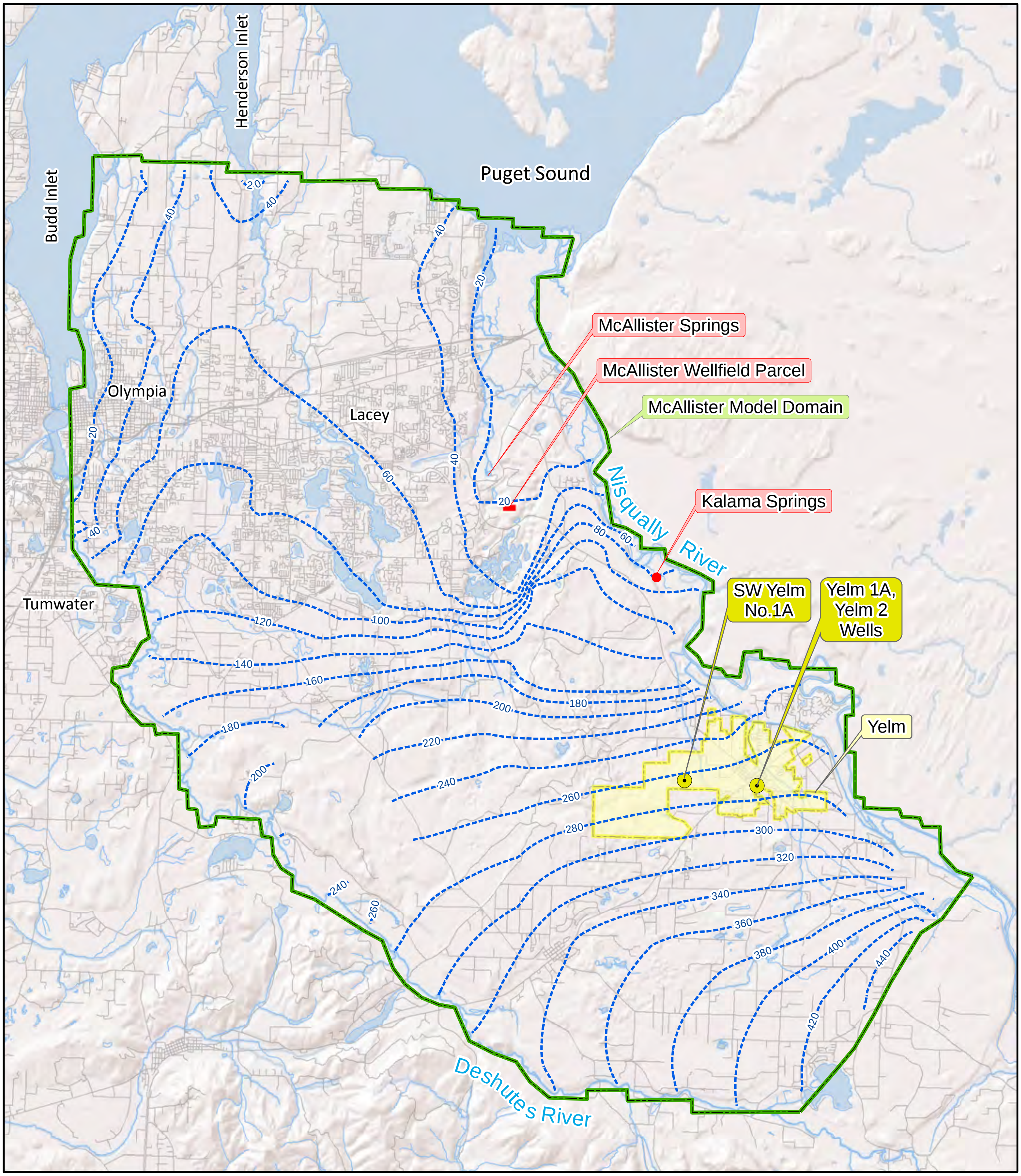
Source:
PSLC, Golder Associates, Inc.

N W E S

FIGURE **5**

Simulated Potentiometric Heads
Qga Aquifer
2010 Baseline Case
September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



LEGEND

- Drawdown (ft msl)
- Model Domain
- City of Yelm
- City of Yelm Well
- Road
- Water Course
- Water Body

