Appendix C – Hydraulic Modeling Technical Memo, King County 2014

King County

Memo

Date:	January 24, 2013
To:	Craig Garric, EIII, PM
Cc:	Willowmoor Team
From:	
Project No./Name:	1112037/WLFL5 WILLOWMOOR FLDPLAIN REST
Subject:	Willowmoor Hydraulics Memo

Introduction:

This technical memo covers the calibration of the hydraulic model used in the evaluation of the Willowmoor Project existing conditions and alternatives. Hydraulic modeling for the Willowmoor project utilized an existing HEC-RAS model for the Sammamish River as its starting point. In 2009 King County contracted with Northwest Hydraulics (NHC) to conduct a flood study for the Sammamish River (from Lake Sammamish to Lake Washington), and part of that effort was creating a calibrated HEC-RAS model for the river (NHC 2010). While only the river was calibrated, the model did include Lake Sammamish that was modeled as a storage area to function as the upstream boundary condition. This was done to address timing issues with respect to flood peaks, i.e. peak lake discharge is not coincident with peak tributary discharges on Bear/Evans, Little Bear, North and Swamp Creeks.

Additional data were available since completion of the flood study. These data include more recent survey data of the transition zone with additional cross-section locations added, and four pressure transducers deployed through the transition zone section of the Sammamish River down to the Bear/Evans Creek confluence with the main stem Sammamish River [see Figure 1]. The data from the pressure transducers were converted into time varying water depths with data collection starting in 2011. Survey of the transducer locations allowed the depths to be converted into elevations creating water surface profiles through the transition zone. These water surface profiles were used to calibrate the model to existing conditions.

Hydraulic Model Calibration:

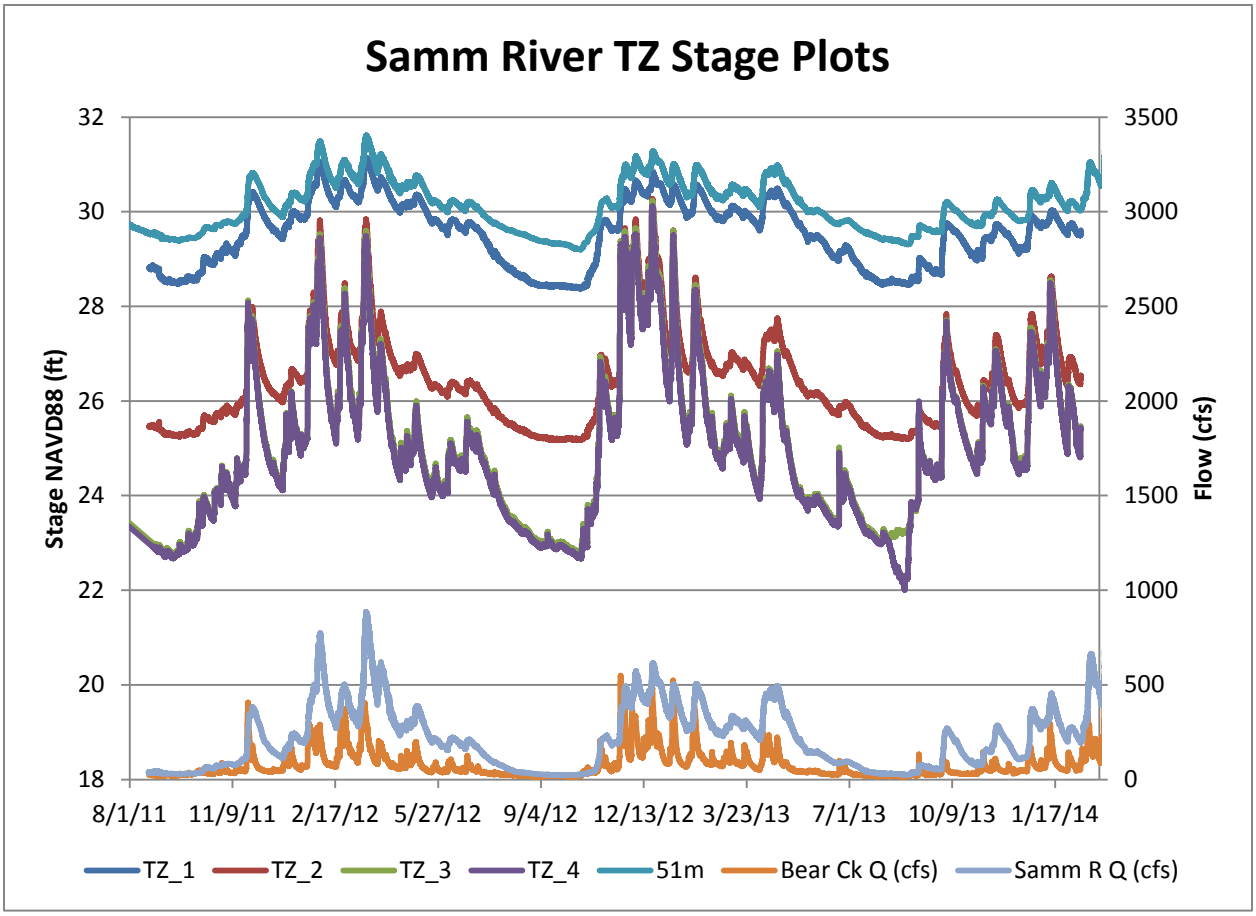
The most recent maintenance action prior to model development in the transition zone of the Sammamish River was conducted in the summer of 2013. The calibration period was set to be August 2013 through March 2014 to capture post maintenance conditions. This calibrated model also resulted in the “Existing Conditions” scenario used to evaluate alternatives against. The model was calibrated in an unsteady flow simulation, that is, flows into the lake and from Bear Creek varied through time. Simulated water levels at the lake, weir, and at the locations of the four pressure transducers were compared to the measured water levels, and model parameters were changed in order to better match the simulated values with the measured ones. The parameter with the most influence on simulated water surfaces is Manning’s n, a roughness coefficient representing the ease of which water can move over the riverbed. Rougher surfaces result in slower and deeper water than smoother surfaces. A further adjustment to Manning’s n was

