Aspect CONSULTING

MEMORANDUM

Project No.: 090180-004-03

August 31, 2012

To: Mark Schuppe – Operations Manager, Office of Columbia River
Washington State Department of Ecology

cc: Dick Ewing, Twin Lakes Aquifer Coalition

State of Washington Hydrogeologist 1537 Licensed Geologist 8-31-12

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From: **Erick W. Miller, LHG** Senior Associate Hydrogeologist | **Peter S. Bannister, PE** Senior Engineer | **Timothy J. Flynn, LHG, CGWP** Principal Hydrogeologist

Re: **Assessment of Maximizing Twin Lakes Project Storage**

1 Introduction

1.1 Purpose and Scope

This memorandum summarizes the results of our analysis for maximizing lake and aquifer storage in the Twin Lakes area near Winthrop, Washington. This work was performed for the Department of Ecology, Water Resources Program under Contract No. C1000185, Work Assignment ASP004 Amendment 1, Task 1. Under this task, the Twin Lakes groundwater flow model (Aspect, 2009 and Aspect, 2012) was used to examine the feasibility and effects of maximizing water storage capacity in Twin Lakes, Barnsley Lake, the adjacent kettle feature (Kettle), and the surrounding aquifer. The project layout is shown on Figure 1. The draft of this memorandum was issued on September 22, 2011

1.2 Summary of Findings

The maximum fill levels for the surface water bodies were staked and surveyed, through coordination with landowners and the Twin Lakes Aquifer Coalition (TLAC). Using the maximum fill levels, the groundwater model was run to simulate the effects of the maximum fill levels on the existing condition project water balance. The water source in the model was two wells at the

locations indicated on the TLAC water right application (Figure 1). The simulation evaluated two withdrawal scenarios, both limited to the irrigation season (April 1 through September 30):

- Minimum Instream Flow (MIF) Limited: Withdrawals are allowed only on days when the average daily flow exceeds the MIF established for USGS gauging stations at Winthrop, Twisp, and Pateros.
- MIF-Mitigated: Withdrawals are allowed each day, and any pumping during days when the river flow is less than the MIF is mitigated. This alternative assumes TLAC is able to secure mitigation water.

The maximum lake and aquifer storage capacity in the Twin Lakes Area is approximately 1,600 acre-feet, based on our analysis. Once the maximum fill levels in these surface water bodies are reached, the lake and aquifer storage will likely require pumping 450-650 acre-feet per year (afy) to maintain maximum storage. About 70% of this volume discharges back to the Methow River as return flow, with the balance going to evapotransipration and year-to-year changes in storage.

The mitigation volume under the MIF-Mitigated scenario ranged from years when no mitigation is required up to 468 afy and averaged 76 afy. The water level change in Big Twin Lake was approximately 2 feet during years with low river flow under the MIF-limited scenario, and was generally 1-foot during other years—similar to the MIF-Mitigated scenario. The annual TLAC withdrawals and other water balance components vary more under the MIF-Limited scenario than under the MIF-Mitigated scenario. The maximum storage for the MIF-Limited scenario was 5% lower than the MIF-Mitigated scenario.

2 Maximum Fill Level Surveying

To evaluate the maximum storage in Twin Lakes, Barnsley Lake, and the Kettle, a survey was made to establish the maximum fill level for these surface water features. This task involved extensive coordination between the landowners and members of the TLAC. On June 15, 2011, recent and historical high water levels were staked in Barnsley Lake and the Kettle, and the maximum fill level was staked for Big Twin Lake. The maximum fill levels were surveyed at 1,800 feet elevation for Big Twin Lake, and 1,785 feet elevation for both Barnsley Lake and the Kettle. These surveyed levels supersede previously modeled target fill levels.

3 Groundwater Model Update

The Twin Lakes numerical groundwater model was previously constructed and calibrated (Aspect, 2009 and Aspect, 2012). The groundwater model was updated to provide a longer simulation period, and to accommodate the Kettle feature as an additional point of use for TLAC withdrawals. The TLAC pumping schedules were updated to reflect the two new withdrawal scenarios. No other changes were made. The calibrated model without the TLAC project represents “existing buildout” under average recharge conditions. The TLAC project was simulated using the “existing buidout” model calibration. A future buildout scenario was not simulated in this analysis.

3.1 Model Period

The predictive model represents the period from October 2010 through September 2031, or Water Years 2011 through 2031.The model period was extended to simulate the 5 additional years of river flow data published since the model was first constructed. The model uses average conditions for transient boundary conditions, except TLAC pumping and diversion schedules.

3.2 Target Fill Levels and Priority of Use

Based on previous project simulations, model results predict winter and spring recharge have the potential to raise Big Twin Lake levels above the target fill level. To allow for an operational contingency to prevent over-filling Twin Lakes, the target fill level was assigned to be 1-foot lower than the maximum fill level, or 1,799 feet elevation. The target fill levels for Barnsley Lake and the Kettle were the maximum fill levels.

Project withdrawals were simulated in the groundwater model using two wells pumping up to 1,000 gallons per minute (gpm) combined. Pumped water was first used to fill Big Twin Lake to 1,799 feet elevation, then Barnsley Lake to 1,785 feet elevation, and then the Kettle to 1,785 feet elevation. Withdrawals were reduced as needed to avoid exceeding the target fill levels during the pumping period. Although direct discharge to the Kettle feature was used in the model, in practice it may be that water levels in the Kettle feature rise in response to seepage from Barnsley Lake.

3.3 MIF-Limited Scenario

The MIF-Limited scenario restricted TLAC pumping to the irrigation season (April 1 through September 30) when the daily average river flows on the Upper, Middle, and Lower Methow River were above the respective MIF. The following river flow data were used:

- Upper Methow: USGS Station # 12448500 (Methow River at Winthrop)
- Middle Methow: USGS Station # 12449500 (Methow River at Twisp)
- Lower Methow: USGS Station # 12449950 (Methow River near Pateros)

Table 1 shows the MIF for each half-month period, and statistics for the amount of time flows were above the MIF at each gauging station. Figure 2 shows when flows were below the MIF for the model period.

3.4 MIF-Mitigated Scenario

The MIF-Mitigated scenario restricted TLAC pumping to the irrigation season (April 1 through September 30) and assumed mitigation when pumping occurred during low river flows. Originally, the MIF-Mitigated scenario was not restricted to the irrigation season. However, we concluded that the irrigation season provided sufficient water supply in light of the practical limitations of over-filling the lakes and operating the project during the winter.

4 Model Results

The numerical model worked well with the TLAC withdrawal scenarios provided. The model calculation uncertainty was less than ±10 afy. The model results show the effect of the TLAC project on “existing buildout” under average recharge conditions.

