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Expires: 3/31/16

Memorandum

To:	Kameron DeLashmutt Central Land and Cattle, LLC	**Date:**	October 20, 2015
		From:	A. Scott Yankey, R.G. James B. Newton, R.G. E.I.T., C.W.R.E.
		Project Name:	Proposed Thornburgh Development
Subject:	Whychus Creek Impact and Mitigation Analysis	**Project No.:**	1130-101

REGISTERED PROFESSIONAL GEOLOGIST
OREGON
JAMES B. NEWTON
G2122
4/30/2016

Newton Consultants Inc. (Newton) worked extensively with Thornburgh Resort, the Oregon Department of Fish and Wildlife (ODFW), the Oregon Water Resources Department (OWRD), and Tetra Tech on issues pertaining to Thornburgh's Groundwater permit as well as issues pertaining to mitigation of stream and seeps related to Thornburgh application for Final Master Plan. The work done relating to the latter resulted in ODFW making the determination that Thornburgh had fully mitigated all impacts to springs and seeps and because of its full mitigation plan, which included providing cold spring water in an amount in excess of the impacts it caused, was providing a net benefit to the resource. Resort opponents disagreed claiming that an impact to Whychus Creek was not being mitigated.

This memorandum has been prepared by Newton on behalf of Thornburgh Resort LLC to provide the results of data review and analyses related to potential for impact to lower Whychus Creek from the proposed Thornburgh development (Project) groundwater pumping activities and the effectiveness of the proposed mitigation, if necessary to offset the potential impact.

CONCLUSIONS

Based upon review of the existing data and the analyses provided in this memorandum, Newton has arrived at the following conclusions:

- The proposed Project mitigation of retaining 106 acre-feet (AF) of cold water instream during the irrigation season from the Three Sisters Irrigation District (TSID) diversion, located at approximate river mile (RM) 24.25, will improve the resource from the TSID diversion to at least Forest Service (FS) Road 6360, approximate RM 6.0, by reducing stream temperature by 0.03°C.

- Mass balance calculations that utilize the correlation between temperature and stream flow rate established by the Upper Deschutes Watershed Council (UDWC) and reported groundwater discharge rates from the literature for the lower Whychus Creek indicate that the proposed Project mitigation is more than adequate to address potential temperature increases in Whychus Creek, including Lower Whychus Creek that might occur due to Thornburgh well pumping.
- The impact to lower Whychus Creek previously submitted by Project opponents (Yinger and Strauss, 2008) was based upon inaccurate Project groundwater pumping rates that overestimate the impact. The Project pumping rate input into the groundwater flow model used by Yinger/Strauss (3.25 cubic feet per second [cfs]) is 1.74 times higher than the project consumptive use rate equivalent (1.87 cfs). This overestimate negates the model-predicted impact quantification of 0.145 cfs, in reduced groundwater discharge, to lower Whychus Creek claimed by Project opponents. This overestimate also brings into question whether the Project will result in any reduction in creek flows or increase in temperatures in lower Whychus Creek.

WATER USE ISSUES VS. MITIGATION

The Land Use Board of Appeals (LUBA) Opinion and Final Order includes findings of the hearings officer in addressing the potential thermal impact on Whychus Creek. The hearings officer findings included the following:

"The OWRD mitigation requirement adequately addresses water quantity; it does not fully address water habitat quality. Its assumptions regarding the benefits of replacing more water during the irrigation season than is consumed on an average daily basis by the resort does not account for the higher water consumption that will likely occur during the summer months. Therefore, the hearings officer concludes that the additional mitigation offered through the Three Sisters Irrigation District restoration program is necessary to assure that water temperatures on Whychus Creek are not affected by the proposed development." Record 34.

To address this concern, Newton provides the following discussion of the proposed mitigation and compares it to the water use. A summary of the monthly volume of mitigation water provided by Thornburgh and the monthly volume of water consumption by Thornburgh are shown on Table 1 and is shown graphically on Figure 1. The monthly volumes of mitigation water are based on the distribution of water necessary to meet crop net irrigation requirements over the summer irrigation season. The distribution is based on monthly net irrigation requirement data presented in the *"Oregon Crop Water Use and Irrigation Requirements,"* Extension Miscellaneous 8530, Oregon State University. The net irrigation requirement is the amount of water that crops require for evapotranspiration and does not include irrigation evaporation, deep percolation into the soil, and other irrigation losses. Net irrigation requirements peak in July as shown in the table.

The monthly volume of water consumption by Thornburgh is also shown on Table 1 and Figure 1. These volumes show the variation in water consumption for agricultural and quasi-municipal

water use over the year, with peak consumption occurring in August. In general, peak month volume of water use can range from about 1.9 to 2.2 times the average month volume of water use.

Figure 1 shows that total mitigation provided by Thornburgh exceeds the total consumption by Thornburgh for the seven months from April till September, including the peak water use months of June, July, and August. When looking specifically at Whychus Creek, the mitigation provided by Thornburgh exceeds consumption from March through October.

The net effect of the Thornburgh mitigation is that it accounts for the higher water consumption that will likely occur during summer months. Since the mitigation accounts for the higher water consumption that will likely occur during the summer months, the concern of the hearings officer in this regard is resolved.

PROPOSED PROJECT MITIGATION FOR WHYCHUS CREEK

The Project offered to provide mitigation to Whychus Creek in 2008. The Project proposed to retain 106 AF of cold upstream water from being diverted at the TSID diversion at approximately RM 24.25. This proposed mitigation would occur annually throughout the irrigation season. This volume over the 180 day irrigation season is equivalent to a flow of 0.297 cfs. Mitigation over the irrigation season was proposed since irrigation diversions are the largest cause of reduced flow and increased temperature within Whychus Creek.

PROJECT EFFECT ON WHYCHUS CREEK TEMPERATURE

Temperature and Flow Correlation

The UDWC have been measuring and/or compiling Whychus Creek temperature data since 1995. The UDWC analyses of Whychus Creek temperature data from 2000 through 2014 indicate a strong correlation with flow conditions (Mork, 2014). Regression models fitted to the seven-day moving average maximum temperature (7DMAX) and flow data set from Whychus Creek were used by UDWC to generate 7DMAX temperatures at a corresponding flow rate at two locations; Sisters City Park (approximate RM 24.25) and FS Road 6360 (approximate RM 6.0). The UDWC data may be utilized to determine the average temperature reduction within Whychus Creek per cfs of stream flow.

The UDWC data for the Sisters City Park location plotted for flows from 10 to 60 cfs, representing anticipated flows during the irrigation season, with the resulting 7DMAX temperatures are shown in Figure 2. A linear regression was fit to the data and the resulting linear equation was determined and is also provided in Figure 2. The slope of the linear regression line represents the average temperature reduction to the 7DMAX in °C for each cfs of stream flow increase. At Sisters City Park, the reduction is 0.1048°C/cfs. As stated above, the proposed mitigation for Whychus Creek is to retain 0.297 cfs of cold upstream water instream. A mitigation flow increase of 0.297 cfs results in a temperature reduction of 0.03°C at Sisters

City Park (0.297cfs x 0.1048°C/cfs = 0.03°C). The same logic was applied to the UDWC flow and average temperature data at the FS Road 6360 location and the data plot is shown in Figure 3. At this location, the average temperature reduction per cfs of increased flow is 0.1133°C/cfs. A mitigation flow increase of 0.297 cfs also results in a stream average temperature reduction of 0.03°C at FS Road 6360 (0.297cfs x 0.1133°C/cfs = 0.03°C).

The next step in this analysis is to assume some reduction in groundwater discharge to lower Whychus Creek so that a temperature increase resulting from the reduced flow can be compared with the above results. Since the groundwater model Project pumping rate (3.25 cfs) was 1.74 times the Project approved consumptive use rate (1.87 cfs), and the groundwater flow model predicted impact to lower Whychus Creek was 0.145 cfs (represented as a reduction in groundwater discharge to the stream), a linear relationship between pumping rate and groundwater discharge rate was assumed. Therefore the model predicted groundwater discharge reduction was reduced to 0.083 cfs (0.145 cfs/1.74 = 0.083 cfs). Based upon the same UDWC data correlation from FS Road 6360, the groundwater flow model predicted reduction in groundwater discharge to lower Whychus Creek of 0.083 cfs results in an average temperature increase of 0.1133°C/cfs, or 0.009°C (0.083cfs x 0.1133°C/cfs = 0.009°C) at the mouth of Whychus Creek. Therefore, the proposed mitigation is more than effective since it would have a resultant cooling temperature reduction of 0.021°C.

Based upon the UDWC data, the proposed mitigation flow will reduce the average temperature within Whychus Creek 0.03°C from river mile 24.25 to river mile 6.0. It seems safe to assume that the mitigation flow will also reduce the temperature slightly further downstream and into lower Whychus Creek. Therefore, the proposed mitigation will improve the resource for the entire downstream reach from RM 24.25.

Mass Balance Calculations

Mass balance calculations can also be used in combination with the flow and temperature correlation developed by UDWC to provide another analysis of the impact of a potential groundwater flow discharge reduction on stream temperature to lower Whychus Creek. The definition of "lower Whychus Creek" reach does not appear to be defined in past reports. However, it appears that "lower Whychus Creek" is the reach from Alder Springs to the mouth (approximately river mile 1.5 to 0.0) and is used as such in this memorandum. The mass balance equation is the same as used previously by both Project supporters and opponents:

$$T_{Resulting} = \frac{(T_{Stream} \times Q_{Stream}) + (T_{Inflow} \times Q_{Inflow})}{(Q_{Stream} + Q_{Inflow})}$$

Where:

$T_{Resulting}$ = Whychus Creek temperature after mixing
T_{Stream} = Whychus Creek temperature prior to mixing
Q_{Stream} = Whychus Creek flow rate prior to mixing
T_{Inflow} = Temperature of groundwater discharge to lower Whychus Creek
Q_{Inflow} = Groundwater discharge flow rate to lower Whychus Creek

The difficulty of using this equation is the lack of flow data within Whychus Creek below Camp Polk Road. However, the UDWC correlation between flow and temperature established at FS Road 6360 can be used to establish flow and temperature data for Whychus Creek. The rate of groundwater discharge to lower Whychus Creek was estimated at 94 cfs by the United States Geological Survey (USGS) in its establishment of the basin-wide groundwater flow model as 94 cfs (Gannett, et al., 2001). The temperature of the groundwater discharge was documented as 7 to 9°C (Watershed Sciences, 2008). A groundwater discharge temperature of 9°C is used in this analysis. This is a conservative assumption as Yinger used a temperature of 11°C in the math balance equation to predict temperature change at Alder Spring (one point of a stream complex) on a single day with low water flows. Rec. 896. This analysis relies upon the following assumption: the correlation between flow and temperature defined by UDWC at FS Road 6360 is similar to that just above lower Whychus Creek.