the inclusion of seasonality – the time of the year with fully grown vegetation is specified to have a higher roughness than the time of year when most vegetation is dead or senescent.

Figure 1: Hydraulic Model Cross-Sections and Locations of Gages.

The data used in model calibration are shown in Figure 2. The top five lines track observed stage (NAVD88; left axis) over time from the Weir (gage 51m) through the four transition zone data loggers. The bottom two lines track flow (cfs, right axis) for the Sammamish River (also at 51m) and Bear Creek. Figure 2 shows the hydraulic behavior necessary to capture in the calibrated model. In periods of low flow, the stages at the locations of the pressure transducers (TZ_1 through TZ_4) are separated in elevation – with the exception of TZ_3 and TZ_4 both at the mouth of Bear Creek (note the spurious data from TZ_4 in Sept. 2013) – with substantial drop between locations. This reflects the change in bottom elevation of the channel through the transition zone. At higher flows the differences in stages among the locations of the transducers drops markedly. This is especially apparent when Bear Creek flows are large when the stages at TZ_2, TZ_3, and TZ_4 plot on top of each other. Towards the end of December 2012, after a period of high flows in Bear Creek and from the lake, the total drop in water surface from the weir to Bear Creek is approximately six inches. This reflects the backwater condition created by high Bear Creek flows. The unsteady model was set up to capture this range of stages.

Figure 2. Sammamish River Transition Zone Stage Plots.



Model output locations were set up at the same locations of observed stage. Manning's n values were adjusted to capture the physical condition of the transition zone after the summer maintenance actions in 2013.