4.1 TLAC Withdrawals and Distribution of Use

Water available for TLAC withdrawals ranged from approximately 10 to 800 afy under the MIF-Limited scenario, and were approximately 800 afy under the MIF-Mitigated scenario. The actual TLAC withdrawals were generally less than the water available for withdrawal. As the system equilibrated, the average TLAC withdrawals were 551 afy and 538 afy under the MIF-Limited scenario and MIF-Mitigated scenario, respectively. The mitigation volume under the MIF-Mitigated

scenario ranged up to 468 afy, and averaged 76 afy, to account for pumping when the river flow is less than the MIF.

Initially, Big Twin Lake received most of the project water under both of the TLAC withdrawal scenarios. As the system equilibrated, Big Twin Lake received 45-50%, the Kettle received 40-50%, and Barnsley Lake received the balance of the project water. The reason the Kettle received more water than Barnsley Lake was because it is located closer to the Methow River than Barnsley Lake and the model predicts relatively rapid drainage toward the Methow as a result of the steep groundwater gradient. A combination of mounding effects from the Kettle and return flow from Twin Lakes toward the Methow River minimized the quantity of water necessary to maintain Barnsley Lake levels.

Annual diversion quantities for the two TLAC withdrawal scenarios are shown in Figure 3. The upper graph shows the distribution of project water and total project use under the MIF-Limited scenario. The lower graph shows the distribution of project water and total project use under the MIF-Mitigated scenario, and includes the annual mitigation quantities.

Monthly diversion quantities for the two TLAC withdrawal scenarios are shown in Figure 4. These monthly quantities represent the “equilibrium” condition during the last 5 years of the model period. The upper graph shows the distribution of project water and total project use under the MIF-Limited scenario. The lower graph shows the distribution of project water and total project use under the MIF-Mitigated scenario.

4.2 Lake Levels

Figure 5 shows the range of water levels simulated under the “existing buildout” scenario, and the two TLAC withdrawal scenarios. Figure 5 also shows the observed water levels through September 2010. Under the TLAC project, Big Twin Lake levels ranged approximately 1-2 feet around the target fill level of 1,799 feet (Figure 5). Barnsley Lake levels rapidly achieve the target lake level, but drop approximately 5-7 feet from the maximum fill level during the winters. The greater water level fluctuating at Barnsley Lake appears to be a result of the shallow lake depth coupled with dissipation of the seasonal mound build-up beneath the lake.

The model simulates average recharge conditions, and does not reflect inter-annual variability in recharge due to precipitation or snow melt. The 2006-2008 water level monitoring data were used to calibrate the model (Aspect, 2009). Since 2008, the water level in Big Twin Lake declined 5 feet through the beginning of the 2011 water year, whereas Barnsley Lake dried up after a decline of less than 2 feet. These observed changes in lake levels are associated with inter-annual variability in precipitation or snow melt.

4.3 Water Balance

The water balance was evaluated to assess the fate of water used to fill Twin Lakes, Barnsley Lake, and the Kettle. As the lakes were filled, lake and aquifer storage increased. Larger lake surface areas and shoreline lengths resulted in increased evapotranspiration (ET). Higher groundwater levels in the aquifer increased the groundwater return flow to the river. The water balance is described in the following equation:

TLAC Withdrawals = Lake and Aquifer Storage + Increase in ET + Total Return Flow

Table 2 shows the water balance totals for the 21-year model period, and the water balance averages for the last 5 years of the model period. Figure 6 shows the annual water balance for the two TLAC withdrawal scenarios. Figure 7 shows the average monthly water balance for the two TLAC withdrawal scenarios for the last 5 years of the model period. Elements of the water balance are described below.

4.3.1 Lake and Aquifer Storage

Over the 21-year model period, lake and aquifer storage increased by approximately 1,546 to 1,633 acre-feet. Initially, most of the TLAC withdrawals fills lake and aquifer storage (top graph, Figure 6). As the system equilibrates, the increase in storage approaches an average of zero afy. Model results showed sensitivity to climate cycles under the MIF-Limited scenario, where lake and aquifer storage decreased during years with low river flow and increased during years with higher river flow as the lakes were re-filled. Under equilibrium conditions in the last 5 years of the model, lake and aquifer storage was approximately 5 and 64 afy for the MIF-Mitigated and MIF-Limited scenarios, respectively (Table 2).

Average monthly storage shown on the top graph on Figure 7 indicates positive storage values as the lakes and aquifer are filled, and negative storage values as the stored water is slowly released during the non-pumping period.

4.3.2 Increase in ET

ET from the increased lake areas and longer shorelines after the lakes filled accounted for approximately 20-22% of the TLAC withdrawals. The middle graph on Figure 6 shows ET quickly approached equilibrium as lakes were filled to maximum levels. Under equilibrium conditions, ET was approximately 121 and 116 afy for the MIF-Mitigated and MIF-Limited scenarios, respectively (Table 2).

The middle graph on Figure 7 shows lowest ET during December/January, and highest ET during July.

4.3.3 Total Return Flow

Return flow is water that is not consumed by evapotranspiration that flows toward the Methow River, and is eventually discharged to the Methow River or captured by TLAC wells. Groundwater return flow accounted for 67-77% of TLAC withdrawals (equilibrium conditions, last 5 years of model). The bottom graph on Figure 6 shows return flow requires a few years to reach equilibrium. Under equilibrium conditions, return flow was approximately 413 and 370 afy for the MIF-Mitigated and MIF-Limited scenarios, respectively (Table 2).

Groundwater flows from the Twin Lakes area to the north or south toward the Methow River. A bedrock boundary limits flow to the east, where the river is closest to the Twin Lakes. Return flow to the south has been termed “bypass” since this water returns to the Methow River downstream of the point of withdrawal. Return flow to the south represents 52 to 56 afy, or 14% of the total return flow. Return flow to the south is shown with a dotted line in the bottom graph on Figure 6.

The bottom graph on Figure 7 shows total return flow increasing as the lakes are filled, and decreasing as lake levels decline during the winter. Return flow to the south is relatively constant throughout the year, and is shown with a dotted line in the bottom graph on Figure 7. Northerly return flow is expected to be captured in part by the TLAC wells when they are pumping. Northerly

return flow during the non-pumping window (October through March) averages about 124 afy and during the pumping period (April through September) averages 195 afy. Return flow to the by-pass reach is not captured by the TLAC wells.

References

Aspect Consulting, LLC (Aspect), 2009, Hydrogeologic Evaluation Report Water Right Application G4-34915, Twin Lakes Aquifer Coalition, Cost Reimbursement Project, prepared for Washington State Department of Ecology. Bainbridge Island, Washington. Unpublished Work. December 29, 2009.

Aspect Consulting, LLC (Aspect), 2012, RE: Preliminary Feasibility Assessment of Multipurpose Storage, Twin Lakes Area, Okanogan County, Washington. Bainbridge Island, Washington. Unpublished Work. August 31, 2012.