The next step in this analysis is to assume some reduction in groundwater discharge to lower Whychus Creek so that a comparison of resulting temperatures from the mass balance equation can be done. Since the groundwater model Project pumping rate (3.25 cfs) was 1.74 times the Project approved consumptive use rate (1.87 cfs), and the groundwater flow model predicted impact to lower Whychus Creek was 0.145 cfs (represented as a reduction in groundwater discharge to the stream), a linear relationship between pumping rate and groundwater discharge rate was assumed. Therefore the model predicted groundwater discharge reduction was reduced to 0.083 cfs (0.145 cfs/1.74 = 0.083 cfs). The 0.145 cfs figure is the entire amount of flow reduction predicted by Yinger/Strauss in lower Whychus Creek. Yinger assumed that all of the flow reduction would occur at Alder Springs when predicting temperature impacts at Alder Springs (not for lower Whychus Creek). Rec. 895-896.

The results of the mass balance calculations are presented in Table 2 and graphically presented in Figure 4. As shown in Figure 4, based upon the assumed reduction in groundwater discharge of 0.083 cfs to lower Whychus Creek, temperature increases above 0.002°C do not occur for any stream flow between 2 and 200 cfs. Since calculations in the previous section indicated that the proposed Project mitigation reduced the temperature of Whychus Creek by 0.03°C, the proposed mitigation is more than adequate to mitigate for the reduction in groundwater discharge to lower Whychus Creek.[1]

PAST ESTIMATE OF PROJECT IMPACT ON GROUNDWATER DISCHARGE

A document submitted in February 2008 (Yinger and Strauss, 2008) contained the results of groundwater flow modeling performed by Mark Yinger Associates and Northwest Land & Water, Inc. to simulate the Project impact caused by groundwater pumping. The model results indicated that the Project pumping impact to the Deschutes River from Odin Falls to Whychus Creek and to the lower Whychus Creek totaled 1.65 to 1.78 cfs under two scenarios. The impact resulted by reducing the amount of groundwater discharging to these streams. The model results

[1] This memorandum assumes that there will be an impact to Whychus Creek from Thornburgh's groundwater pumping, based on the Yinger/Strauss adaptation of the USGS model, in order to show that the mitigation required by the County will mitigate the assumed impact.

did not specify the impact to lower Whychus Creek. In a later submittal (Yinger, 2008a), the impact to lower Whychus Creek was quantified to be 0.145 cfs. This potential impact was assigned to the 8.7 cfs reported by Yinger as the discharge of Alder Springs, when Alder Springs is one of multiple areas of groundwater discharge into lower Whychus Creek as shown by the USGS in its report on hydrology of the upper Deschutes Basin (Gannett, et al., 2001). Assignment of impact to a point groundwater discharge in a reach of groundwater discharge exaggerates the potential impact, and does not reflect the hydrogeologic function of the lower Whychus Creek groundwater discharge area.

An issue with the groundwater flow model results includes the use of a total annual pumping volume of 2,355 AF for the Project with a 100 percent consumption rate. This volume equals an average annual pumping rate of 3.25 cfs. The model used this flow rate. The Project annual pumping volume is limited to 2,129 AF by the groundwater permit issued to Thornburgh by the OWRD. The Project consumptive use has been contentious but was decided by the LUBA to be 1,356 AF, in agreement with OWRD guidelines and in agreement with the Project consumptive use also as stipulated by the groundwater pumping permit. This volume equals an annual pumping rate of 1.87cfs. Therefore, the model assumed a pumping rate that is nearly double (1.74 times higher) the approved consumptive use rate equivalent. The model has not been used to determine the reduced impact to either the Deschutes River or lower Whychus Creek based upon the accurate pumping rate. As a result, it can not be definitively determined that there is an actual degradation to lower Whychus Creek. This conclusion was apparently that reached by the ODFW in their approval of the Project Final Master Plan (Stewart, 2008)[2]. This letter stated that the ODFW considered that the mitigation proposed without addressing lower Whychus Creek was adequate to address potential impacts to springs and seeps and provide a net benefit to the resource.

PAST ESTIMATES OF PROJECT IMPACT ON WHYCHUS CREEK TEMPERATURE

Past estimates of the temperature impact to lower Whychus Creek by Yinger (Yinger, 2008b) due to the model predicted groundwater discharge reduction have used flow and temperature data collected and presented by Watershed Sciences and MaxDepth Aquatics, Inc. (Watershed Sciences, 2008). The lower Whychus Creek and Alder Springs flow data used by Yinger were obtained from one-time, instantaneous flow measurements made in 2000. No permanent flow gauges existed below Sisters at that time. Even now, only one additional permanent flow gauge is present below Sisters on Whychus Creek at Camp Polk Road. The temperature data for Whychus Creek in the Watershed Sciences document were also collected in 2000. The use of one-time data points for flow and temperature from a single day in 2000 to determine impact to lower Whychus Creek caused by the Project would does not offer reliable, conclusive evidence. In addition, the groundwater discharge flow rate in the Alder Springs area used in past calculations used the Watershed Sciences measured flow of surface discharge from Alder

[2] In an earlier letter in January 2008 ODFW informed that they had received information from Mark Yinger claiming that the Resort would have an impact on the fisheries resource in the Middle Deschutes and Whychus Creek. ODFW recommended that Thornburgh "document that no net loss of either habitat quantity or quality will occur as a result of water withdrawals". Rec. 2785.

Springs directly as the total groundwater discharge. Alder Springs is at the head of a stream complex that, according to Yinger, adds approximately 100 cfs of water to lower Whychus Creek (not just 8.7 cfs used by Yinger in the mass balance equation). The use of these data is exacerbated by the fact that Whychus Creek as a resource is much improved since 2000. Significant restoration projects were initiated along Whychus Creek in 2000 and continue today. The results of stream restoration can be seen by increased flows and decreases in temperature. Examples of the effect of stream improvement measured on flow and temperature at Sisters City Park from 2000 to 2014 are shown in Figures 5 and 6, respectively.

CALCULATIONS USING MODEL PREDICTED GROUNDWATER FLOW REDUCTION

Temperature and Flow Correlation Method

As stated above, the groundwater flow model project pumping rate inputs were incorrect and result in, at best, elevated estimates of groundwater flow reduction to lower Whychus Creek, or at worst, they predict degradation to the resource that does not occur if the correct pumping rates were input into the model. However, even if the model predicted reduction to groundwater discharge to lower Whychus Creek of 0.145 cfs is used in the temperature and flow correlation calculations presented above, the mitigation is still more than adequate to address the impact.

The proposed mitigation would still reduce the temperature within the stream by 0.03°C. The model predicted impact of 0.145 cfs within the lower Whychus Creek only would result in a temperature increase of 0.016°C (0.145 cfs x 0.1133°C/cfs = 0.016°C). This increase would only be seen in the reach of the lower Whychus from RM 1.5 to 0.0. Therefore, the mitigation is more than adequate to address impact and improved the resource from RM 24.25 to 0.0.

Mass Balance Calculation Method

If the mass balance calculation method presented above also assumes that the impact to lower Whychus is 0.145 cfs, a figure that is too high, the temperature increase to the lower reach of the Whychus would be a maximum of 0.0035°C at a stream flow rate of around 40 cfs, and lower for all other flows between 2 and 200 cfs. The results of these calculations are provided in Table 3 and are shown graphically in Figure 7. Once again, the proposed mitigation is more than adequate to address the impact.

CONCLUSIONS

Based upon review of the existing data and the analyses provided in this memorandum, Newton has arrived at the following conclusions:

- The proposed Project mitigation of retaining 106 AF of cold water instream during the irrigation season from the TSID diversion, located at approximate RM 24.25, will improve the resource from the TSID diversion to at least FS Road 6360, approximate RM 6.0, by reducing stream temperature by 0.03°C.

- Mass balance calculations that utilize the correlation between temperature and stream flow rate established by the UDWC and reported groundwater discharge rates from the literature for the lower Whychus Creek indicate that the proposed Project mitigation is more than adequate to address potential temperature increases. Yinger's use of the mass balance equation in his July 23, 2008 letter to Munson is not valid and does not accurately predict temperature change in lower Whychus Creek.
- The impact to lower Whychus Creek previously submitted by Project opponents (Yinger and Strauss, 2008) was based upon inaccurate Project groundwater pumping rates that overestimate the impact. The Project pumping rate input into the groundwater flow model (3.25 cfs) is 1.74 times higher than the project consumptive use rate equivalent (1.87 cfs). This overestimate negates the model-predicted impact quantification of 0.145 cfs, in reduced groundwater discharge, to lower Whychus Creek.
- Considering the full spectrum of Whychus Creek flow and temperature conditions, and the results of analysis based on the applicable groundwater permit limits including annual consumptive water use, there is no clear basis to conclude that groundwater pumping by the Project will result in degradation of the resource.

REFERENCES

Gannett, Marshall W., Kenneth E. Lite Jr., David S. Morgan, and Charles A. Collins, 2001, *"Ground-Water Hydrology of the Upper Deschutes Basin, Oregon"*, United States Geological Survey, Water-Resources Investigations Report 00-4162.

Mork, Lauren, 2014, *"Whychus Creek Water Quality Status, Temperature Trends, and Stream Flow Restoration"*, Upper Deschutes Watershed Council, 2014 Whychus Creek Monitoring Report.

Stuart, Amy, 2008, *"Thornburgh Resort Company – Final Master Plan Approval"*, Oregon Department of Fish and Wildlife, Letter to Deschutes County Community Development Board, June 13, 2008.

Watershed Sciences and MaxDepth Aquatics, 2008, *"Deschutes River, Whychus Creek, and Tumalo Creek Temperature Modeling"*, January 23, 2008.

Yinger, Mark, 2008a, *"Review of portions of the Thornburgh Final Master Plan Application, Deschutes County file number M-07-2"*, Mark Yinger Associates, Letter to Steve Munson, Vulcan Power Company, June 5, 2008.