Calibration runs covered time prior to the date of the most recent maintenance; although, the calibration was limited to the post maintenance condition. This was done for two reasons: to facilitate creation of the "Existing Conditions" scenario, and to inform creation of project alternatives. Once calibrated, differences between observed and modeled stages prior to the most recent maintenance action are largely due to the actual physical conditions of the transition zone not being accurately simulated in the model. This can be seen by comparing the calibrated stages (late summer 2013 on) to earlier stages for pressure transducer locations TZ_1, and TZ_2 in Figures 3 and 4. At the TZ_2 location midway down the transition zone, modeled stages are higher indicating more flow through maintained transition zone than actually occurred in the record. This is reflected in the peak lake level stages that occurred in the winter of 2012 [Figure 5].

Figure 3. Modeled and Observed Stage at TZ_1.

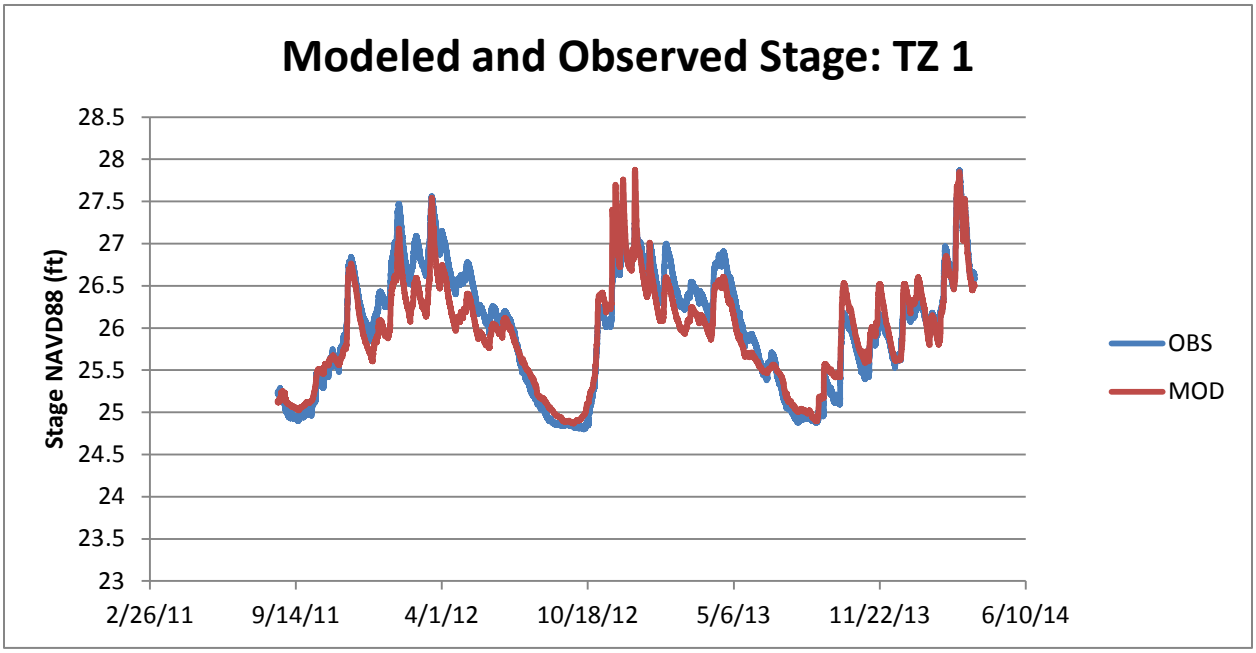
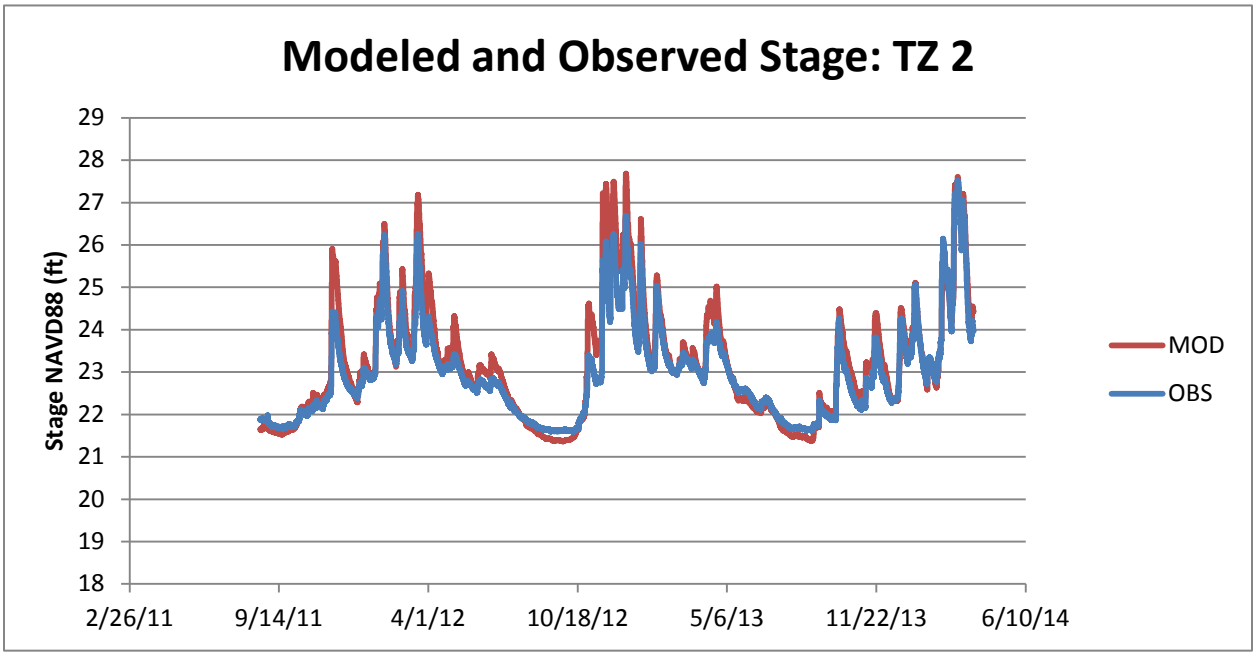