Limitations

Work for this project was performed and this memorandum prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

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Attachments

Table 1 – Mean Daily Methow River Exceedances of Minimum Instream Flows
Table 2 – Water Balance Analysis Results
Figure 1 – Twin Lakes Project Layout
Figure 2 – Compliance with WAC 173-548 MIF
Figure 3 – Annual Diversion Quantities
Figure 4 – Average Monthly Diversion Quantities
Figure 5 – Observed and Calculated Lake Levels
Figure 6 – Annual Water Balances
Figure 7 – Average Monthly Water Balances

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Table 1: Mean Daily Methow River Exceedances of Minimum Instream Flows

TLAC Storage Evaluation

Time Period	WAC 173-548 Minimum Instream Flows (MIF)					
	Winthrop		Twisp		Pateros	
	MIF (cfs)	% Above MIF	MIF (cfs)	% Above MIF	MIF (cfs)	% Above MIF
January 1 - 14	120	100.0%	260	65.4%	350	57.6%
January 15 - 31	120	100.0%	260	66.3%	350	62.5%
February 1 - 14	120	100.0%	260	69.9%	350	61.3%
February 15 - 28	120	100.0%	260	74.5%	350	64.2%
March 1 - 14	120	100.0%	260	80.8%	350	71.8%
March 15 - 31	120	100.0%	260	92.3%	350	88.6%
April 1 - 14	199	94.9%	430	83.4%	590	76.0%
April 15 - 30	300	92.6%	650	87.5%	860	86.5%
May 1 - 14	480	98.3%	1000	94.6%	1300	93.4%
May 15 - 31	690	100.0%	1500	99.1%	1940	95.7%
June 1 - 14	790	100.0%	1500	98.6%	2220	95.1%
June 15 - 30	790	100.0%	1500	87.5%	2220	82.0%
July 1 - 14	694	93.2%	1500	63.6%	2150	55.8%
July 15 - 31	240	100.0%	500	87.9%	800	74.5%
August 1 - 14	153	100.0%	325	85.4%	480	76.8%
August 15 - 31	100	100.0%	220	89.4%	300	83.8%
September 1 - 14	100	100.0%	220	80.0%	300	77.7%
September 15 - 30	100	100.0%	220	74.4%	300	79.1%
October 1 - 14	122	100.0%	260	76.3%	360	69.6%
October 15 - 31	150	100.0%	320	53.6%	425	57.4%
November 1 - 14	150	100.0%	320	52.3%	425	58.4%
November 15 - 30	150	100.0%	320	57.2%	425	52.3%
December 1 - 14	135	100.0%	290	57.1%	390	51.5%
December 15 - 31	120	100.0%	260	65.0%	350	59.4%

Notes:

Upper Methow flow data from USGS Station # 12448500 (Methow River at Winthrop) for period of record 1989 - 2010

Middle Methow flow data from USGS Station # 12449500 (Methow River at Twisp) for the period of record 1991 - 2010

Lower Methow flow data from USGS Station # 12449950 (Methow River near Pateros) for period of record 1959 - 2010

Table 2: Water Balance Analysis Results

TLAC Storage Evaluation

Water Balance Totals - 21-year Model Period

	Water Balance Input				Water Balance Output				
TLAC Use Scenario	**Total TLAC Use**	Big Twin Lake Input	Barnsley Lake Input	Kettle Input	**Lake and Aquifer Storage**	**Change in ET**	**Total Return Flow**	Return Flow to the North	Return Flow to the South
MIF-limited	**10742**	*5741*	*1248*	*3753*	**1546**	**2283**	**6913**	*5952*	*961*
MIF-mitigated	**11873**	5953	586	5333	**1633**	**2420**	**7820**	*6802*	*1018*

Note: All values are in acre-feet.

Water Balance Statistics - 21-year Model Period

TLAC Use Scenario	**Total TLAC Use**	Big Twin Lake Input	Barnsley Lake Input	Kettle Input	**Lake and Aquifer Storage**	**Change in ET**	**Total Return Flow**	Return Flow to the North	Return Flow to the South
MIF-limited	**512 ± 180**	*273 ± 156*	*59 ± 49*	*179 ± 87*	**74 ± 237**	**109 ± 18**	**329 ± 93**	*283 ± 80*	*46 ± 14*
MIF-mitigated	**565 ± 73**	283 ± 128	28 ± 41	254 ± 69	**78 ± 191**	**115 ± 18**	**372 ± 101**	*324 ± 86*	*48 ± 15*

Notes: All values are in acre-feet per year (afy).
Statistics include the average ± standard deviation.

Water Balance Percentages - 21-year Model Period

TLAC Use Scenario	**Total TLAC Use**	Big Twin Lake Input	Barnsley Lake Input	Kettle Input	**Lake and Aquifer Storage**	**Change in ET**	**Total Return Flow**	Return Flow to the North	Return Flow to the South
MIF-limited	**100%**	*53%*	*12%*	*35%*	**14%**	**21%**	**64%**	*86%*	*14%*
MIF-mitigated	**100%**	50%	5%	45%	**14%**	**20%**	**66%**	*87%*	*13%*

Water Balance Statistics - Final 5 Years of Model Period

TLAC Use Scenario	**Total TLAC Use**	Big Twin Lake Input	Barnsley Lake Input	Kettle Input	**Lake and Aquifer Storage**	**Change in ET**	**Total Return Flow**	Return Flow to the North	Return Flow to the South
MIF-limited	**551 ± 65**	*271 ± 50*	*65 ± 36*	*215 ± 47*	**64 ± 98**	**116 ± 4**	**370 ± 32**	*318 ± 30*	*52 ± 3*
MIF-mitigated	**538 ± 0**	245 ± 0	17 ± 0	276 ± 0	**5 ± 1**	**121 ± 0**	**413 ± 0**	*356 ± 1*	*56 ± 0*

Note: All values are in acre-feet per year (afy).

Water Balance Percentages - Final 5 Years of Model Period

TLAC Use Scenario	**Total TLAC Use**	Big Twin Lake Input	Barnsley Lake Input	Kettle Input	**Lake and Aquifer Storage**	**Change in ET**	**Total Return Flow**	Return Flow to the North	Return Flow to the South
MIF-limited	**100%**	*49%*	*12%*	*39%*	**12%**	**21%**	**67%**	*86%*	*14%*
MIF-mitigated	**100%**	45%	3%	51%	**1%**	**22%**	**77%**	*86%*	*14%*

Total TLAC Use = Big Twin Lake Input + Barnsley Lake Input + Kettle Input
Total TLAC Use = Increase in ET + Aquifer Storage + Total Return Flow
Total Return Flow = Return Flow to the North + Return Flow to the South