0 15,000

Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

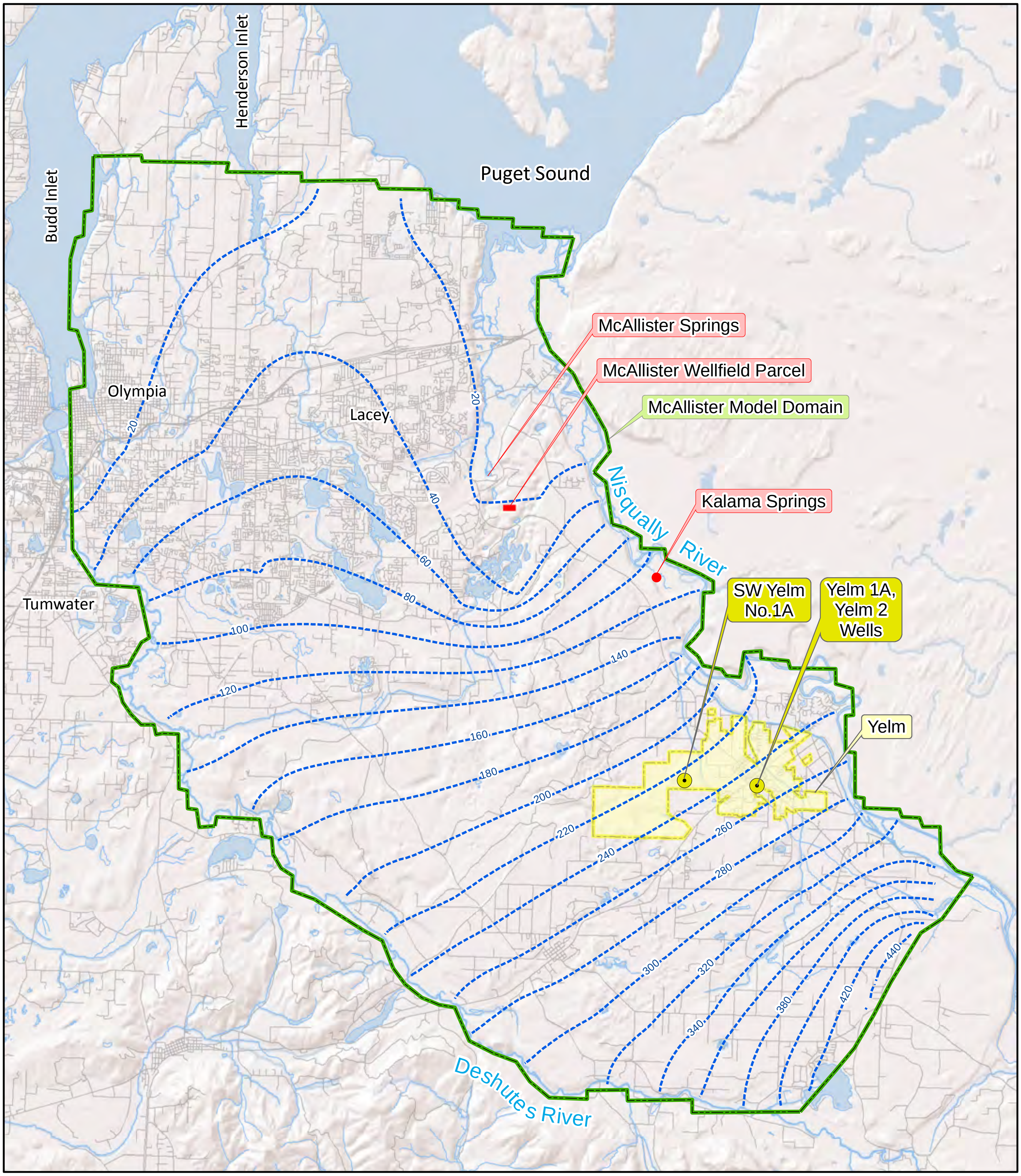
N W E S

Source:
PSLC, Golder Associates, Inc.

FIGURE **6**

Simulated Potentiometric Heads
Qpg Aquifer
2010 Baseline Case
September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



LEGEND

Drawdown (ft msl)

Model Domain

City of Yelm

City of Yelm Well

Road

Water Course

Water Body

0 15,000

Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

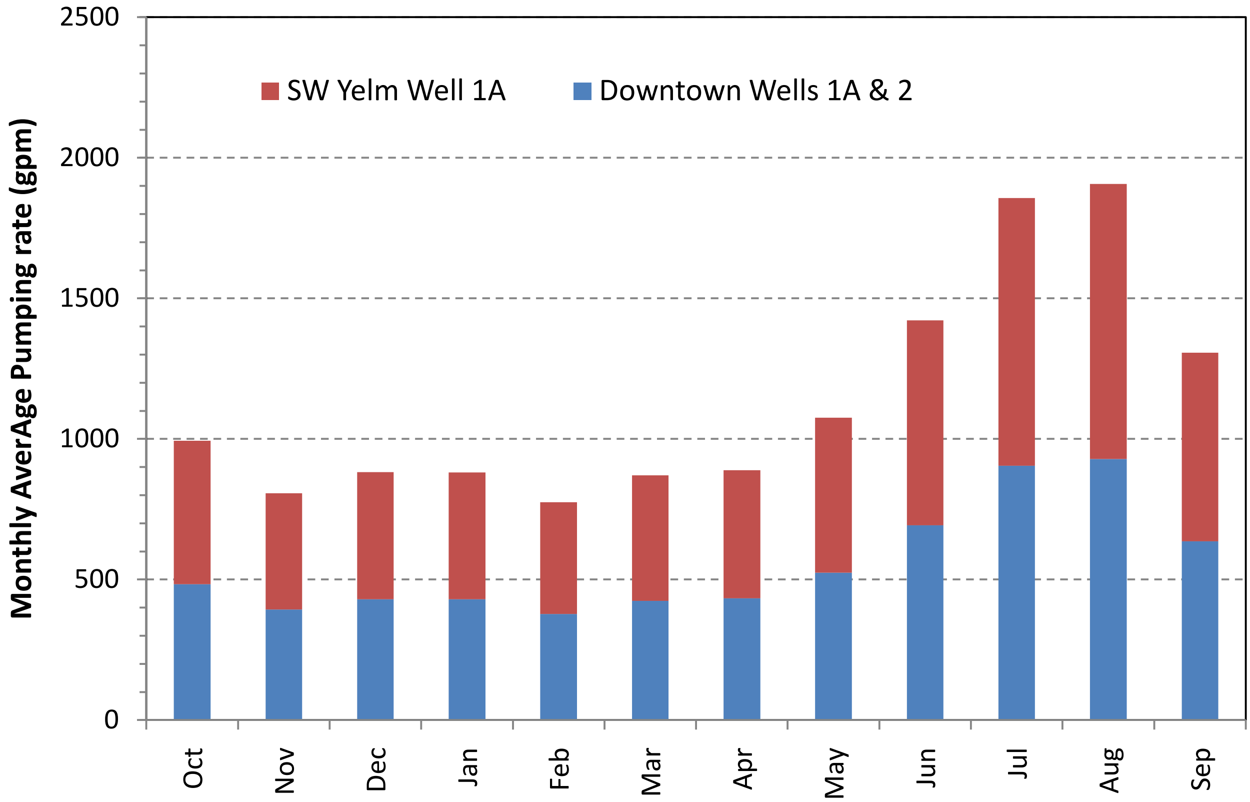
N W E S

Source:
PSLC, Golder Associates, Inc.