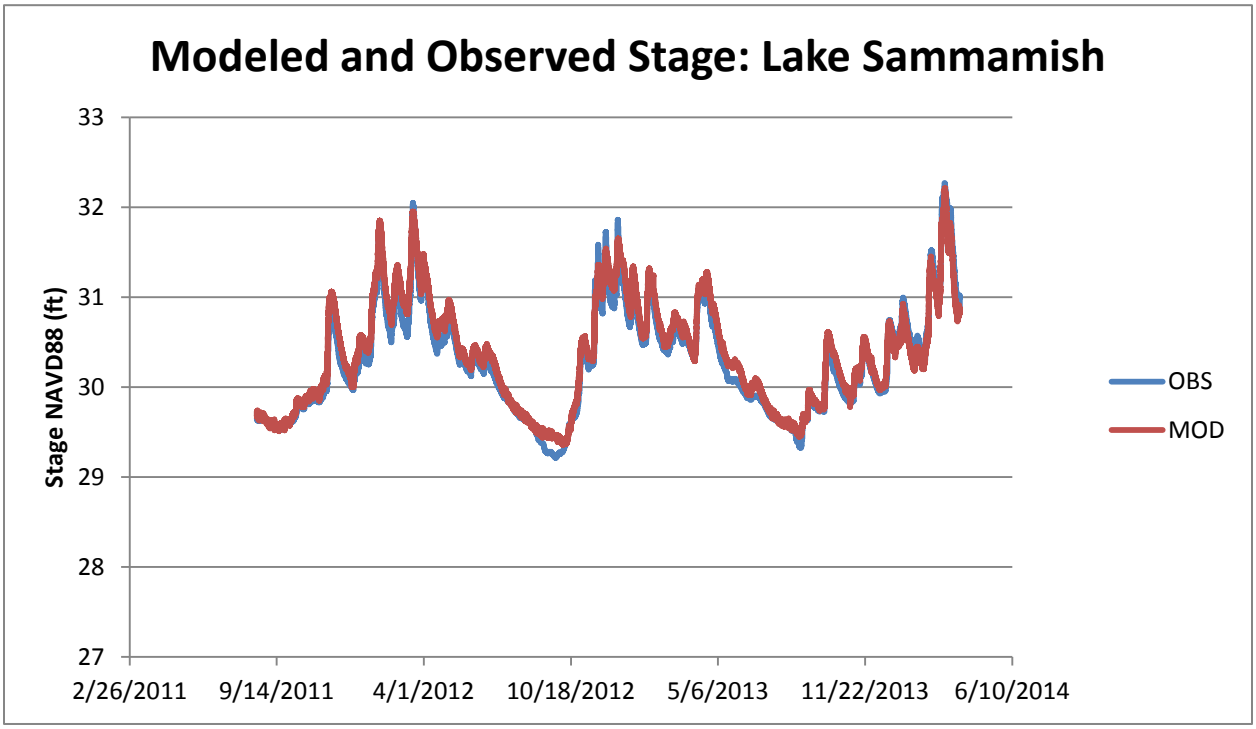
Figure 4. Modeled and Observed Stage at TZ_2.