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Twin Lakes Project Layout

TLAC Storage Evaluation
Winthrop, Washington

Aspect CONSULTING	SEP-2011	BY: PPW	FIGURE NO.
	PROJECT NO. 090180-004-02	REV BY: - - -	1

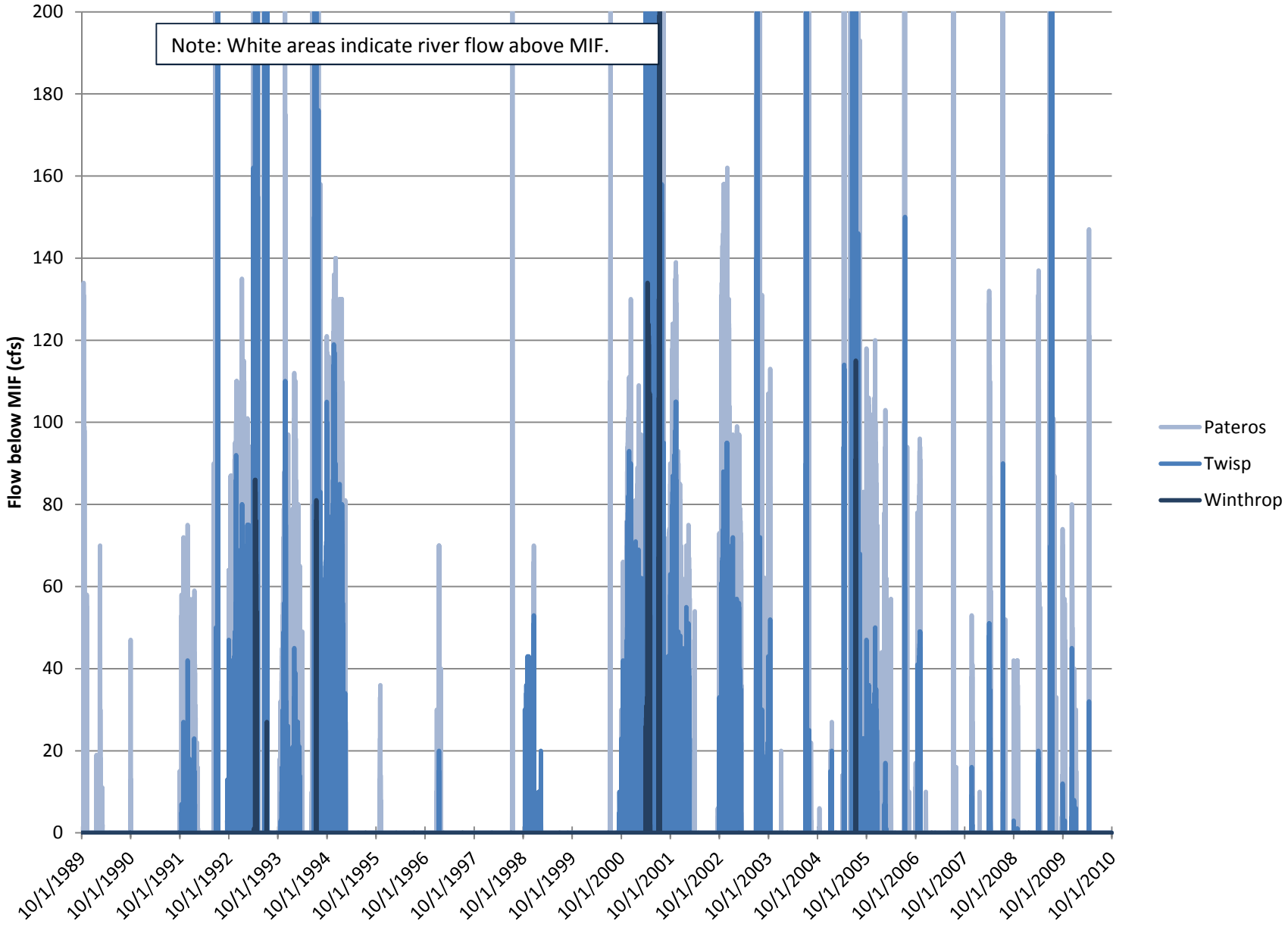

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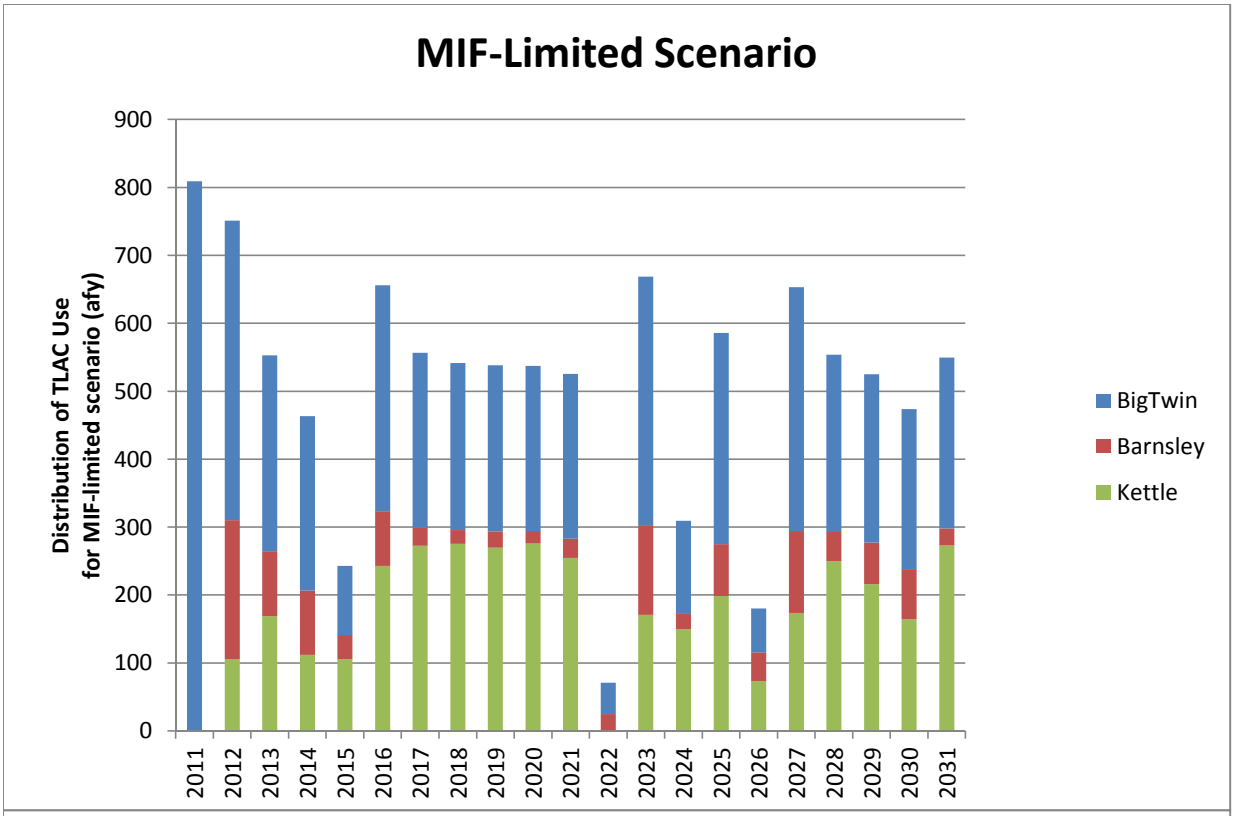
Figure 2: Compliance with WAC 173-548 MIF
TLAC Storage Evaluation
Winthrop, Washington