Yinger, Mark, 2008b, *"Thornburgh Resort – rebuttal and comment in response to applicants written and oral testimony submitted to Anne Corcoran Briggs, Deschutes County Hearings Officer, on July 15, 2008"*, Mark Yinger Associates, Letter to Steve Munson, Vulcan Power Company, July 23, 2008.

Yinger, Mark and Laura Strauss, 2008, *"A Case Study: Thornburgh Resort Water Resources Impact Evaluation, Upper Deschutes Basin, Oregon"*, February 2008.

Attachments:

1. Figures 1-7
2. Tables 1-3

ATTACHMENT 1

Figures

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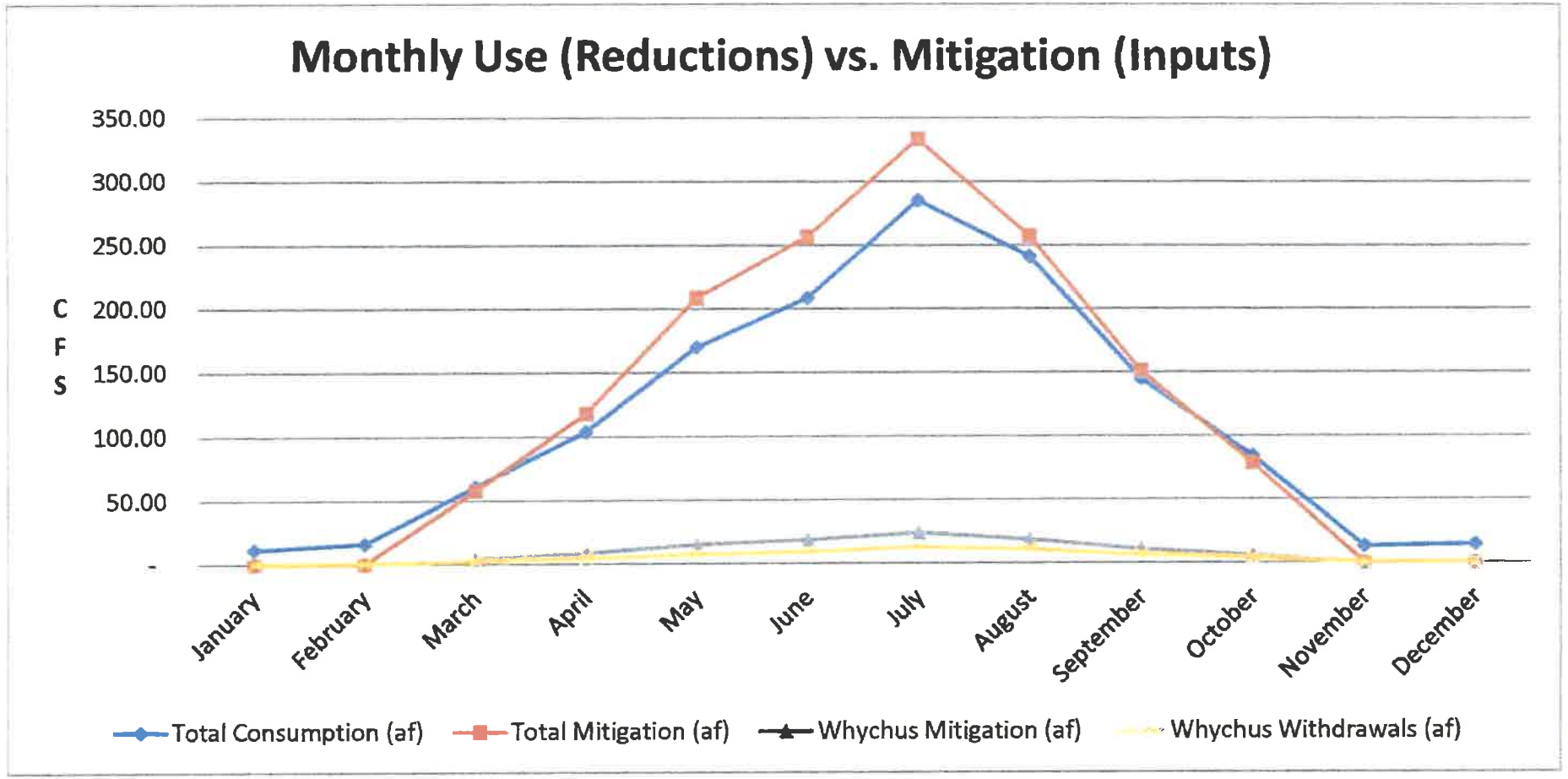

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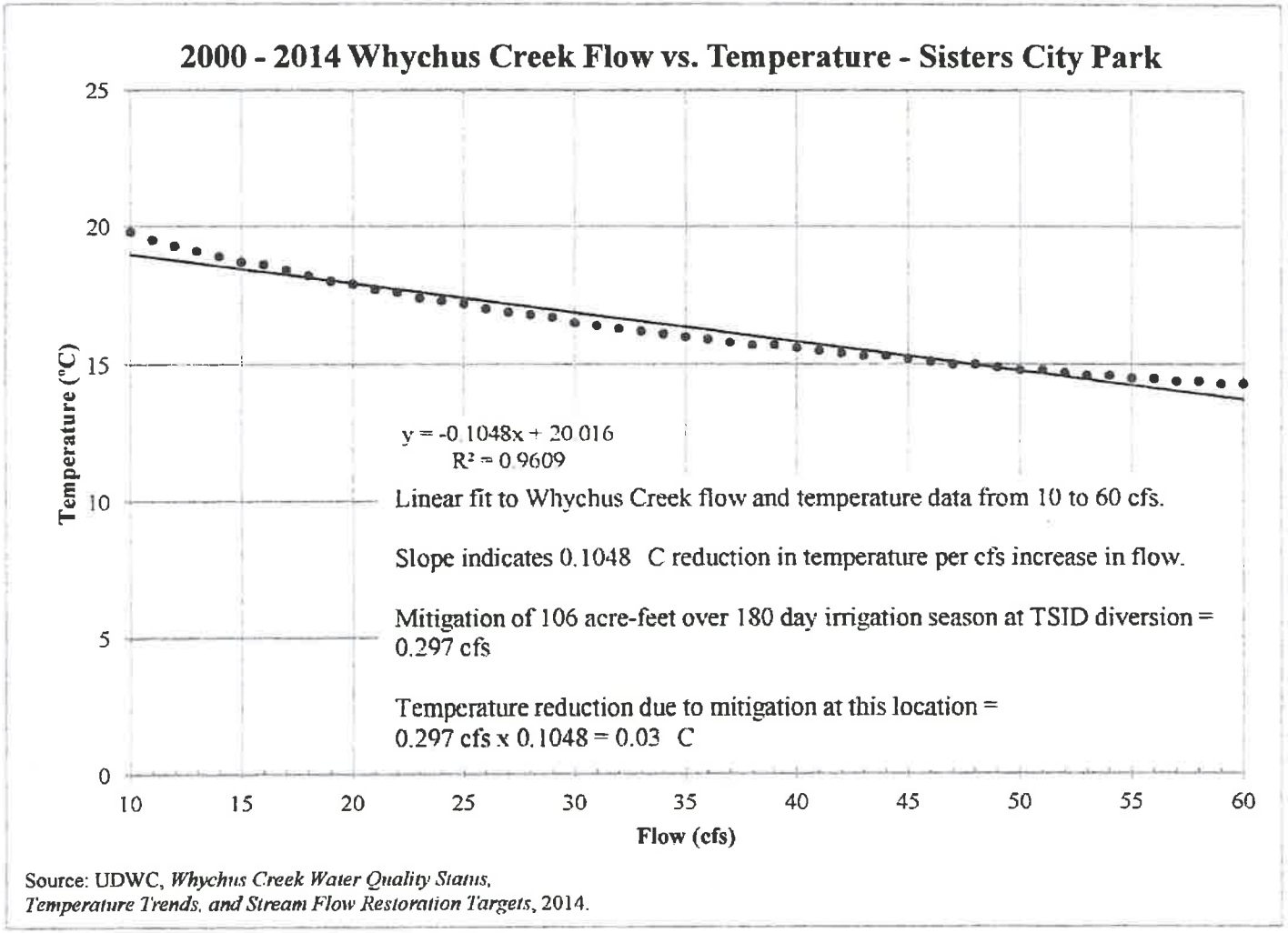
Monthly Use (Reductions) vs Mitigation (Inputs)
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO.	FIGURE
S. Yankey	S. Schenck	Oct 2015	1130-101	1



Source: UDWC, *Whychus Creek Water Quality Status, Temperature Trends, and Stream Flow Restoration Targets*, 2014.