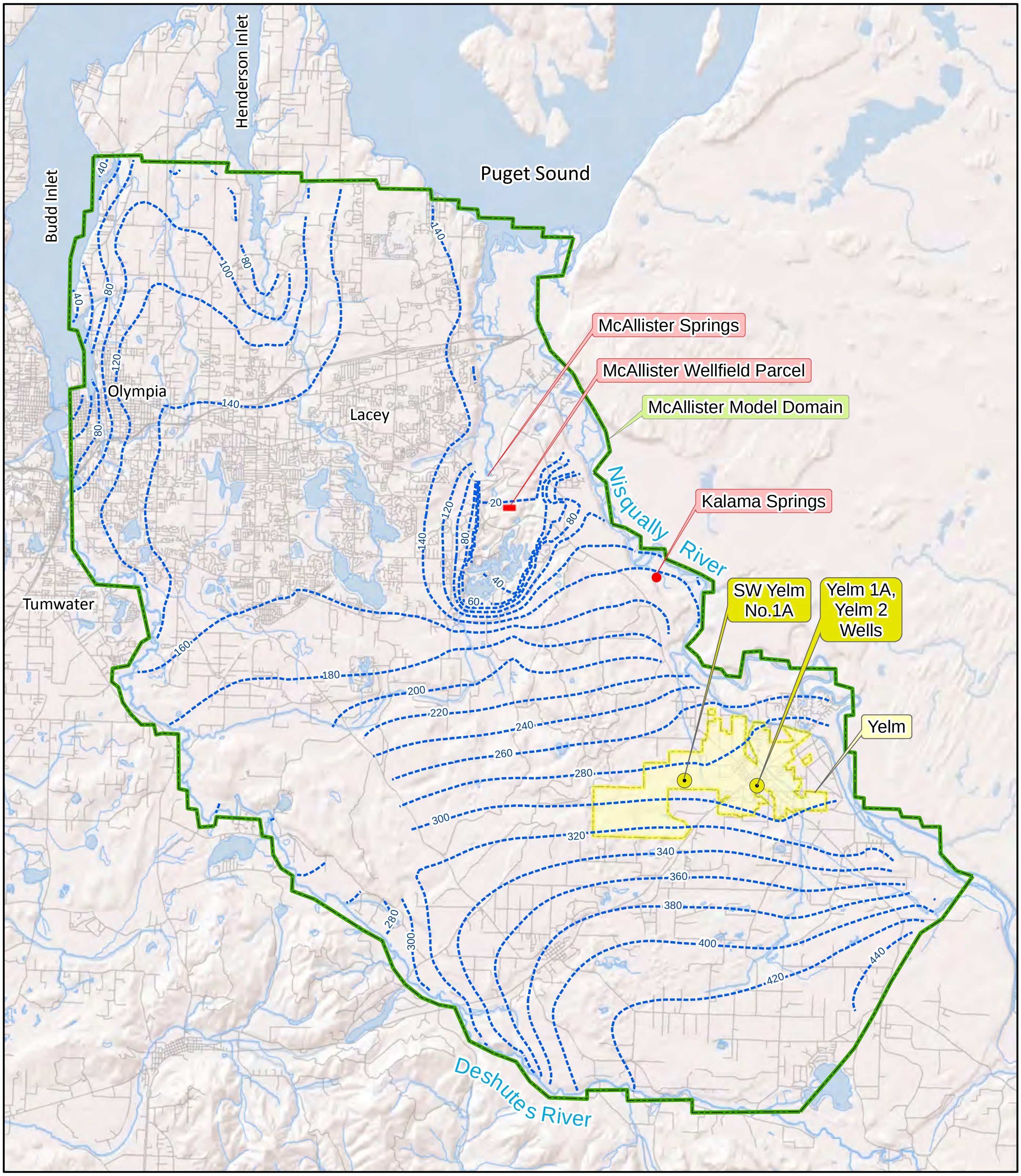
FIGURE **7**

Simulated Potentiometric Heads
TQu Aquifer
2010 Baseline Case
September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



City of Yelm – 2010 Water Rights Mitigation Plan	**SIMULATED PUMPING AT YELM'S WELLS FOR FUTURE PUMPING**			
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	Project No: 21-1-12322.003	Date: 11/23/10	Drawn by: SDT Checked by: LMW	**FIG 8**



LEGEND

Drawdown (ft msl)