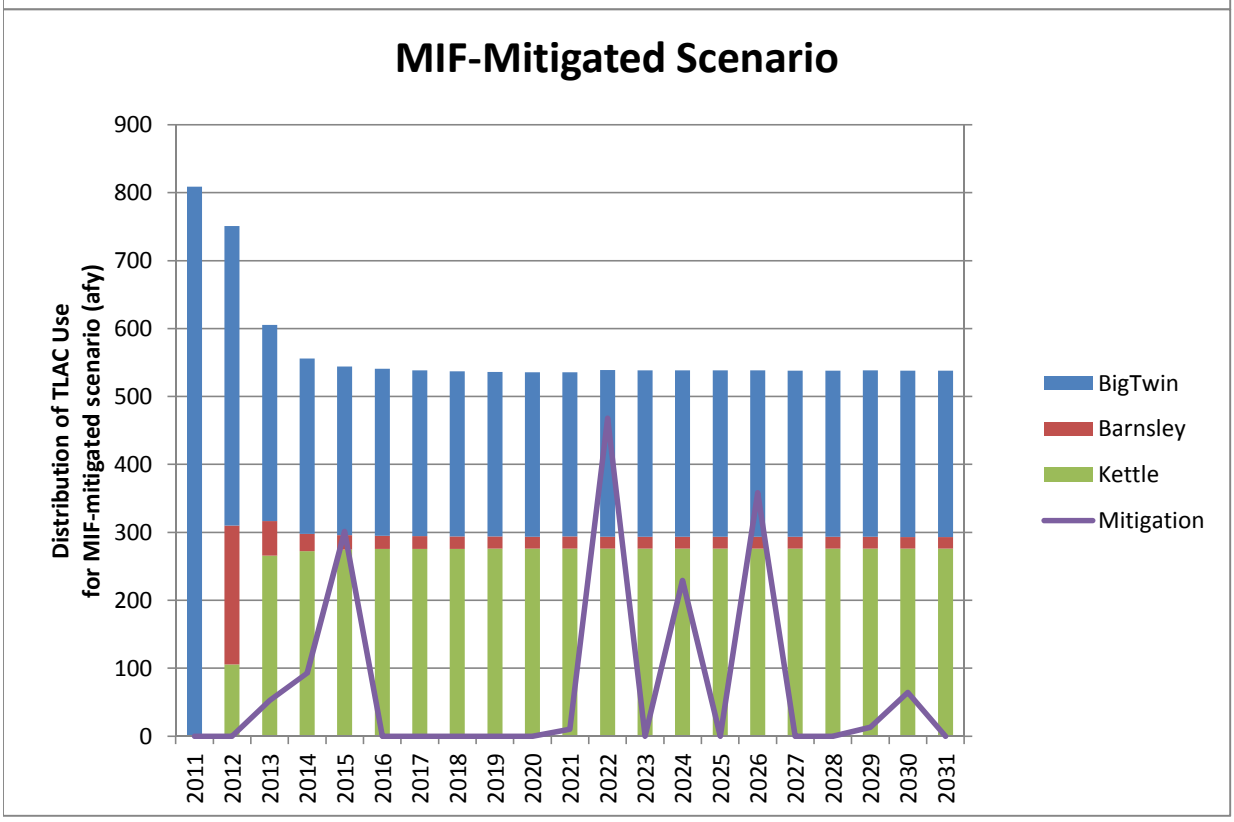


Figure 3
Annual Diversion Quantities
TLAC Storage Evaluation
Winthrop, Washington

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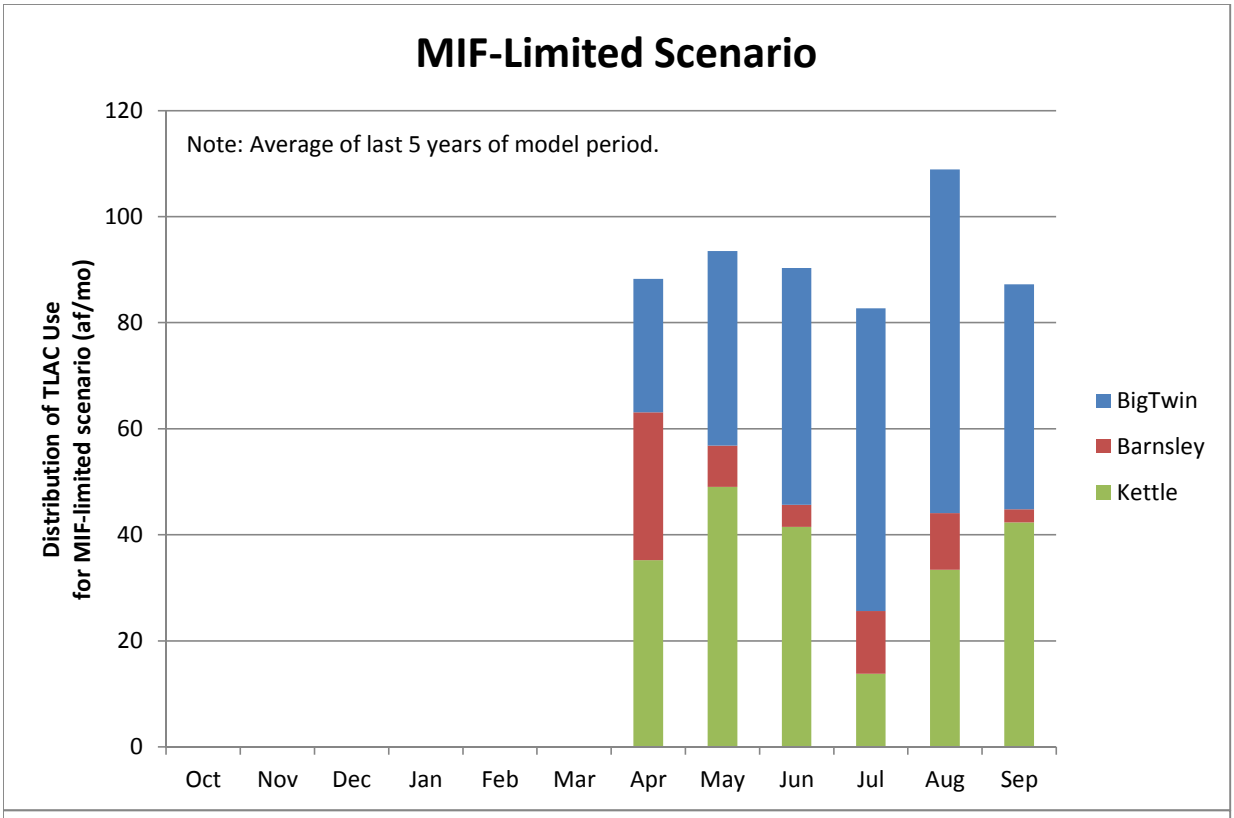