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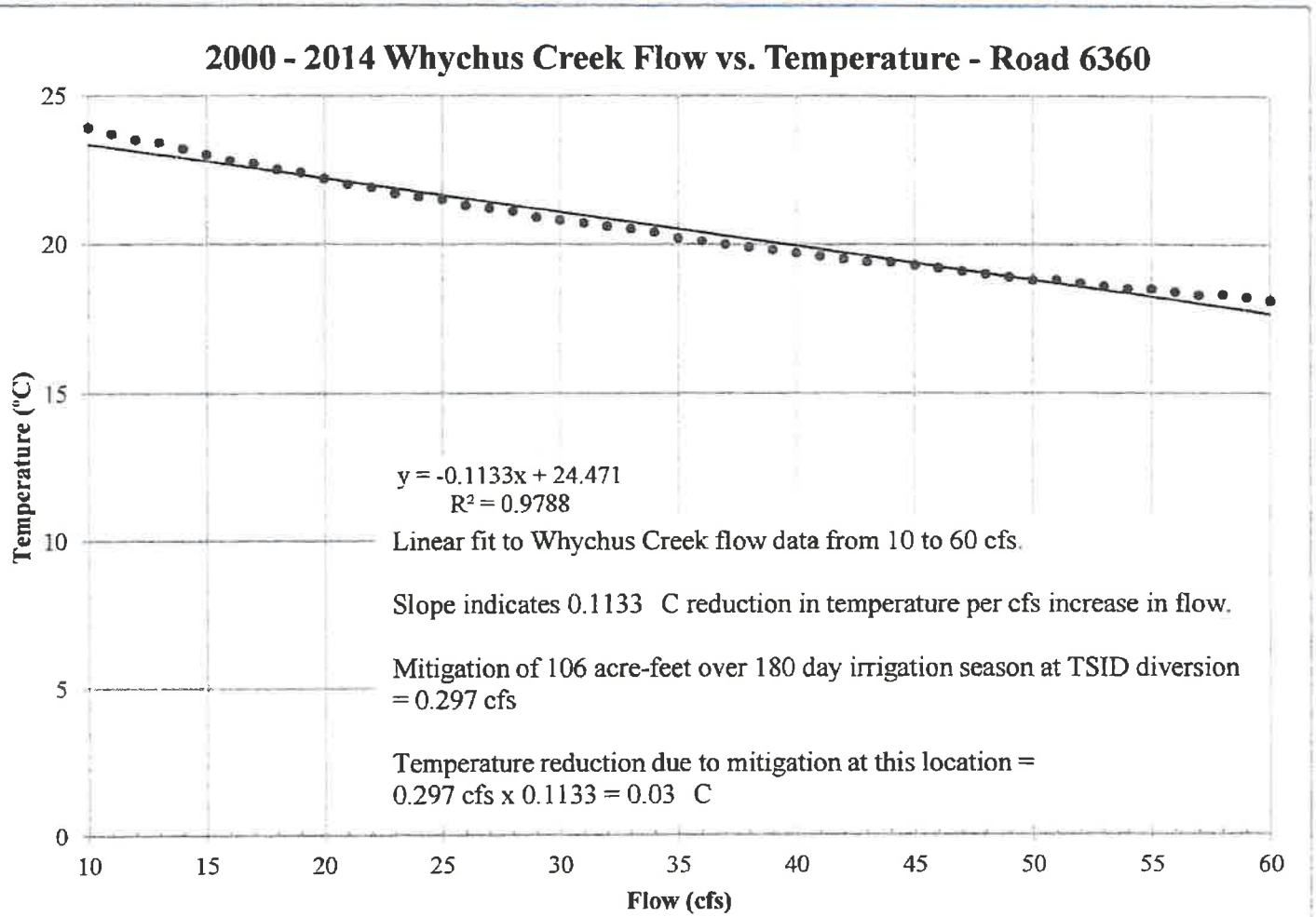
Wychus Mitigation Temperature Reduction, Road 6360
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO.	FIGURE
S. Yankey	S. Schenck	Oct 2015	1130-101	2

LUBA NO. 2015-107



Source: UDWC, *Whychus Creek Water Quality Status, Temperature Trends, and Stream Flow Restoration Targets*, 2014.

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Wychus Mitigation Temperature Reduction, Sisters Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	FIGURE
S. Yankey	S. Schenck	Oct 2015	1130-101	3

LUBA NO. 2015-107

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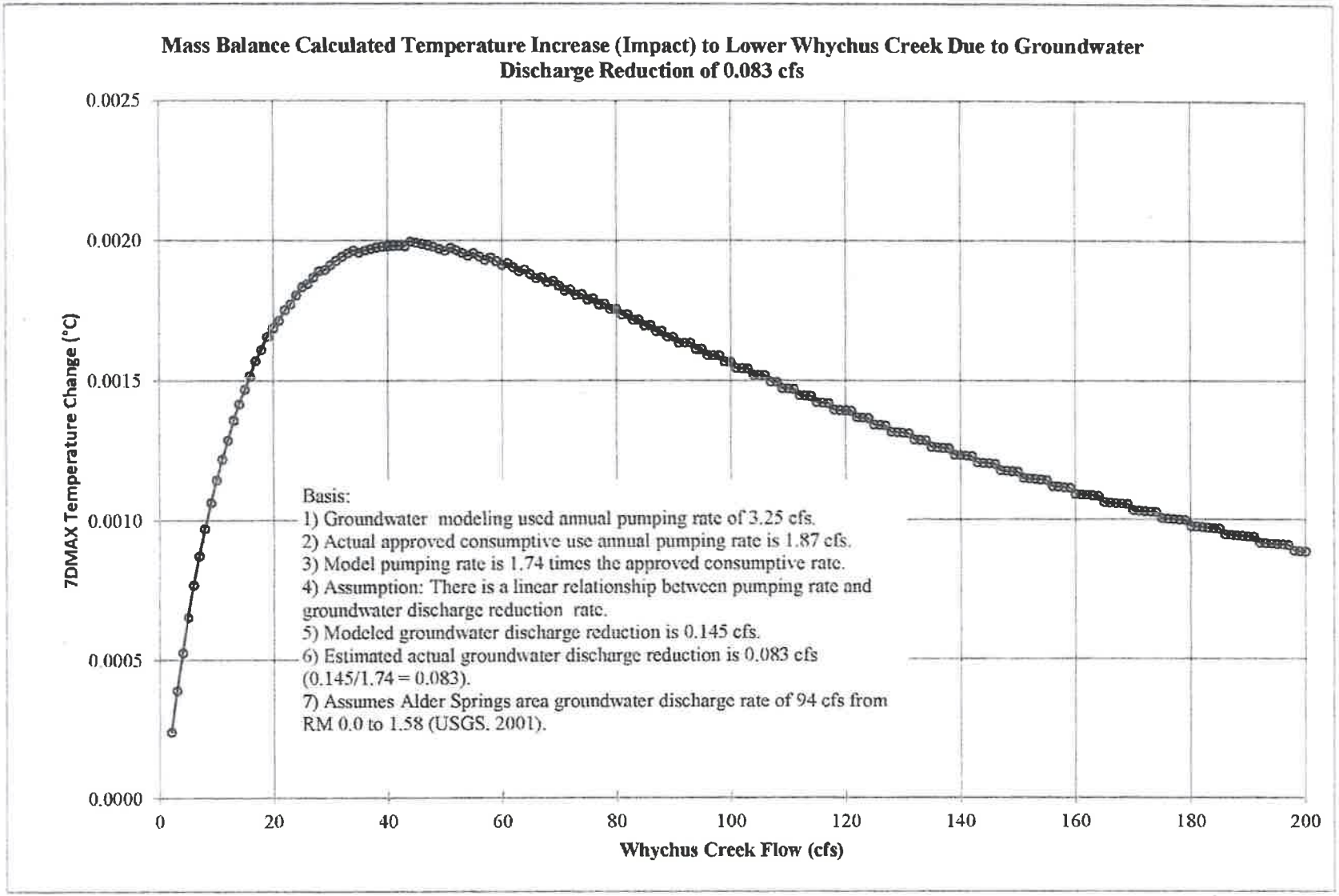

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Mass Balance Discharge Reduction of 0.083 cfs
Thornburgh Resort
Deschutes County, Oregon

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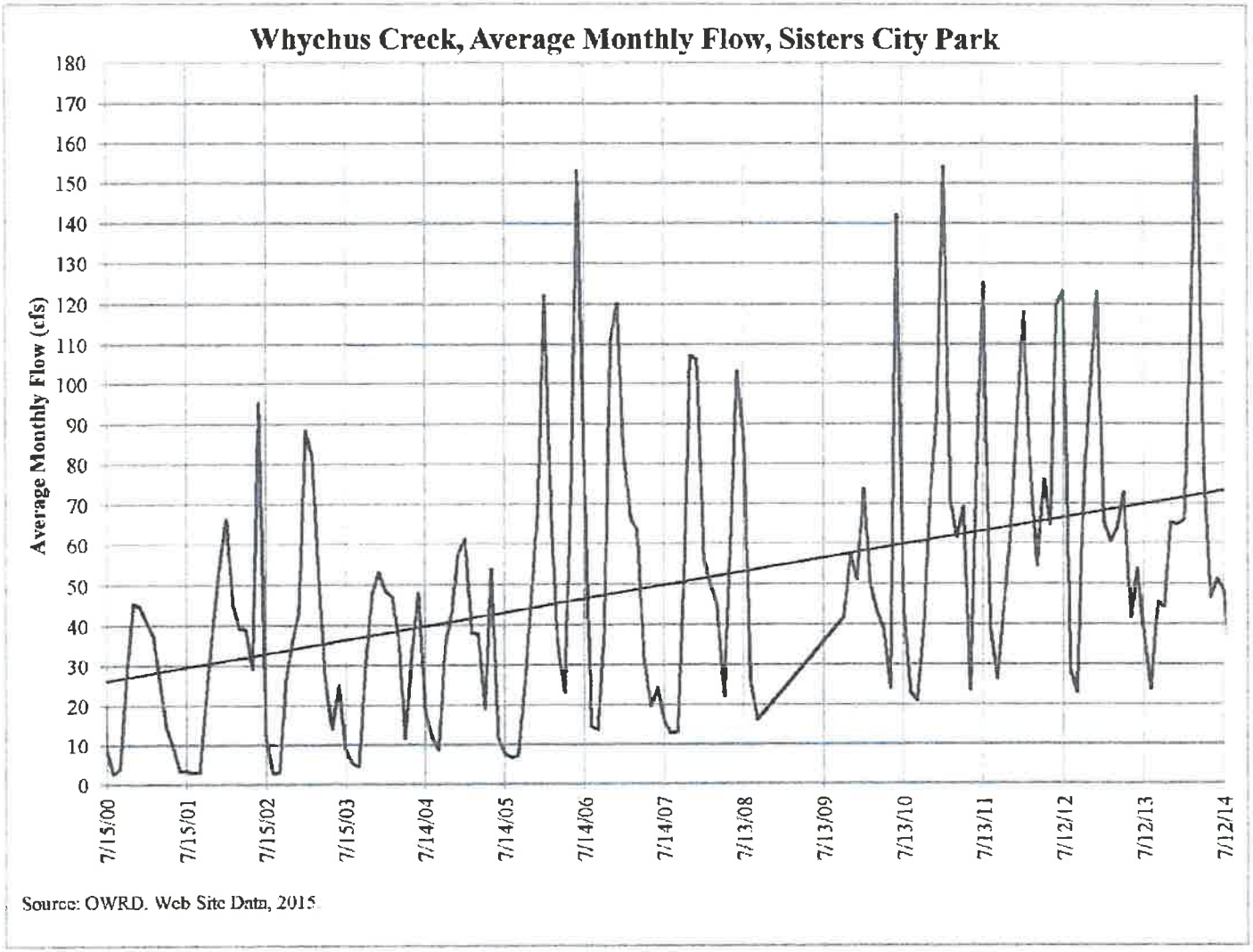