Modeled stages were well within +/-12 inches of observed – considered the threshold for a good calibration [US Army Corps of Engineers, 2010] and were often within +/-6 inches of observed. These thresholds come from the inherent uncertainty in flow measurements and the stage-discharge relationship for a gage location. Once calibration is complete, the assessment of alternative performance is done relative to the calibrated model, which in this case

also serves as the no action (Maintenance) condition of the transition zone. At that point any difference in the hydraulic performance of the alternatives is due to the changes in model configuration for those alternatives.

Figure 5. Modeled and Observed Stage, Lake Sammamish.



Hydraulic Simulation of Alternatives:

Each alternative was designed to meet objectives under several goals, but only hydraulic objectives are discussed here. Alternatives were assessed using the calibrated model in two phases: the initial round of conceptual alternatives and a subsequent round of integrated alternatives incorporating feedback from the SAC. Each alternative was created by modifying the existing conditions model. This entailed changing the channel geometry, adding complexity in the form of lateral structures and split flow channels where appropriate. Lateral structures were used to simulate both hydraulic structures (the weir inlet to the proposed side channel in Concept 4) and to simulate areas where portions of the main flow would spread over the river bank into a separate channel (Concepts 3 and 2). Split flow channels were used in the side channel concept (4) and in Concepts 2 and 3 to capture overbank flows and backwater conditions. Manning's n values were also changed to reflect post construction conditions and roughness of the maintained channel in all alternatives.

Performance of Alternatives:

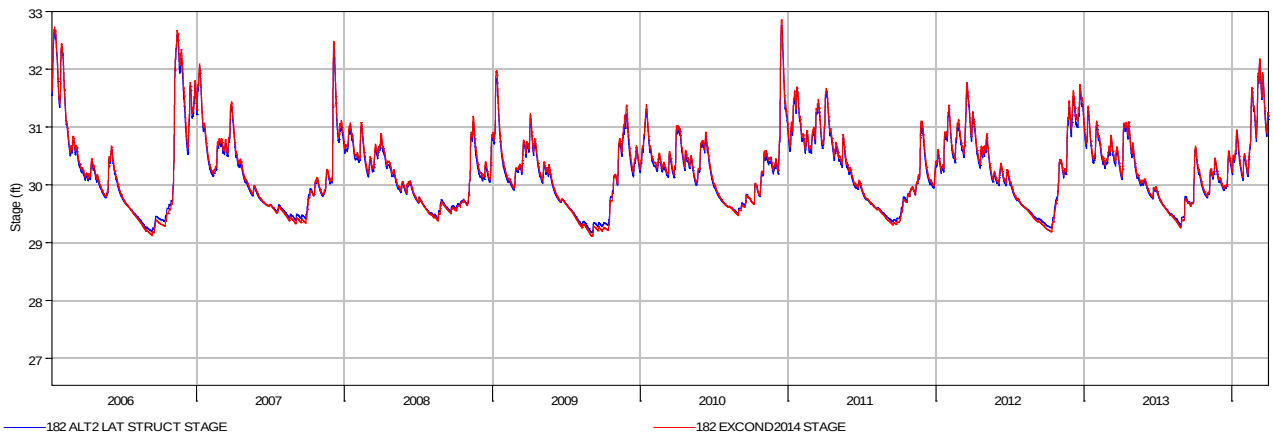
Alternatives were analyzed relative to the performance criteria established under Goal #1 in the Goals and Objectives Table over the time period of available measured data at both Bear Creek and the Weir (2001-2014). It is important to note that the Existing Conditions run (Alternative 1. Maintenance) is not the same as historic conditions but rather