Model Domain

City of Yelm

City of Yelm Well

Road

Water Course

Water Body

0 15,000

Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

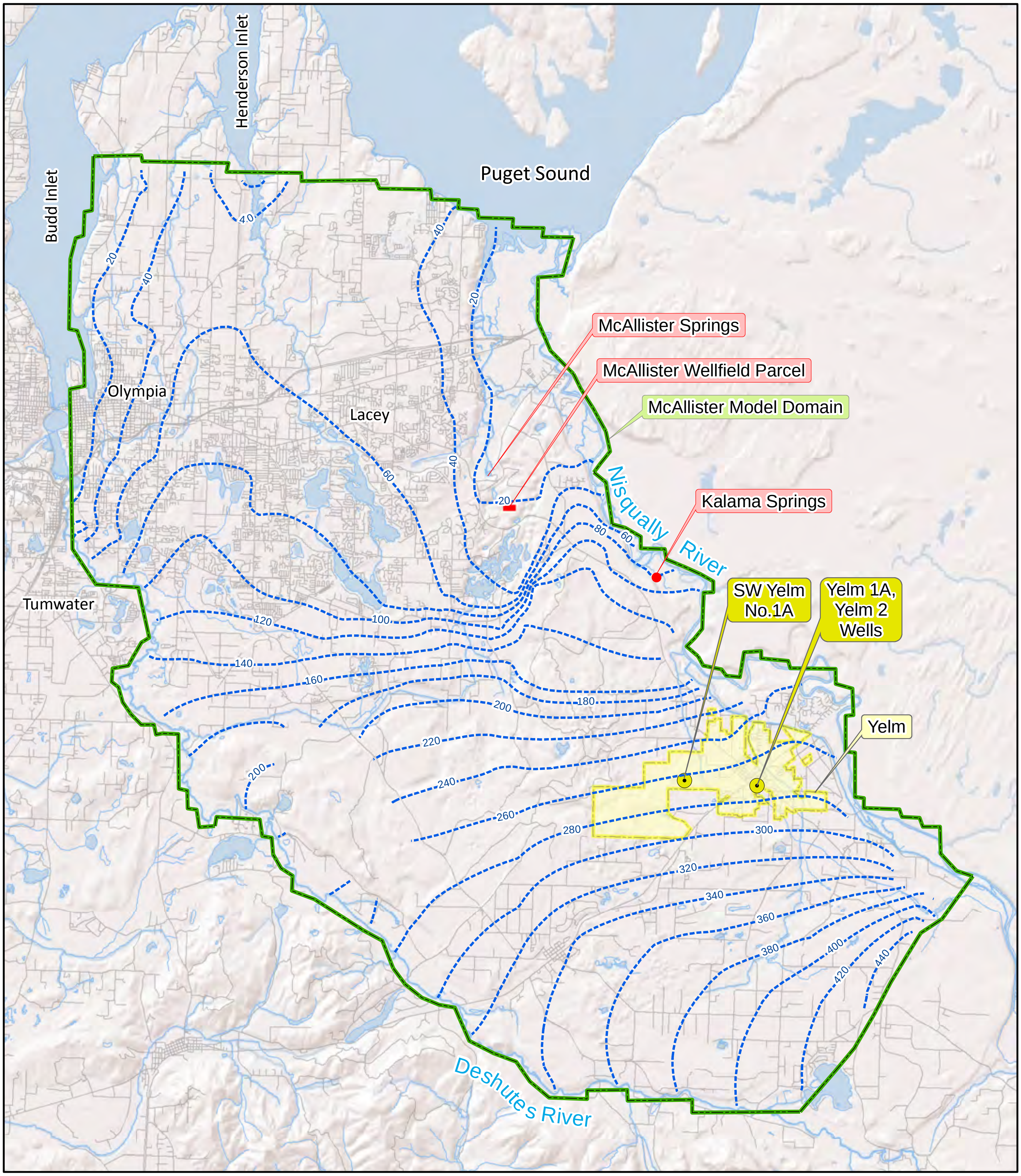
N W E S

Source:
PSLC, Golder Associates, Inc.

FIGURE 9

Simulated Potentiometric Heads
Qga Aquifer
Future Pumping Case
September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



LEGEND

- Drawdown (ft msl)
- Model Domain
- City of Yelm
- City of Yelm Well
- Road
- Water Course
- Water Body

0 15,000
Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

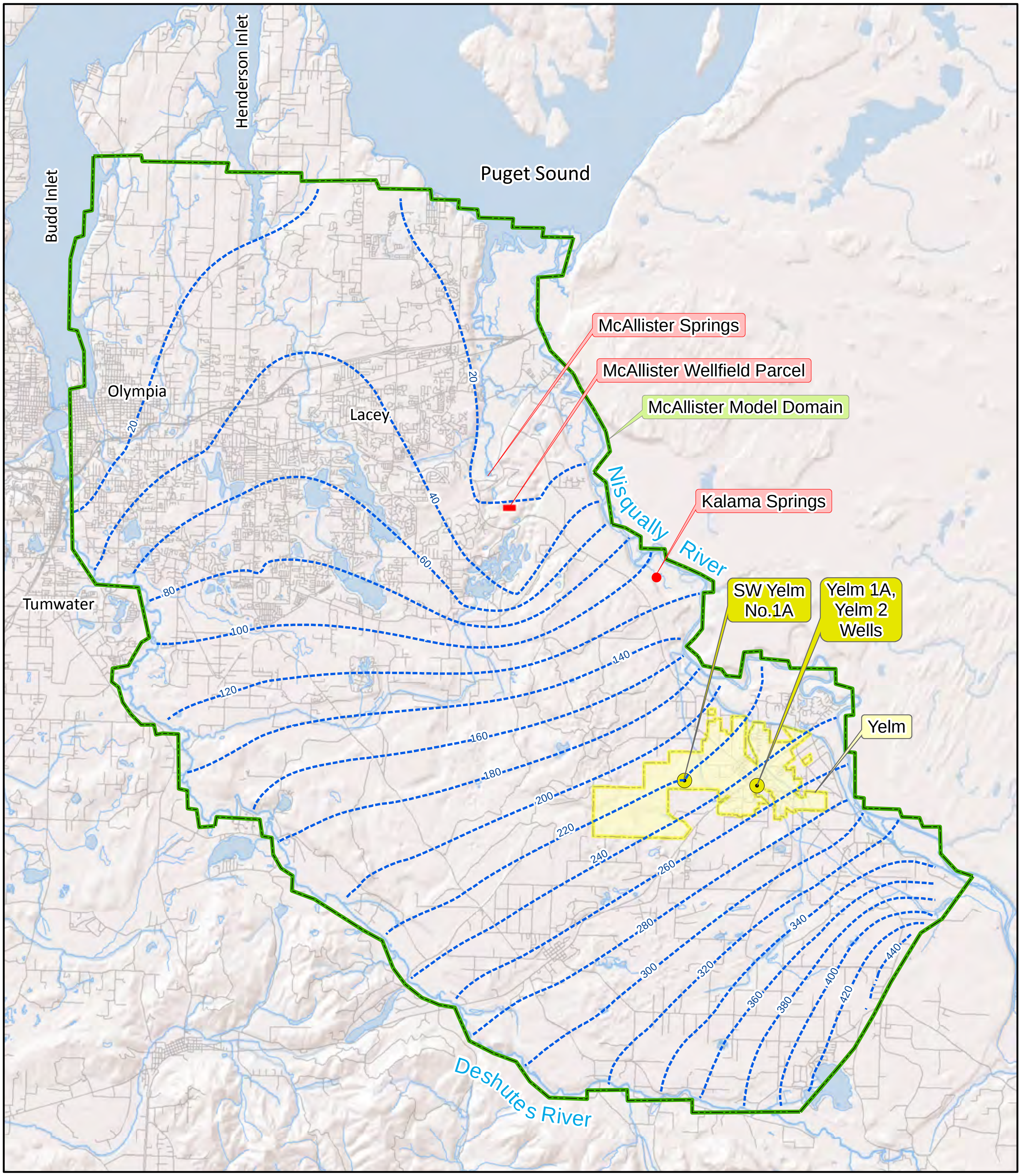
Source:
PSLC, Golder Associates, Inc.