Source: OWRD. Web Site Data, 2015

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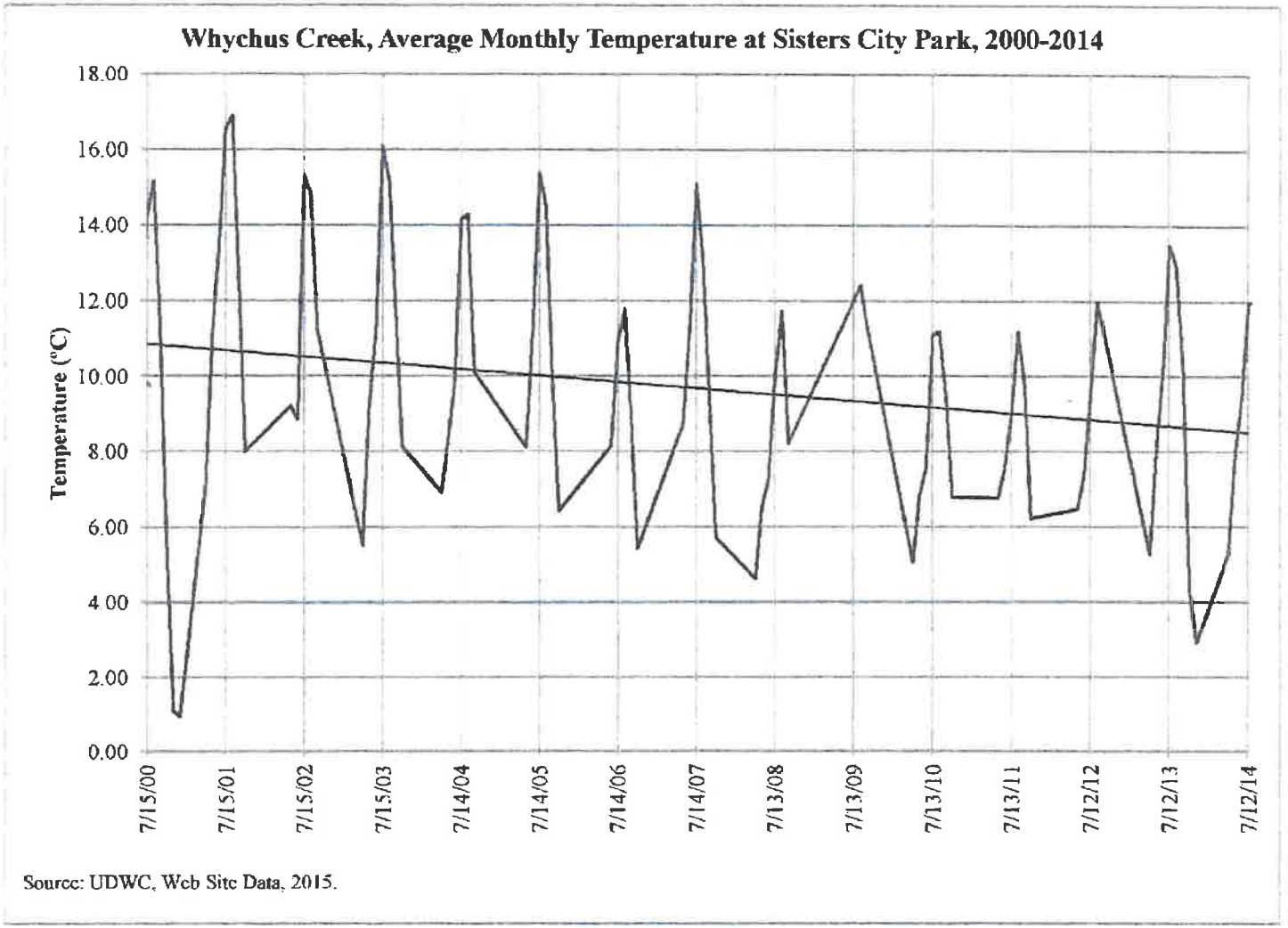
Wychus Creek Flow Trend, 2000-2014
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO.	FIGURE
S. Yankey	S. Schenck	Oct 2015	1130-101	5



Source: UDWC, Web Site Data, 2015.

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Wychus Creek Temperature Trend, 2000-2014
Thornburgh Resort
Deschutes County, Oregon

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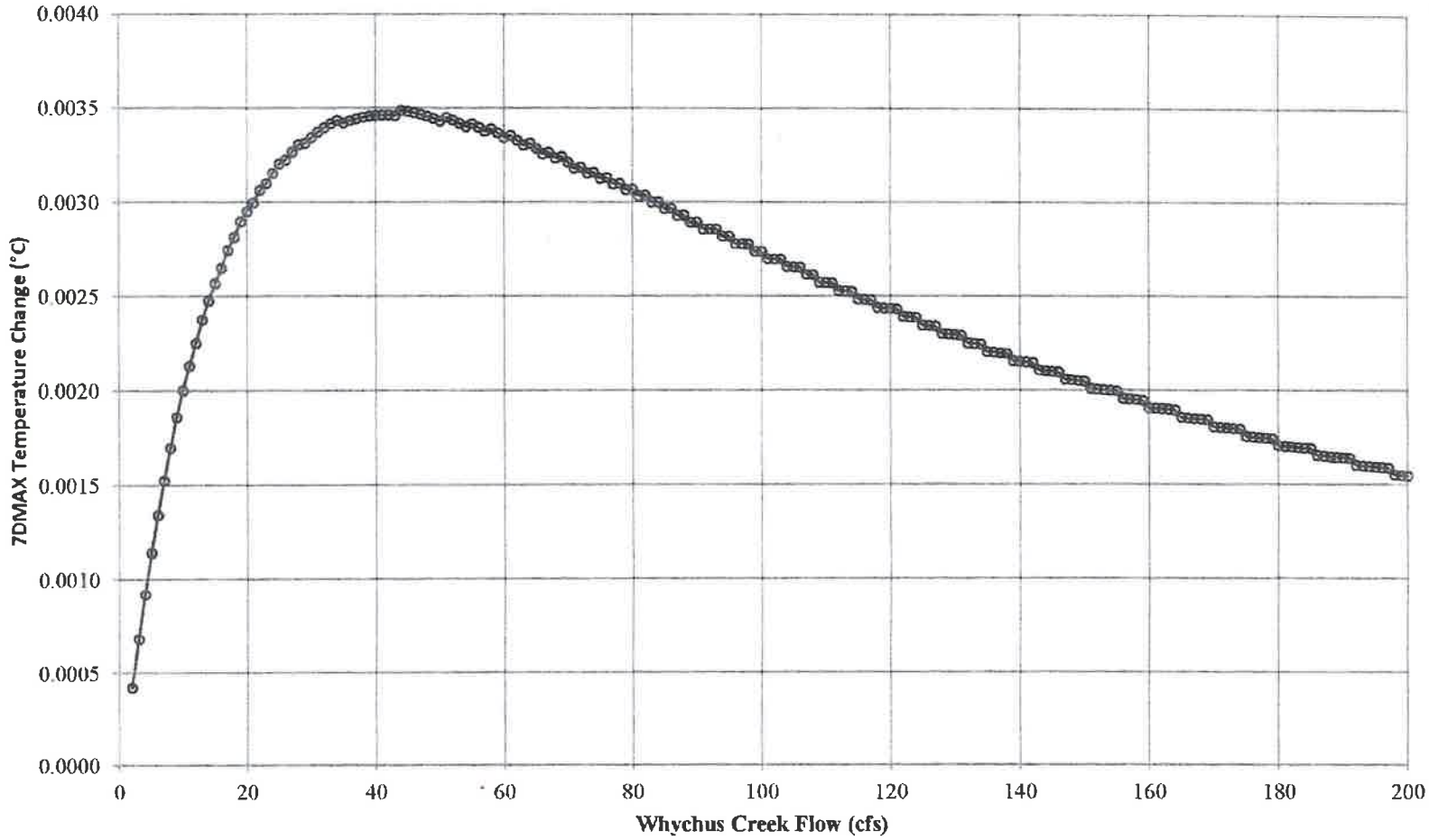
Mass Balance Calculated Temperature Increase (Impact) to Lower Whychus Creek Due to Groundwater Discharge Reduction of 0.145 cfs



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Mass Balance Discharge Reduction of 0.145 cfs
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO
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ATTACHMENT 2

Tables

	MITIGATION AMOUNTS						AG USAGE				QUASI MUNI USE		TOTAL USAGE DATA		WHYCHUS DATA		DESCHUTES DATA	
Month	Ag Use	Monthly COID Mit	Monthly BF Mit	Monthly Deschutes Total Mit	Monthly Whychus Total Mit	Total Monthly Mit	Monthly Golf Use	Monthly Stnd Irr Use	Monthly Res. Use	Total Monthly Ag Use	Monthly QM %	Monthly QM Use	Total Use Ag + QM	Difference	Whychus Use	Difference	Deschutes Use	Difference
January		0 00		0 00		0 00	-	-	-	-		11 32	11 32	11.32	0 50	0 50	10 81	10 81
February		0.00		0 00		0 00	-	-	-	-		16 17	16 17	16 17	0 72	0 72	15 45	15 45
March		20 55	33 13	53.68	4 20	57 87	25.53	4 63	8.15	38 32		22 63	60 95	3 08	2 72	-1.48	58.23	4 55
April		41 97	67.65	109 63	8.57	118 20	52.15	9 46	16 65	78.26		25 87	104 13	-14 07	4 65	-3 92	99.48	-10.15
May		74 05	119 36	193 41	15 12	208.53	92 00	16 69	29 38	138.07		32 33	170 40	-38 13	7 60	-7.52	162 80	-30 61
June		91 18	146.96	238 14	18 62	256.76	113 28	20.55	36.18	170.00		38 80	208 80	-47 96	9 32	-9.30	199 48	-38.66
July		118.36	190 78	309 14	24.17	333.31	147.05	26 67	46.96	220.69		64 67	285 35	-47.96	12.73	-11.43	272.62	-36.52
August		91.40	147.31	238 71	18 66	257.37	113.55	20.60	36.26	170.41		71 13	241.54	-15.83	10 78	-7.88	230.76	-7.95
September		53 77	86.67	140 44	10.98	151 42	66 80	12 12	21.34	100.26		45 27	145.52	-5 90	6 49	-4 49	139 03	-1.41
October		27 89	44 96	72 85	5 69	78.54	34 65	6.29	11 07	52.00		32 33	84.34	5 79	3.76	-1 93	80 57	7 73
November		0 00	0 00	0 00	0 00	0 00	0 00	0.00	0 00	-		12 93	12 93	12 93	0 58	0 58	12.36	12 36
December		0 00	0 00	0 00	0 00	0 00	-	-		-		14 55	14 55	14 55	0 65	0 65	13 90	13 90
Total		519 18	836 82	1356 00	106 00	1462.00						388.00	1356.00	-106 18	68 50	-45 50		