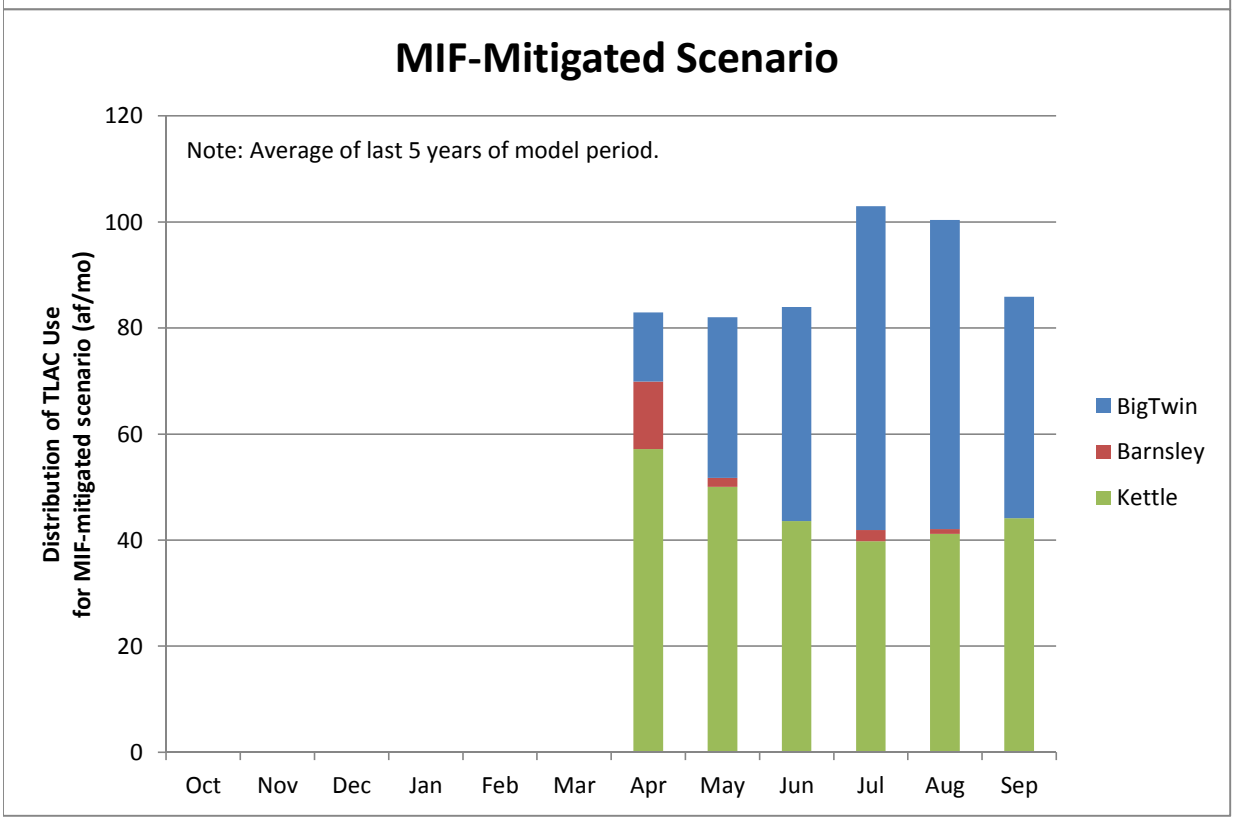

Figure 4
Average Monthly Diversion Quantities
TLAC Storage Evaluation
Winthrop, Washington

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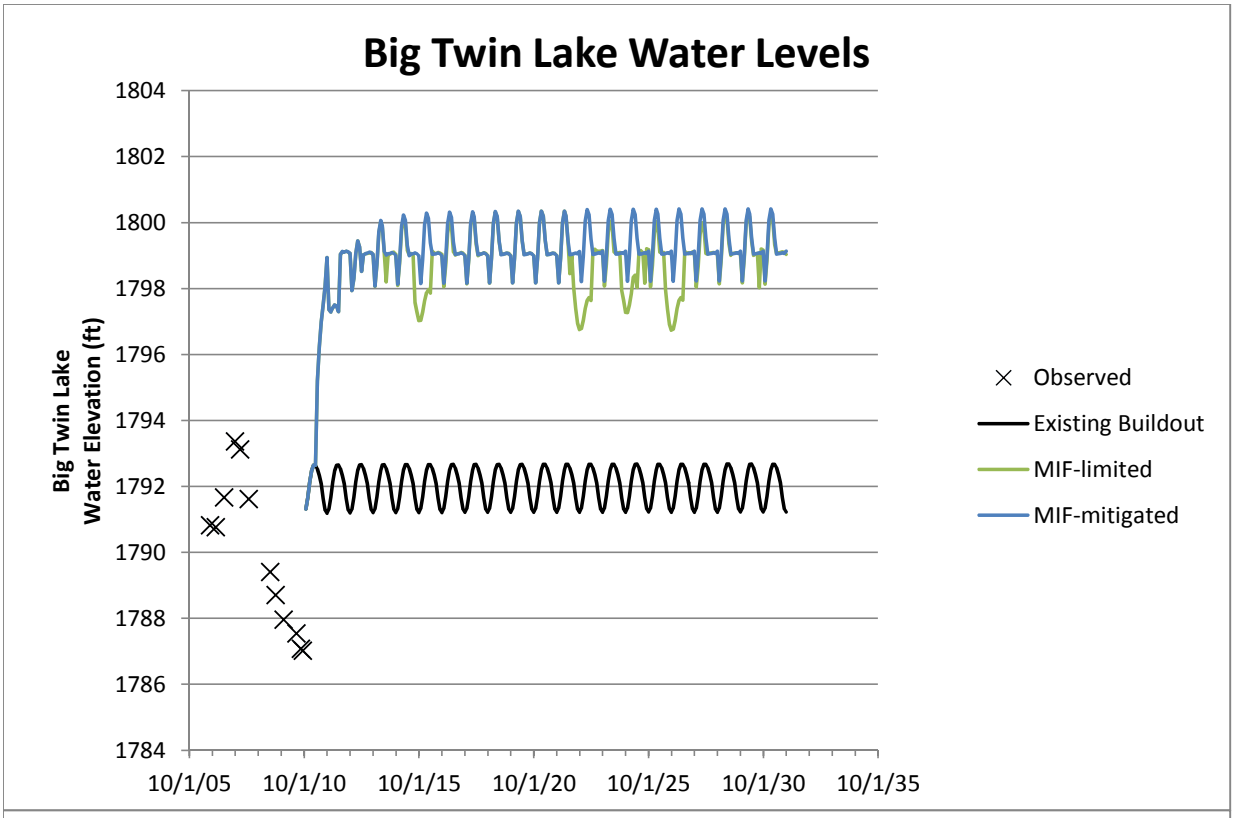