simulates how a fully maintained transition zone would have performed. For specific metrics, see the table of goals, objectives, and metrics in the main report. What follows here is a summary of each alternative's hydraulic performance.

Alternative 1, Maintenance: This alternative meets all the downstream hydraulic criteria, but does not reduce lake levels upstream of the project, nor does it reduce the frequency and duration of high winter and spring lake levels relative to current conditions (i.e. itself). This alternative, like all others, does demonstrate improvement over historic conditions [see Figures 3-5].

Concept Alternative 2, Single Meander: The model was changed to reflect the longer winding path of the main stem channel through the meander. Cross sections through the meander were developed such that lower flows are completely contained in the main channel. Higher flows were simulated as overbank flows through the use of a lateral structure on the right bank. Overbank flows are collected in a separate channel, which joins the main channel at the end of the meander. At low flows the separate channel functions as a backwater pool. This alternative meets all upstream and downstream hydraulic criteria. While meeting the criteria, the magnitudes of improvement were modest. See Figure 6 for a comparison of Lake Levels between Alternative 2 and Existing Conditions.

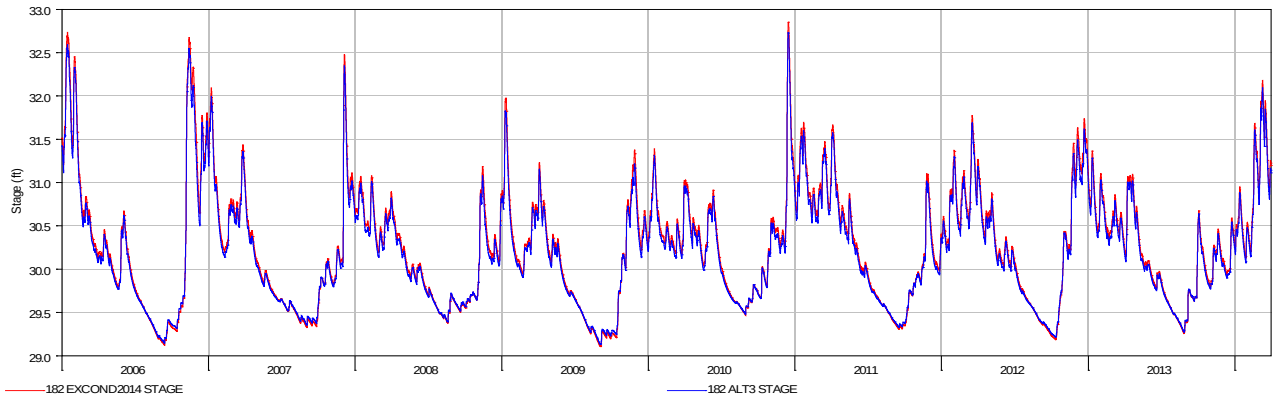
Figure 6. Existing Conditions (red) vs. Alternative 2 (blue).



Concept Alternative 3, Hyporheic Channels: The model was changed to reflect the longer winding path of the main stem channel through the meander as in Concept Alternative 2. The wetland complex was simulated as a storage area allowing water levels to fluctuate more like a pond, which was the expectation for the multiple low gradient back channels. The connection from the main channel to the wetland complex was simulated using a lateral structure to functionally simulate the porous gravel weir. Overbank flows on the left bank are collected in the storage area. In order to simulate the porous nature of the gravel weir, eight small pipes were included in the weir at elevations well below the weir invert. These allowed a constant background flow to pass through the weir year round. The HEC-RAS modeling software doesn't not allow for explicitly "leaky" structures, which is why this approach was taken.