1 Total Mitigation (af)
2 Total Consumption (af)
3 Deschutes Mitigation (af)
4 Deschutes Consumption (af)
5 Whychus Mitigation (af)
6 Whychus Withdrawals (af)

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Project Mitigation by Use
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY	DRAWN BY	DATE	PROJECT NO	
S. Yankey	S.Schenck	Oct 2015	1130-101	Table 1

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.083 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of lower Whychus (IMPACT)
138	14.9	94	9	12.51	138	14.9	93.917	9	12.51	0.001
139	14.8	94	9	12.46	139	14.8	93.917	9	12.46	0.001
140	14.8	94	9	12.47	140	14.8	93.917	9	12.47	0.001
141	14.8	94	9	12.48	141	14.8	93.917	9	12.48	0.001
142	14.8	94	9	12.49	142	14.8	93.917	9	12.49	0.001
143	14.7	94	9	12.44	143	14.7	93.917	9	12.44	0.001
144	14.7	94	9	12.45	144	14.7	93.917	9	12.45	0.001
145	14.7	94	9	12.46	145	14.7	93.917	9	12.46	0.001
146	14.7	94	9	12.47	146	14.7	93.917	9	12.47	0.001
147	14.6	94	9	12.42	147	14.6	93.917	9	12.42	0.001
148	14.6	94	9	12.42	148	14.6	93.917	9	12.43	0.001
149	14.6	94	9	12.43	149	14.6	93.917	9	12.43	0.001
150	14.6	94	9	12.44	150	14.6	93.917	9	12.44	0.001
151	14.5	94	9	12.39	151	14.5	93.917	9	12.39	0.001
152	14.5	94	9	12.40	152	14.5	93.917	9	12.40	0.001
153	14.5	94	9	12.41	153	14.5	93.917	9	12.41	0.001
154	14.5	94	9	12.42	154	14.5	93.917	9	12.42	0.001
155	14.5	94	9	12.42	155	14.5	93.917	9	12.42	0.001
156	14.4	94	9	12.37	156	14.4	93.917	9	12.37	0.001
157	14.4	94	9	12.38	157	14.4	93.917	9	12.38	0.001
158	14.4	94	9	12.39	158	14.4	93.917	9	12.39	0.001
159	14.4	94	9	12.39	159	14.4	93.917	9	12.39	0.001
160	14.3	94	9	12.34	160	14.3	93.917	9	12.34	0.001
161	14.3	94	9	12.35	161	14.3	93.917	9	12.35	0.001
162	14.3	94	9	12.35	162	14.3	93.917	9	12.35	0.001
163	14.3	94	9	12.36	163	14.3	93.917	9	12.36	0.001
164	14.3	94	9	12.37	164	14.3	93.917	9	12.37	0.001
165	14.2	94	9	12.31	165	14.2	93.917	9	12.31	0.001
166	14.2	94	9	12.32	166	14.2	93.917	9	12.32	0.001
167	14.2	94	9	12.33	167	14.2	93.917	9	12.33	0.001
168	14.2	94	9	12.33	168	14.2	93.917	9	12.34	0.001
169	14.2	94	9	12.34	169	14.2	93.917	9	12.34	0.001
170	14.1	94	9	12.28	170	14.1	93.917	9	12.29	0.001
171	14.1	94	9	12.29	171	14.1	93.917	9	12.29	0.001

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Mass Balance Calculation with 0.083 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 2 5-6
S. Yankey	S. Schenck	Oct 2015	1130-101	LUBA NO 2015-107

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.083 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of lower Whychus (IMPACT)
2	22.3	94	9	9.28	2	22.3	93.917	9	9.28	0.000
3	23.7	94	9	9.45	3	23.7	93.917	9	9.46	0.000
4	24.2	94	9	9.62	4	24.2	93.917	9	9.62	0.001
5	24.4	94	9	9.78	5	24.4	93.917	9	9.78	0.001
6	24.4	94	9	9.92	6	24.4	93.917	9	9.92	0.001
7	24.3	94	9	10.06	7	24.3	93.917	9	10.06	0.001
8	24.2	94	9	10.19	8	24.2	93.917	9	10.19	0.001
9	24.1	94	9	10.32	9	24.1	93.917	9	10.32	0.001
10	23.9	94	9	10.43	10	23.9	93.917	9	10.43	0.001
11	23.7	94	9	10.54	11	23.7	93.917	9	10.54	0.001
12	23.5	94	9	10.64	12	23.5	93.917	9	10.64	0.001
13	23.4	94	9	10.75	13	23.4	93.917	9	10.75	0.001
14	23.2	94	9	10.84	14	23.2	93.917	9	10.84	0.001
15	23.0	94	9	10.93	15	23.0	93.917	9	10.93	0.001
16	22.8	94	9	11.01	16	22.8	93.917	9	11.01	0.002
17	22.7	94	9	11.10	17	22.7	93.917	9	11.10	0.002
18	22.5	94	9	11.17	18	22.5	93.917	9	11.17	0.002
19	22.4	94	9	11.25	19	22.4	93.917	9	11.25	0.002
20	22.2	94	9	11.32	20	22.2	93.917	9	11.32	0.002
21	22.0	94	9	11.37	21	22.0	93.917	9	11.38	0.002
22	21.9	94	9	11.45	22	21.9	93.917	9	11.45	0.002
23	21.7	94	9	11.50	23	21.7	93.917	9	11.50	0.002
24	21.6	94	9	11.56	24	21.6	93.917	9	11.56	0.002
25	21.5	94	9	11.63	25	21.5	93.917	9	11.63	0.002
26	21.3	94	9	11.67	26	21.3	93.917	9	11.67	0.002
27	21.2	94	9	11.72	27	21.2	93.917	9	11.72	0.002
28	21.1	94	9	11.78	28	21.1	93.917	9	11.78	0.002
29	20.9	94	9	11.81	29	20.9	93.917	9	11.81	0.002
30	20.8	94	9	11.85	30	20.8	93.917	9	11.86	0.002
31	20.7	94	9	11.90	31	20.7	93.917	9	11.90	0.002
32	20.6	94	9	11.95	32	20.6	93.917	9	11.95	0.002
33	20.5	94	9	11.99	33	20.5	93.917	9	11.99	0.002
34	20.4	94	9	12.03	34	20.4	93.917	9	12.03	0.002
35	20.2	94	9	12.04	35	20.2	93.917	9	12.04	0.002

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Mass Balance Calculation with 0.083 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 2 1-6
S. Yankey	S. Schenck	Oct 2015	1130-101	LUBA NO 2015-107

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.083 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of lower Whychus (IMPACT)
36	20.1	94	9	12.07	36	20.1	93.917	9	12.08	0.002
37	20.0	94	9	12.11	37	20.0	93.917	9	12.11	0.002
38	19.9	94	9	12.14	38	19.9	93.917	9	12.14	0.002
39	19.8	94	9	12.17	39	19.8	93.917	9	12.17	0.002
40	19.7	94	9	12.19	40	19.7	93.917	9	12.20	0.002
41	19.6	94	9	12.22	41	19.6	93.917	9	12.22	0.002
42	19.5	94	9	12.24	42	19.5	93.917	9	12.24	0.002
43	19.4	94	9	12.26	43	19.4	93.917	9	12.27	0.002
44	19.4	94	9	12.32	44	19.4	93.917	9	12.32	0.002
45	19.3	94	9	12.33	45	19.3	93.917	9	12.34	0.002
46	19.2	94	9	12.35	46	19.2	93.917	9	12.35	0.002
47	19.1	94	9	12.37	47	19.1	93.917	9	12.37	0.002
48	19.0	94	9	12.38	48	19.0	93.917	9	12.38	0.002
49	18.9	94	9	12.39	49	18.9	93.917	9	12.39	0.002
50	18.8	94	9	12.40	50	18.8	93.917	9	12.40	0.002
51	18.8	94	9	12.45	51	18.8	93.917	9	12.45	0.002
52	18.7	94	9	12.45	52	18.7	93.917	9	12.46	0.002
53	18.6	94	9	12.46	53	18.6	93.917	9	12.46	0.002
54	18.5	94	9	12.47	54	18.5	93.917	9	12.47	0.002
55	18.5	94	9	12.51	55	18.5	93.917	9	12.51	0.002
56	18.4	94	9	12.51	56	18.4	93.917	9	12.51	0.002
57	18.3	94	9	12.51	57	18.3	93.917	9	12.51	0.002
58	18.3	94	9	12.55	58	18.3	93.917	9	12.55	0.002
59	18.2	94	9	12.55	59	18.2	93.917	9	12.55	0.002
60	18.1	94	9	12.55	60	18.1	93.917	9	12.55	0.002
61	18.1	94	9	12.58	61	18.1	93.917	9	12.58	0.002
62	18.0	94	9	12.58	62	18.0	93.917	9	12.58	0.002
63	17.9	94	9	12.57	63	17.9	93.917	9	12.57	0.002
64	17.9	94	9	12.61	64	17.9	93.917	9	12.61	0.002
65	17.8	94	9	12.60	65	17.8	93.917	9	12.60	0.002
66	17.7	94	9	12.59	66	17.7	93.917	9	12.59	0.002
67	17.7	94	9	12.62	67	17.7	93.917	9	12.62	0.002
68	17.6	94	9	12.61	68	17.6	93.917	9	12.61	0.002
69	17.6	94	9	12.64	69	17.6	93.917	9	12.64	0.002

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Mass Balance Calculation with 0.083 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 2
S. Yankey	S. Schenck	Oct 2015	1130-101	2-6