N E S W

FIGURE **10**

Simulated Potentiometric Heads
Qpg Aquifer
Future Pumping Case
September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



LEGEND

- Drawdown (ft msl)
- Model Domain
- City of Yelm
- City of Yelm Well
- Road
- Water Course
- Water Body

0 15,000

Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

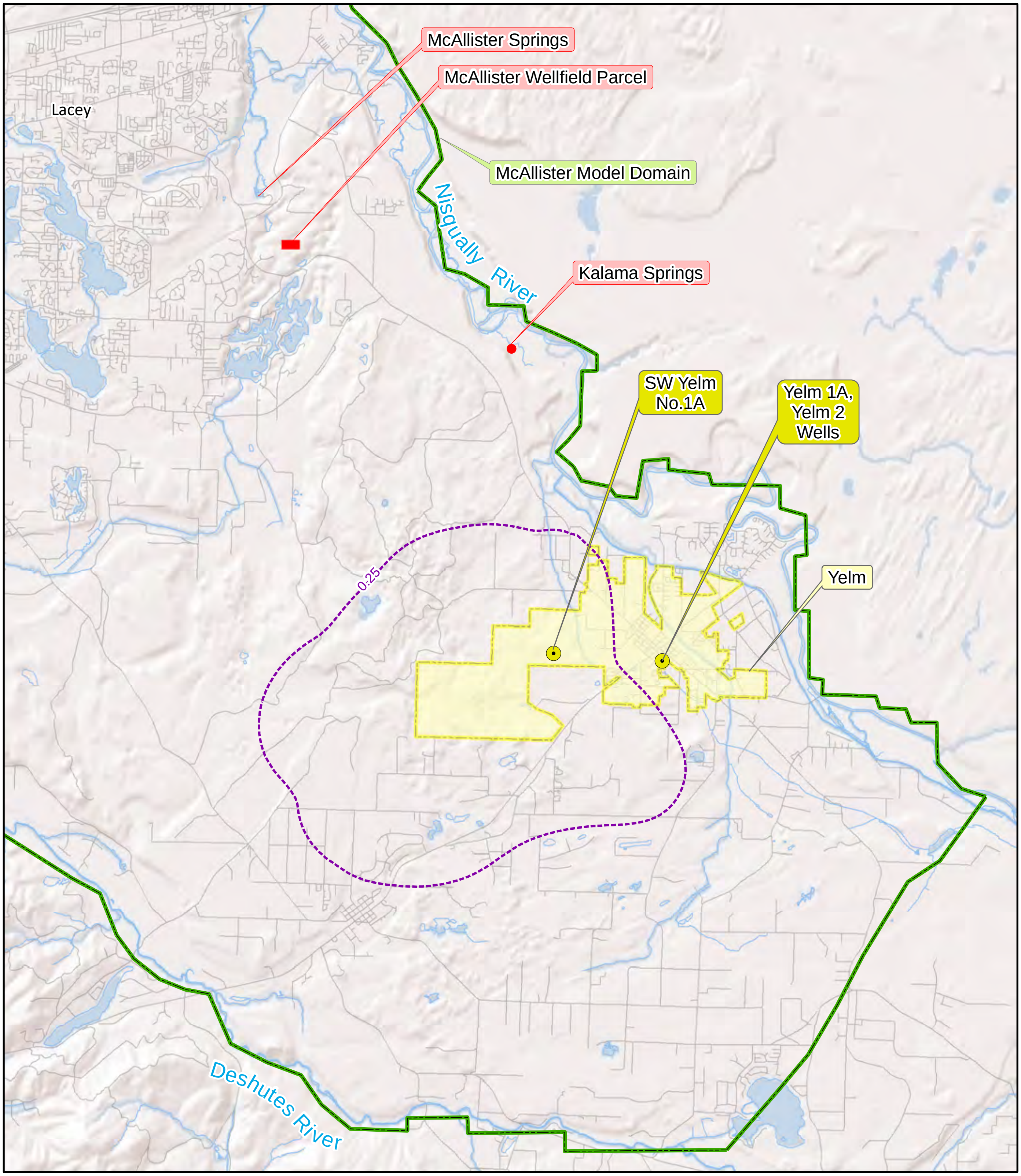
N W E S

Source:
PSLC, Golder Associates, Inc.

FIGURE **11**

Simulated Potentiometric Heads
TQu Aquifer
Future Pumping Case
September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



LEGEND

Drawdown (ft msl)
Model Domain
City of Yelm
City of Yelm Well
Road
Water Course
Water Body

0 10,000
Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

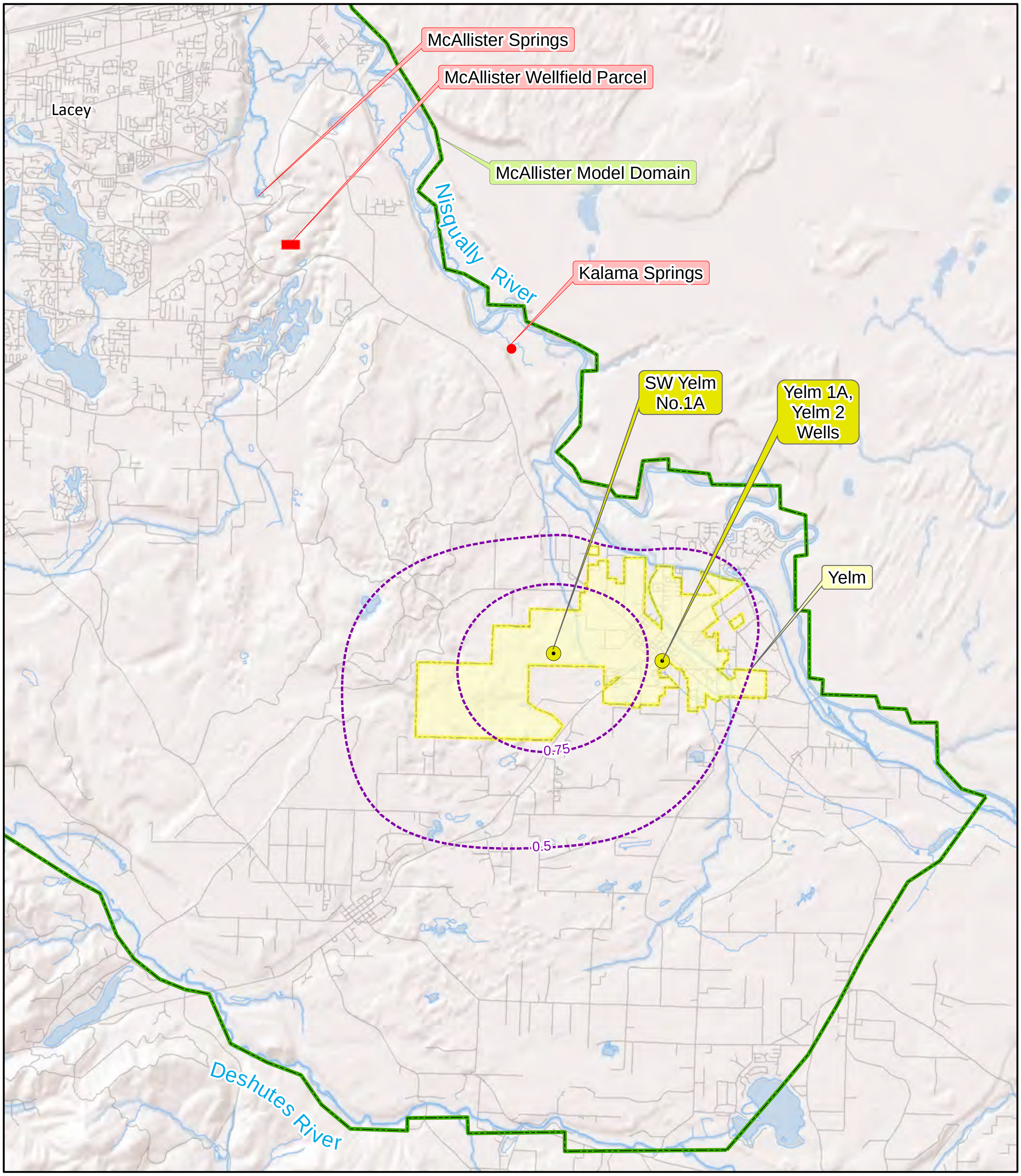
Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