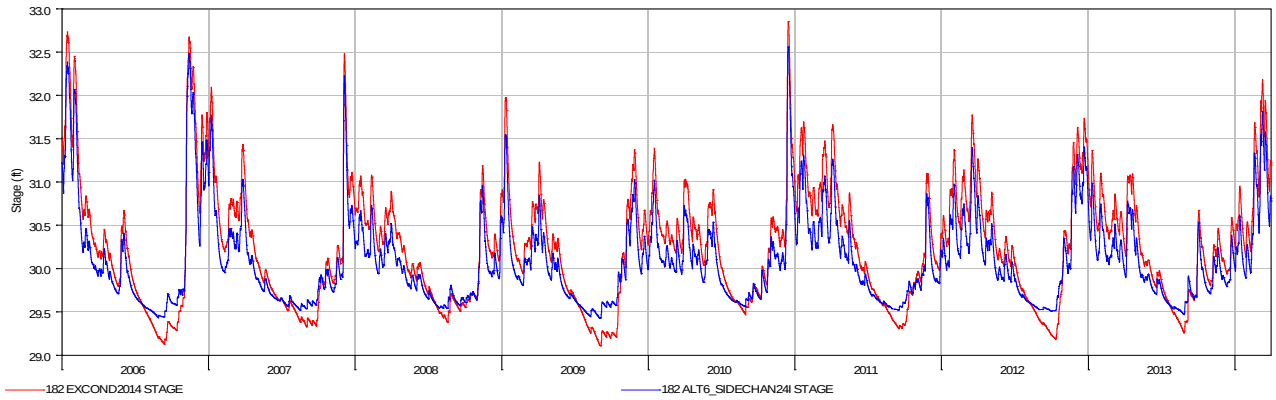
This alternative meets all upstream and downstream hydraulic criteria. This alternative showed greater improvements upstream due to the increased capacity to pass higher flows through the transition zone. Lower lake levels were very similar to Existing Conditions. See Figure 7 for a comparison of Lake Levels between Concept Alternative 3 and Existing Conditions.

Figure 7. Existing Conditions (red) vs. Alternative 3 (blue).



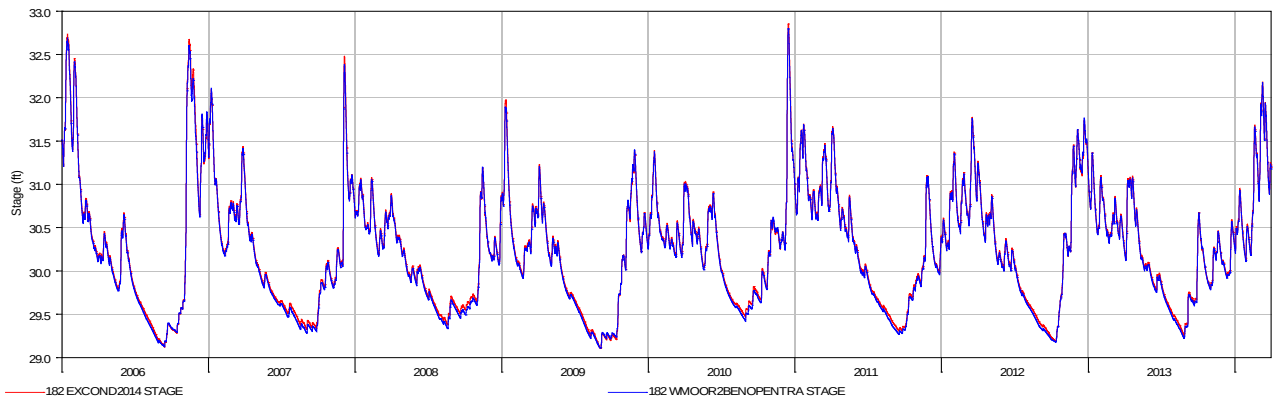
Concept Alternative 4, Split Channel: The model was changed by adding a small channel on the west side of the main channel. This split flow channel begins upstream of the weir and enters the main stem channel at the bottom of the transition zone. Immediately downstream of the entrance to the side channel is a weir with crest and invert elevations set to maintain a year round flow. This alternative meets all upstream and downstream hydraulic criteria save for minimum summer flows; although, further refinements to the side channel weir are likely to result in meeting this criterion should it become the preferred alternative. This alternative showed the greatest improvements upstream due to the side channel maintaining a flow year round lowering the initial lake level during flood events. See Figure 8 for a comparison of Lake Levels between Concept Alternative 4 and Existing Conditions.