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.083 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of lower Whychus (IMPACT)
70	17.5	94	9	12.63	70	17.5	93.917	9	12.63	0.002
71	17.4	94	9	12.61	71	17.4	93.917	9	12.62	0.002
72	17.4	94	9	12.64	72	17.4	93.917	9	12.65	0.002
73	17.3	94	9	12.63	73	17.3	93.917	9	12.63	0.002
74	17.3	94	9	12.66	74	17.3	93.917	9	12.66	0.002
75	17.2	94	9	12.64	75	17.2	93.917	9	12.64	0.002
76	17.2	94	9	12.67	76	17.2	93.917	9	12.67	0.002
77	17.1	94	9	12.65	77	17.1	93.917	9	12.65	0.002
78	17.1	94	9	12.67	78	17.1	93.917	9	12.68	0.002
79	17.0	94	9	12.65	79	17.0	93.917	9	12.65	0.002
80	17.0	94	9	12.68	80	17.0	93.917	9	12.68	0.002
81	16.9	94	9	12.66	81	16.9	93.917	9	12.66	0.002
82	16.9	94	9	12.68	82	16.9	93.917	9	12.68	0.002
83	16.8	94	9	12.66	83	16.8	93.917	9	12.66	0.002
84	16.8	94	9	12.68	84	16.8	93.917	9	12.68	0.002
85	16.7	94	9	12.66	85	16.7	93.917	9	12.66	0.002
86	16.7	94	9	12.68	86	16.7	93.917	9	12.68	0.002
87	16.6	94	9	12.65	87	16.6	93.917	9	12.65	0.002
88	16.6	94	9	12.67	88	16.6	93.917	9	12.68	0.002
89	16.5	94	9	12.65	89	16.5	93.917	9	12.65	0.002
90	16.5	94	9	12.67	90	16.5	93.917	9	12.67	0.002
91	16.4	94	9	12.64	91	16.4	93.917	9	12.64	0.002
92	16.4	94	9	12.66	92	16.4	93.917	9	12.66	0.002
93	16.4	94	9	12.68	93	16.4	93.917	9	12.68	0.002
94	16.3	94	9	12.65	94	16.3	93.917	9	12.65	0.002
95	16.3	94	9	12.67	95	16.3	93.917	9	12.67	0.002
96	16.2	94	9	12.64	96	16.2	93.917	9	12.64	0.002
97	16.2	94	9	12.66	97	16.2	93.917	9	12.66	0.002
98	16.2	94	9	12.68	98	16.2	93.917	9	12.68	0.002
99	16.1	94	9	12.64	99	16.1	93.917	9	12.64	0.002
100	16.1	94	9	12.66	100	16.1	93.917	9	12.66	0.002
101	16.0	94	9	12.63	101	16.0	93.917	9	12.63	0.002
102	16.0	94	9	12.64	102	16.0	93.917	9	12.64	0.002
103	16.0	94	9	12.66	103	16.0	93.917	9	12.66	0.002

NEWTON CONSULTANTS INC.
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Mass Balance Calculation with 0.083 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 2 3-6
S. Yankey	S. Schenck	Oct 2015	1130-101	LUBA NO. 2015-107

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.083 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of lower Whychus (IMPACT)
104	15.9	94	9	12.62	104	15.9	93.917	9	12.63	0.002
105	15.9	94	9	12.64	105	15.9	93.917	9	12.64	0.002
106	15.9	94	9	12.66	106	15.9	93.917	9	12.66	0.002
107	15.8	94	9	12.62	107	15.8	93.917	9	12.62	0.001
108	15.8	94	9	12.64	108	15.8	93.917	9	12.64	0.001
109	15.7	94	9	12.60	109	15.7	93.917	9	12.60	0.001
110	15.7	94	9	12.61	110	15.7	93.917	9	12.61	0.001
111	15.7	94	9	12.63	111	15.7	93.917	9	12.63	0.001
112	15.6	94	9	12.59	112	15.6	93.917	9	12.59	0.001
113	15.6	94	9	12.60	113	15.6	93.917	9	12.60	0.001
114	15.6	94	9	12.62	114	15.6	93.917	9	12.62	0.001
115	15.5	94	9	12.58	115	15.5	93.917	9	12.58	0.001
116	15.5	94	9	12.59	116	15.5	93.917	9	12.59	0.001
117	15.5	94	9	12.60	117	15.5	93.917	9	12.61	0.001
118	15.4	94	9	12.56	118	15.4	93.917	9	12.56	0.001
119	15.4	94	9	12.58	119	15.4	93.917	9	12.58	0.001
120	15.4	94	9	12.59	120	15.4	93.917	9	12.59	0.001
121	15.4	94	9	12.60	121	15.4	93.917	9	12.60	0.001
122	15.3	94	9	12.56	122	15.3	93.917	9	12.56	0.001
123	15.3	94	9	12.57	123	15.3	93.917	9	12.57	0.001
124	15.3	94	9	12.58	124	15.3	93.917	9	12.58	0.001
125	15.2	94	9	12.54	125	15.2	93.917	9	12.54	0.001
126	15.2	94	9	12.55	126	15.2	93.917	9	12.55	0.001
127	15.2	94	9	12.56	127	15.2	93.917	9	12.56	0.001
128	15.1	94	9	12.52	128	15.1	93.917	9	12.52	0.001
129	15.1	94	9	12.53	129	15.1	93.917	9	12.53	0.001
130	15.1	94	9	12.54	130	15.1	93.917	9	12.54	0.001
131	15.1	94	9	12.55	131	15.1	93.917	9	12.55	0.001
132	15.0	94	9	12.50	132	15.0	93.917	9	12.51	0.001
133	15.0	94	9	12.52	133	15.0	93.917	9	12.52	0.001
134	15.0	94	9	12.53	134	15.0	93.917	9	12.53	0.001
135	14.9	94	9	12.48	135	14.9	93.917	9	12.48	0.001
136	14.9	94	9	12.49	136	14.9	93.917	9	12.49	0.001
137	14.9	94	9	12.50	137	14.9	93.917	9	12.50	0.001

NEWTON CONSULTANTS INC.
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Mass Balance Calculation with 0.083 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY	DATE	PROJECT NO	
S. Yankey	S. Schenck	Oct 2015	1130-101	Table 2 4-6

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.083 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of lower Whychus (IMPACT)
172	14.1	94	9	12.30	172	14.1	93.917	9	12.30	0.001
173	14.1	94	9	12.30	173	14.1	93.917	9	12.31	0.001
174	14.1	94	9	12.31	174	14.1	93.917	9	12.31	0.001
175	14.0	94	9	12.25	175	14.0	93.917	9	12.25	0.001
176	14.0	94	9	12.26	176	14.0	93.917	9	12.26	0.001
177	14.0	94	9	12.27	177	14.0	93.917	9	12.27	0.001
178	14.0	94	9	12.27	178	14.0	93.917	9	12.27	0.001
179	14.0	94	9	12.28	179	14.0	93.917	9	12.28	0.001
180	13.9	94	9	12.22	180	13.9	93.917	9	12.22	0.001
181	13.9	94	9	12.23	181	13.9	93.917	9	12.23	0.001
182	13.9	94	9	12.23	182	13.9	93.917	9	12.23	0.001
183	13.9	94	9	12.24	183	13.9	93.917	9	12.24	0.001
184	13.9	94	9	12.24	184	13.9	93.917	9	12.24	0.001
185	13.9	94	9	12.25	185	13.9	93.917	9	12.25	0.001
186	13.8	94	9	12.19	186	13.8	93.917	9	12.19	0.001
187	13.8	94	9	12.19	187	13.8	93.917	9	12.20	0.001
188	13.8	94	9	12.20	188	13.8	93.917	9	12.20	0.001
189	13.8	94	9	12.21	189	13.8	93.917	9	12.21	0.001
190	13.8	94	9	12.21	190	13.8	93.917	9	12.21	0.001
191	13.8	94	9	12.22	191	13.8	93.917	9	12.22	0.001
192	13.7	94	9	12.16	192	13.7	93.917	9	12.16	0.001
193	13.7	94	9	12.16	193	13.7	93.917	9	12.16	0.001
194	13.7	94	9	12.17	194	13.7	93.917	9	12.17	0.001
195	13.7	94	9	12.17	195	13.7	93.917	9	12.17	0.001
196	13.7	94	9	12.18	196	13.7	93.917	9	12.18	0.001
197	13.7	94	9	12.18	197	13.7	93.917	9	12.18	0.001
198	13.6	94	9	12.12	198	13.6	93.917	9	12.12	0.001
199	13.6	94	9	12.12	199	13.6	93.917	9	12.13	0.001
200	13.6	94	9	12.13	200	13.6	93.917	9	12.13	0.001

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Mass Balance Calculation with 0.083 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 2 6-6
S. Yankey	S. Schenck	Oct 2015	1130-101	

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.145 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of Upper Reach lower Whychus (IMPACT)
2	22.3	94	9	9.28	2	22.3	93.855	9	9.28	0.000
3	23.7	94	9	9.45	3	23.7	93.855	9	9.46	0.001
4	24.2	94	9	9.62	4	24.2	93.855	9	9.62	0.001
5	24.4	94	9	9.78	5	24.4	93.855	9	9.78	0.001
6	24.4	94	9	9.92	6	24.4	93.855	9	9.93	0.001
7	24.3	94	9	10.06	7	24.3	93.855	9	10.06	0.002
8	24.2	94	9	10.19	8	24.2	93.855	9	10.19	0.002
9	24.1	94	9	10.32	9	24.1	93.855	9	10.32	0.002
10	23.9	94	9	10.43	10	23.9	93.855	9	10.43	0.002
11	23.7	94	9	10.54	11	23.7	93.855	9	10.54	0.002
12	23.5	94	9	10.64	12	23.5	93.855	9	10.64	0.002
13	23.4	94	9	10.75	13	23.4	93.855	9	10.75	0.002
14	23.2	94	9	10.84	14	23.2	93.855	9	10.84	0.002
15	23.0	94	9	10.93	15	23.0	93.855	9	10.93	0.003
16	22.8	94	9	11.01	16	22.8	93.855	9	11.01	0.003
17	22.7	94	9	11.10	17	22.7	93.855	9	11.10	0.003
18	22.5	94	9	11.17	18	22.5	93.855	9	11.17	0.003
19	22.4	94	9	11.25	19	22.4	93.855	9	11.26	0.003
20	22.2	94	9	11.32	20	22.2	93.855	9	11.32	0.003
21	22.0	94	9	11.37	21	22.0	93.855	9	11.38	0.003
22	21.9	94	9	11.45	22	21.9	93.855	9	11.45	0.003
23	21.7	94	9	11.50	23	21.7	93.855	9	11.50	0.003
24	21.6	94	9	11.56	24	21.6	93.855	9	11.57	0.003
25	21.5	94	9	11.63	25	21.5	93.855	9	11.63	0.003
26	21.3	94	9	11.67	26	21.3	93.855	9	11.67	0.003
27	21.2	94	9	11.72	27	21.2	93.855	9	11.73	0.003
28	21.1	94	9	11.78	28	21.1	93.855	9	11.78	0.003
29	20.9	94	9	11.81	29	20.9	93.855	9	11.81	0.003
30	20.8	94	9	11.85	30	20.8	93.855	9	11.86	0.003
31	20.7	94	9	11.90	31	20.7	93.855	9	11.90	0.003
32	20.6	94	9	11.95	32	20.6	93.855	9	11.95	0.003
33	20.5	94	9	11.99	33	20.5	93.855	9	11.99	0.003
34	20.4	94	9	12.03	34	20.4	93.855	9	12.03	0.003
35	20.2	94	9	12.04	35	20.2	93.855	9	12.04	0.003