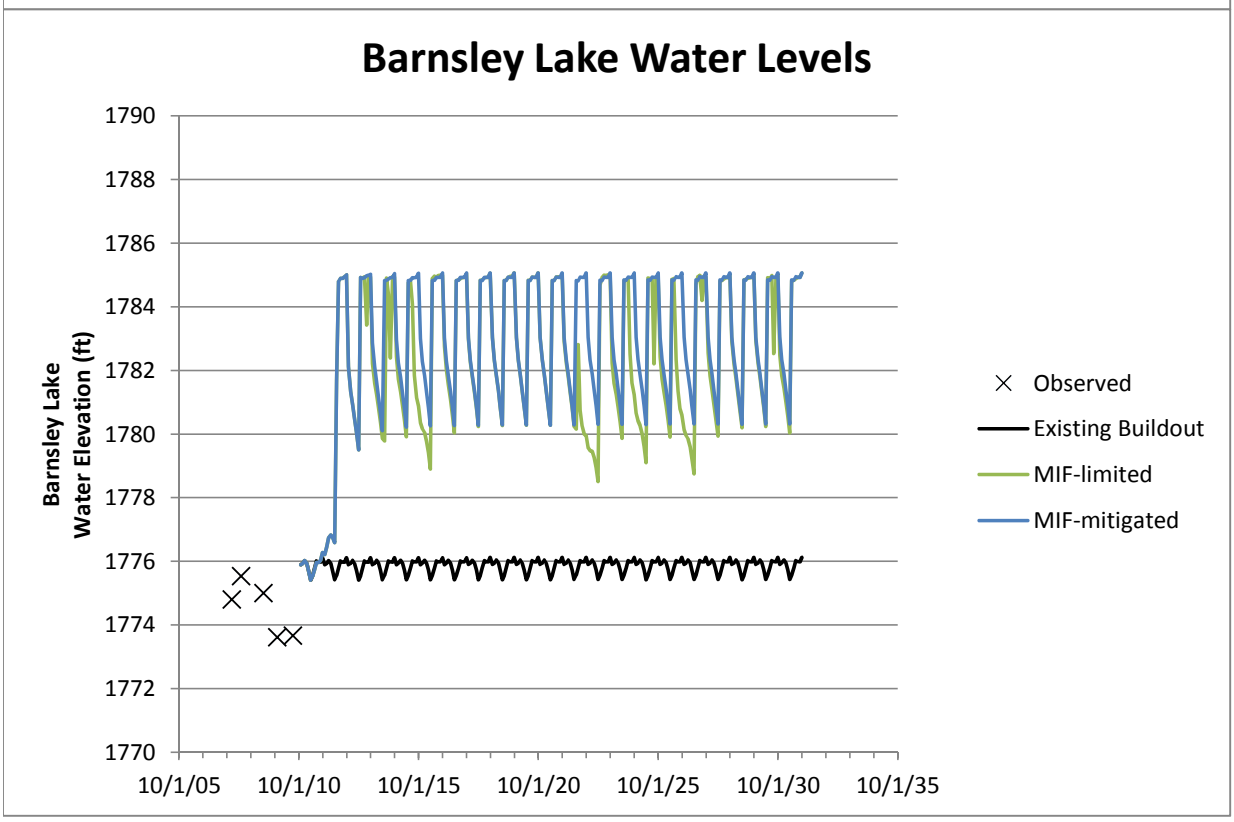

Figure 5
Observed and Calculated Lake Levels
TLAC Storage Evaluation
Winthrop, Washington