Source:
PSLC, Golder Associates, Inc.

FIGURE **12**

Simulated Drawdown in Potentiometric Heads Qga Aquifer September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



LEGEND

Drawdown (ft msl)
Model Domain
City of Yelm
City of Yelm Well
Road
Water Course
Water Body

0 10,000
Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

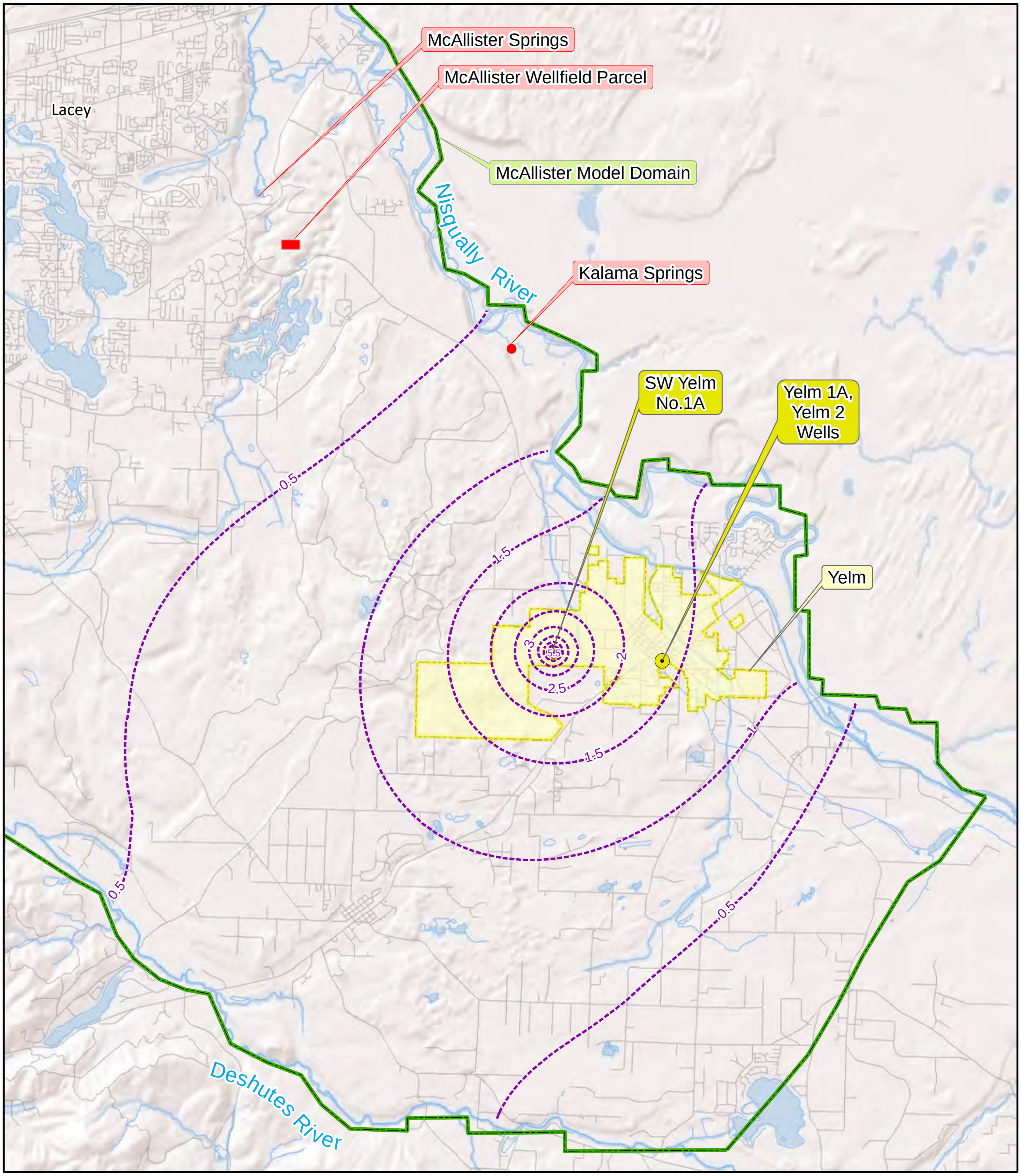
Source:
PSLC, Golder Associates, Inc.

N E S W

FIGURE **13**

Simulated Drawdown in Potentiometric Heads Qpg Aquifer September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



LEGEND

- Drawdown (ft msl)
- Model Domain
- City of Yelm
- City of Yelm Well
- Road
- Water Course
- Water Body

0 10,000
Scale in Feet

Map Projection:
Washington State Plane
South Zone NAD 1983

Figure was originally produced in color. Reproduction in black and white may result in a loss of information.