Figure 8. Existing Conditions (red) vs. Alternative 4 (blue).



Concept Alternative 5, Enhanced Existing Channel: The model was changed through the transition zone only. A prismatic channel was specified with outer side slopes set to act as benches with shallow inundation at times of the year important for fish habitat. Roughness due to the presence of willows was removed. This alternative meets all upstream hydraulic criteria except for reducing average base winter lake level, which remains the same. This alternative meets all downstream hydraulic criteria. While meeting the criteria except the one, the magnitudes of improvements were modest. See Figure 9 for a comparison of Lake Levels between Concept Alternative 5 and Existing Conditions.

Figure 9. Existing Conditions (red) vs. Alternative 5 (blue).



Summary and Discussion of Alternatives:

While only the differences in lake level are shown in Figures 6-9, figures would be similar for flows, depths over and through the weir, depths in riffles and pools, etc. Other metrics, such as maintaining downstream Sammamish River flood levels at or below the current 100-year flood level, are pass/fail criteria already summarized in the main body of this report. Quantitative results were tabulated for the second round of alternatives presented to the SAC; that is, Alternatives 4 and 5 along with Existing Conditions. What follows here are quantitative results for the following objectives: 1) reduce average number of days per year of lake level exceedances (for EL 27, 28, and 29 NGVD29); 2) reduce average base winter lake level; and, 3) minimum summer lake levels. As in the discussion above, the period of record used to calculate performance criteria is the period of observed data for both Bear Creek and the Sammamish River (2001-2013). Table 1 summarizes the average number of days of lake level exceedance for Existing Conditions.

Table 1. Average Number of Days per Year of Lake Level Exceedance.

	Average Annual Days of Exceedance		
Lake Level (NGVD29)	Existing Conditions	Alternative 4	Alternative 5
29	1	0	1
28	12	6	11
27	97	47	94

Alternative 4 shows the greatest improvement across all lake levels while Alternative 5 shows improvement only for lake levels of 28 and 29 feet NGVD29. This is intuitive, as Alternative 5 represents the least amount of change to the transition zone over existing conditions. It should be noted that the Existing Conditions is an improvement over historic conditions (observed data) from 2001-2013.

Average winter lake levels for Existing Conditions, Alternative 4, and Alternative 5 are 30.7, 30.4, and 30.7 feet (NGVD29) respectively. Alternative 4 shows improvement while Alternative 5 does not. Again, it bears mentioning that Existing Conditions is an improvement over historic conditions for this objective.

With respect to maintaining minimum summer lake levels of 25.4 feet (NGVD29), the results for Existing Conditions, Alternative 4, and Alternative 5 are 25.4, 25.8, and 25.4 feet (NGVD) respectively. The magnitude of changes follows the pattern seen in other objectives for the alternatives considered.

Hydraulically, the two objectives carried forward through the SAC process meet - or in the case of minimum summer discharges for Alternative 4 are expected to meet with further refinements - the hydraulic criteria established for the Willowmoor Project. The magnitude of improvements for each Alternative reflects amount of proposed changes to the transition zone. The more extensive changes associated with have larger effects on performance criteria than the more limited changes to the transition zone proposed in Alternative 5.

References:

Northwest Hydraulic Consultants, (2010) Floodplain Mapping Study for the Sammamish River. Prepared for King County.

US Army Corps of Engineers (2010) HEC-RAS River Analysis System User's Manual, Davis CA.