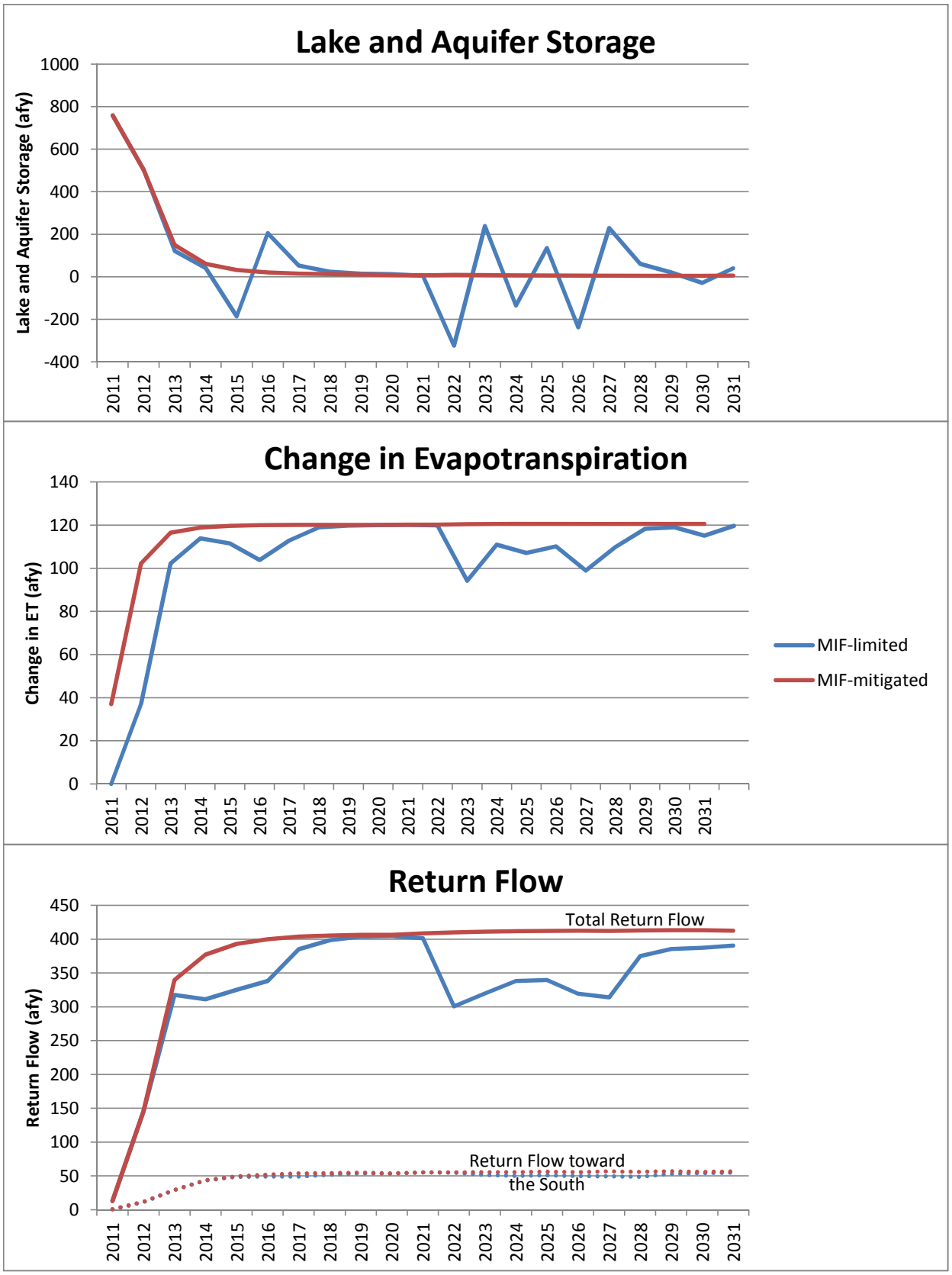

Figure 6
Annual Water Balances
TLAC Storage Evaluation
Winthrop, Washington

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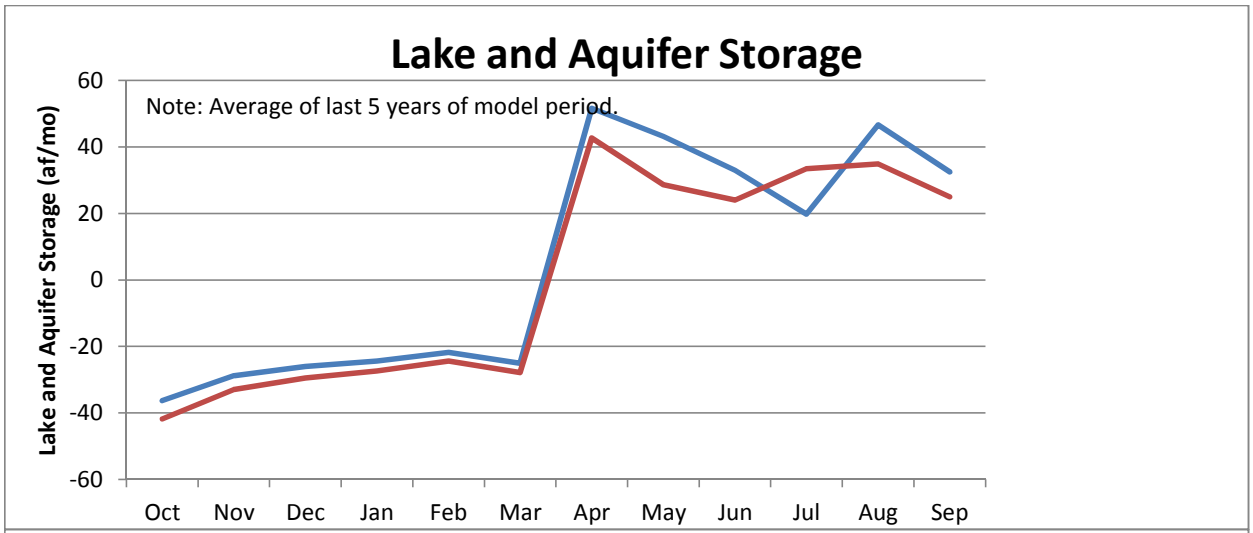

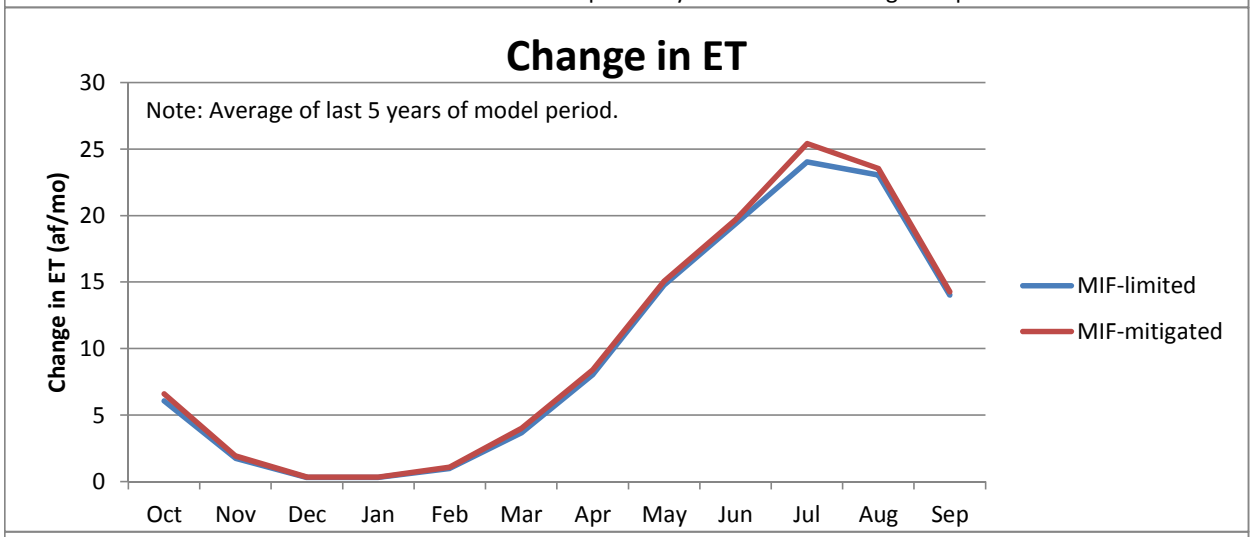

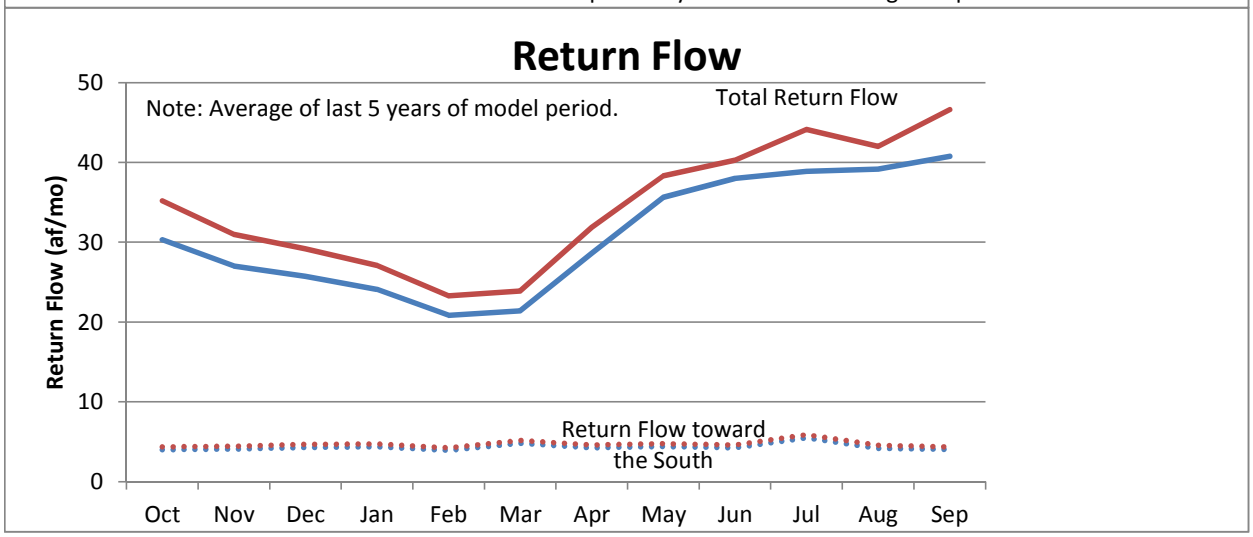

Figure 7
Average Monthly Water Balances
TLAC Storage Evaluation
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