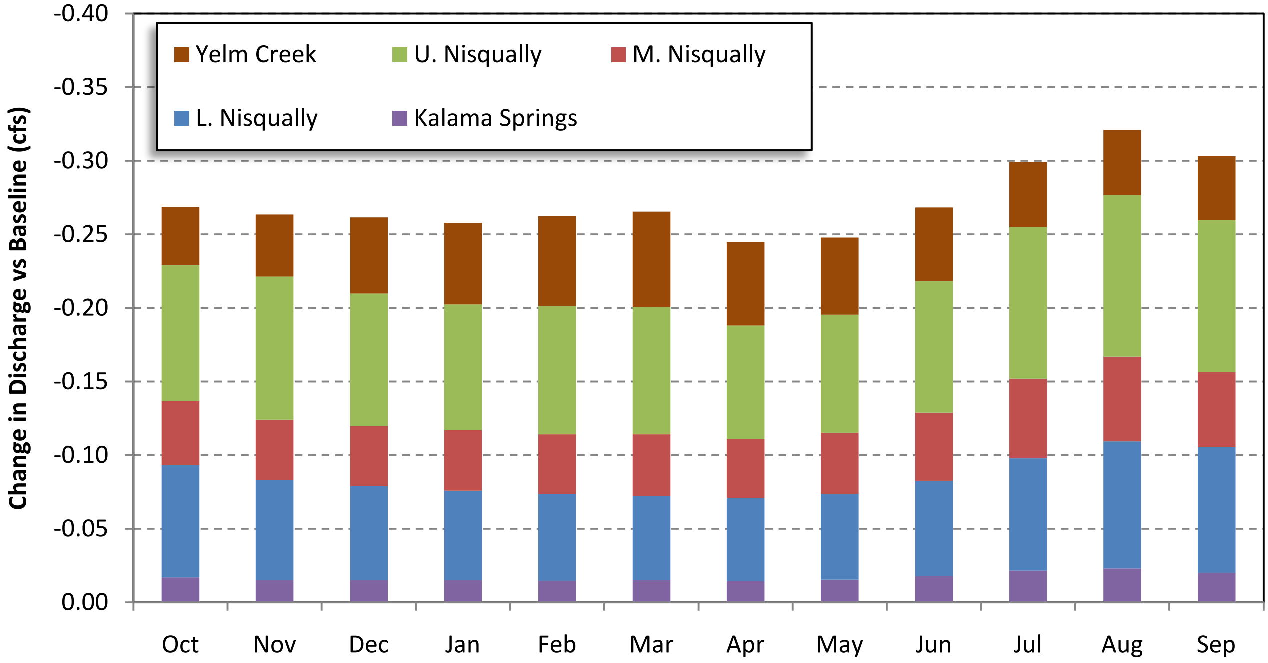
N W E S

Source:
PSLC, Golder Associates, Inc.

FIGURE **14**

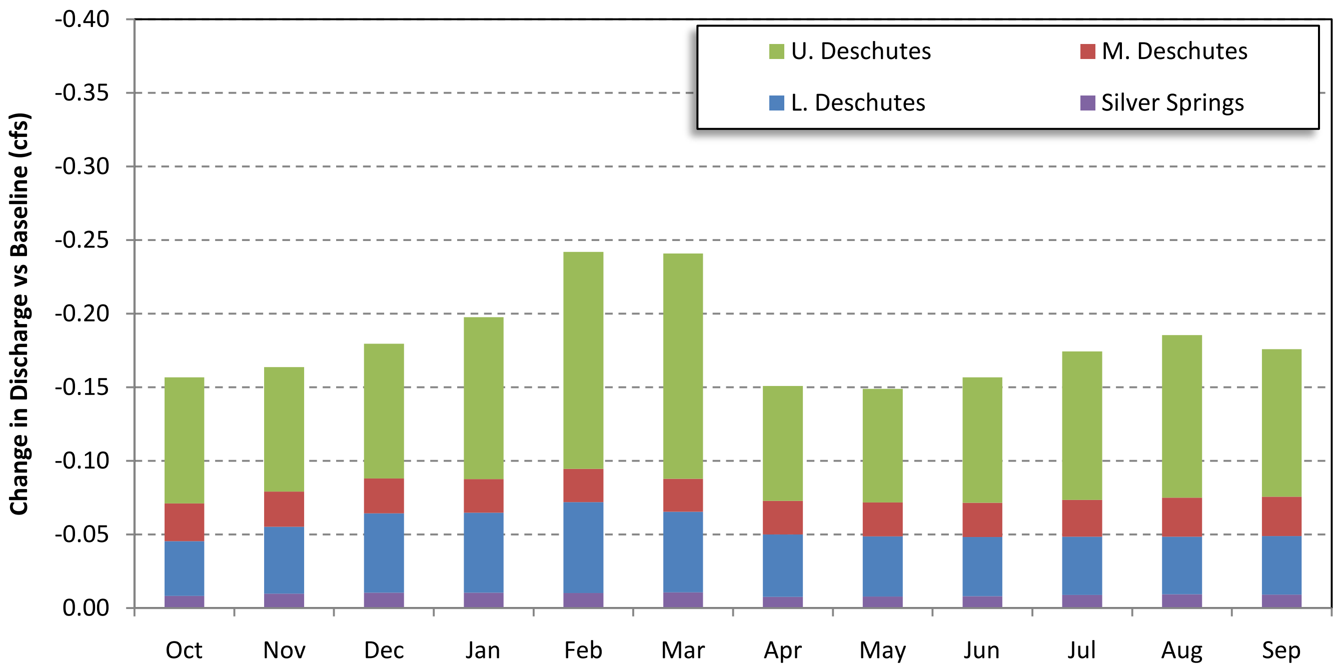
Simulated Drawdown in Potentiometric Heads TQu Aquifer September

Filename: T:\Project\21-1\12322_CityofYelm\AV_mxd\Figures_5-7_9-11.mxd 12/02/2010 beo



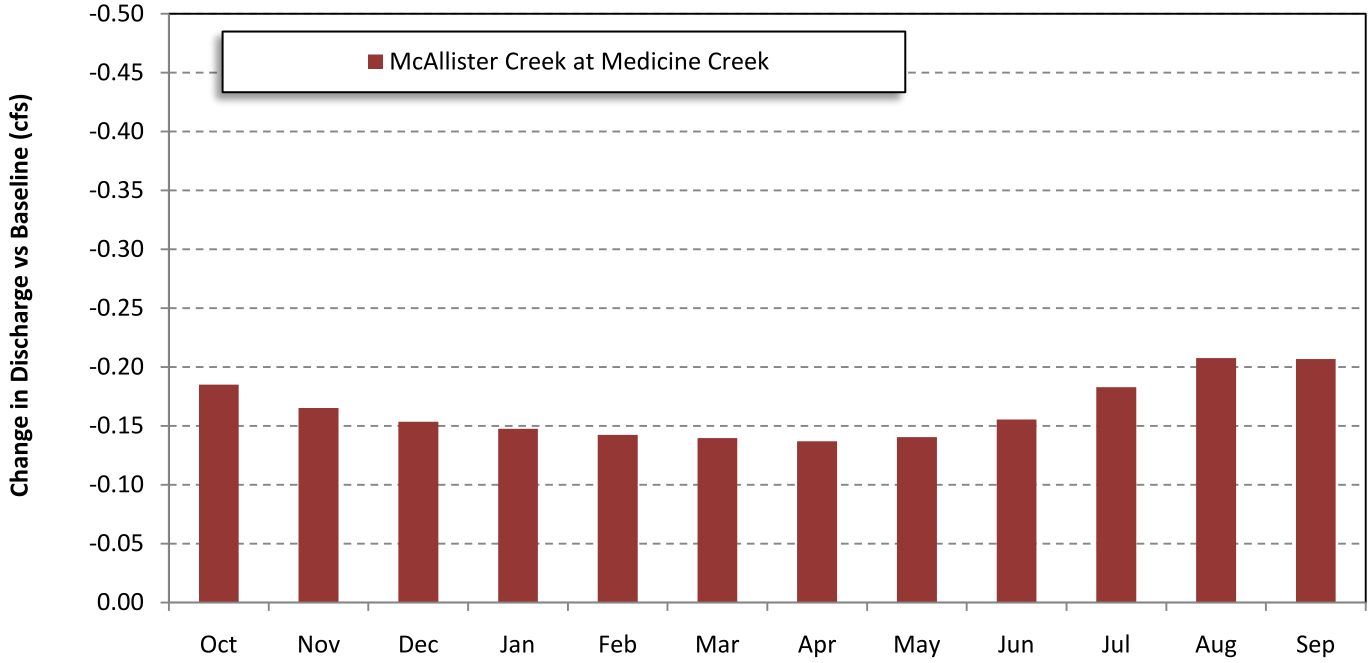
City of Yelm – 2010 Water Rights Mitigation Plan	**PREDICTED MONTHLY CHANGES IN GROUNDWATER DISCHARGE TO THE NISQUALLY RIVER**

SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	Project No: 21-1-12322.003	Date: 11/23/10	Drawn by: SDT Checked by: LMW	**FIG 15**

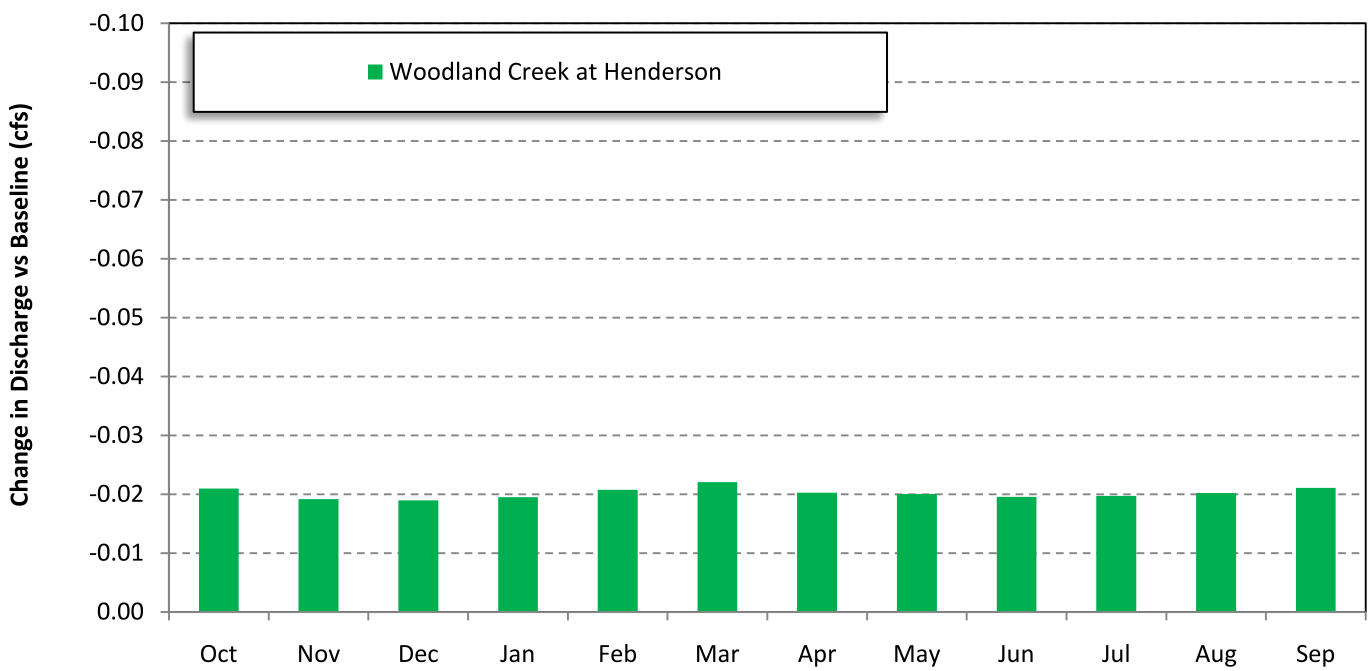


City of Yelm – 2010 Water Rights Mitigation Plan	**PREDICTED MONTHLY CHANGES IN GROUNDWATER DISCHARGE TO THE DESCHUTES RIVER**

SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	Project No: 21-1-12322.003	Date: 11/23/10	Drawn by: SDT Checked by: LMW	**FIG 16**



City of Yelm – 2010 Water Rights Mitigation Plan	**PREDICTED MONTHLY CHANGES IN GROUNDWATER DISCHARGE TO MCALLISTER CREEK AT MEDICINE CREEK**			
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	Project No: 21-1-12322.003	Date: 11/23/10	Drawn by: SDT Checked by: LMW	**FIG 17**



City of Yelm – 2010 Water Rights Mitigation Plan	**PREDICTED CHANGES IN GROUNDWATER DISCHARGE – WOODLAND CREEK AT HENDERSON INLET**			
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	Project No: 21-1-12322.003	Date: 11/23/10	Drawn by: SDT Checked by: LMW	**FIG 18**