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Mass Balance Calculation with 0.145 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 3 1-6
S. Yankey	S. Schenck	Oct 2015	1130-101	

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.145 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of Upper Reach lower Whychus (IMPACT)
36	20.1	94	9	12.07	36	20.1	93.855	9	12.08	0.003
37	20.0	94	9	12.11	37	20.0	93.855	9	12.11	0.003
38	19.9	94	9	12.14	38	19.9	93.855	9	12.14	0.003
39	19.8	94	9	12.17	39	19.8	93.855	9	12.17	0.003
40	19.7	94	9	12.19	40	19.7	93.855	9	12.20	0.003
41	19.6	94	9	12.22	41	19.6	93.855	9	12.22	0.003
42	19.5	94	9	12.24	42	19.5	93.855	9	12.25	0.003
43	19.4	94	9	12.26	43	19.4	93.855	9	12.27	0.003
44	19.4	94	9	12.32	44	19.4	93.855	9	12.32	0.003
45	19.3	94	9	12.33	45	19.3	93.855	9	12.34	0.003
46	19.2	94	9	12.35	46	19.2	93.855	9	12.35	0.003
47	19.1	94	9	12.37	47	19.1	93.855	9	12.37	0.003
48	19.0	94	9	12.38	48	19.0	93.855	9	12.38	0.003
49	18.9	94	9	12.39	49	18.9	93.855	9	12.40	0.003
50	18.8	94	9	12.40	50	18.8	93.855	9	12.41	0.003
51	18.8	94	9	12.45	51	18.8	93.855	9	12.45	0.003
52	18.7	94	9	12.45	52	18.7	93.855	9	12.46	0.003
53	18.6	94	9	12.46	53	18.6	93.855	9	12.46	0.003
54	18.5	94	9	12.47	54	18.5	93.855	9	12.47	0.003
55	18.5	94	9	12.51	55	18.5	93.855	9	12.51	0.003
56	18.4	94	9	12.51	56	18.4	93.855	9	12.51	0.003
57	18.3	94	9	12.51	57	18.3	93.855	9	12.51	0.003
58	18.3	94	9	12.55	58	18.3	93.855	9	12.55	0.003
59	18.2	94	9	12.55	59	18.2	93.855	9	12.55	0.003
60	18.1	94	9	12.55	60	18.1	93.855	9	12.55	0.003
61	18.1	94	9	12.58	61	18.1	93.855	9	12.58	0.003
62	18.0	94	9	12.58	62	18.0	93.855	9	12.58	0.003
63	17.9	94	9	12.57	63	17.9	93.855	9	12.57	0.003
64	17.9	94	9	12.61	64	17.9	93.855	9	12.61	0.003
65	17.8	94	9	12.60	65	17.8	93.855	9	12.60	0.003
66	17.7	94	9	12.59	66	17.7	93.855	9	12.59	0.003
67	17.7	94	9	12.62	67	17.7	93.855	9	12.62	0.003
68	17.6	94	9	12.61	68	17.6	93.855	9	12.61	0.003
69	17.6	94	9	12.64	69	17.6	93.855	9	12.64	0.003

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Mass Balance Calculation with 0.145 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 3 2-6
S. Yankey	S. Schenck	Oct 2015	1130-101	LUBA NO. 2015-107

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.145 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of Upper Reach lower Whychus (IMPACT)
70	17.5	94	9	12.63	70	17.5	93.855	9	12.63	0.003
71	17.4	94	9	12.61	71	17.4	93.855	9	12.62	0.003
72	17.4	94	9	12.64	72	17.4	93.855	9	12.65	0.003
73	17.3	94	9	12.63	73	17.3	93.855	9	12.63	0.003
74	17.3	94	9	12.66	74	17.3	93.855	9	12.66	0.003
75	17.2	94	9	12.64	75	17.2	93.855	9	12.64	0.003
76	17.2	94	9	12.67	76	17.2	93.855	9	12.67	0.003
77	17.1	94	9	12.65	77	17.1	93.855	9	12.65	0.003
78	17.1	94	9	12.67	78	17.1	93.855	9	12.68	0.003
79	17.0	94	9	12.65	79	17.0	93.855	9	12.66	0.003
80	17.0	94	9	12.68	80	17.0	93.855	9	12.68	0.003
81	16.9	94	9	12.66	81	16.9	93.855	9	12.66	0.003
82	16.9	94	9	12.68	82	16.9	93.855	9	12.68	0.003
83	16.8	94	9	12.66	83	16.8	93.855	9	12.66	0.003
84	16.8	94	9	12.68	84	16.8	93.855	9	12.68	0.003
85	16.7	94	9	12.66	85	16.7	93.855	9	12.66	0.003
86	16.7	94	9	12.68	86	16.7	93.855	9	12.68	0.003
87	16.6	94	9	12.65	87	16.6	93.855	9	12.66	0.003
88	16.6	94	9	12.67	88	16.6	93.855	9	12.68	0.003
89	16.5	94	9	12.65	89	16.5	93.855	9	12.65	0.003
90	16.5	94	9	12.67	90	16.5	93.855	9	12.67	0.003
91	16.4	94	9	12.64	91	16.4	93.855	9	12.64	0.003
92	16.4	94	9	12.66	92	16.4	93.855	9	12.66	0.003
93	16.4	94	9	12.68	93	16.4	93.855	9	12.68	0.003
94	16.3	94	9	12.65	94	16.3	93.855	9	12.65	0.003
95	16.3	94	9	12.67	95	16.3	93.855	9	12.67	0.003
96	16.2	94	9	12.64	96	16.2	93.855	9	12.64	0.003
97	16.2	94	9	12.66	97	16.2	93.855	9	12.66	0.003
98	16.2	94	9	12.68	98	16.2	93.855	9	12.68	0.003
99	16.1	94	9	12.64	99	16.1	93.855	9	12.64	0.003
100	16.1	94	9	12.66	100	16.1	93.855	9	12.66	0.003
101	16.0	94	9	12.63	101	16.0	93.855	9	12.63	0.003
102	16.0	94	9	12.64	102	16.0	93.855	9	12.65	0.003
103	16.0	94	9	12.66	103	16.0	93.855	9	12.66	0.003

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Mass Balance Calculation with 0.145 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 3 3-6
S. Yankey	S. Schenck	Oct 2015	1130-101	LUBA NO. 2015-107

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.145 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of Upper Reach lower Whychus (IMPACT)
104	15.9	94	9	12.62	104	15.9	93.855	9	12.63	0.003
105	15.9	94	9	12.64	105	15.9	93.855	9	12.64	0.003
106	15.9	94	9	12.66	106	15.9	93.855	9	12.66	0.003
107	15.8	94	9	12.62	107	15.8	93.855	9	12.62	0.003
108	15.8	94	9	12.64	108	15.8	93.855	9	12.64	0.003
109	15.7	94	9	12.60	109	15.7	93.855	9	12.60	0.003
110	15.7	94	9	12.61	110	15.7	93.855	9	12.62	0.003
111	15.7	94	9	12.63	111	15.7	93.855	9	12.63	0.003
112	15.6	94	9	12.59	112	15.6	93.855	9	12.59	0.003
113	15.6	94	9	12.60	113	15.6	93.855	9	12.61	0.003
114	15.6	94	9	12.62	114	15.6	93.855	9	12.62	0.003
115	15.5	94	9	12.58	115	15.5	93.855	9	12.58	0.002
116	15.5	94	9	12.59	116	15.5	93.855	9	12.59	0.002
117	15.5	94	9	12.60	117	15.5	93.855	9	12.61	0.002
118	15.4	94	9	12.56	118	15.4	93.855	9	12.56	0.002
119	15.4	94	9	12.58	119	15.4	93.855	9	12.58	0.002
120	15.4	94	9	12.59	120	15.4	93.855	9	12.59	0.002
121	15.4	94	9	12.60	121	15.4	93.855	9	12.60	0.002
122	15.3	94	9	12.56	122	15.3	93.855	9	12.56	0.002
123	15.3	94	9	12.57	123	15.3	93.855	9	12.57	0.002
124	15.3	94	9	12.58	124	15.3	93.855	9	12.59	0.002
125	15.2	94	9	12.54	125	15.2	93.855	9	12.54	0.002
126	15.2	94	9	12.55	126	15.2	93.855	9	12.55	0.002
127	15.2	94	9	12.56	127	15.2	93.855	9	12.57	0.002
128	15.1	94	9	12.52	128	15.1	93.855	9	12.52	0.002
129	15.1	94	9	12.53	129	15.1	93.855	9	12.53	0.002
130	15.1	94	9	12.54	130	15.1	93.855	9	12.54	0.002
131	15.1	94	9	12.55	131	15.1	93.855	9	12.55	0.002
132	15.0	94	9	12.50	132	15.0	93.855	9	12.51	0.002
133	15.0	94	9	12.52	133	15.0	93.855	9	12.52	0.002
134	15.0	94	9	12.53	134	15.0	93.855	9	12.53	0.002
135	14.9	94	9	12.48	135	14.9	93.855	9	12.48	0.002
136	14.9	94	9	12.49	136	14.9	93.855	9	12.49	0.002
137	14.9	94	9	12.50	137	14.9	93.855	9	12.50	0.002

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Mass Balance Calculation with 0.145 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO.	Table 3 4-6
S. Yankey	S. Schenck	Oct 2015	1130-101	

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.145 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of Upper Reach lower Whychus (IMPACT)
138	14.9	94	9	12.51	138	14.9	93.855	9	12.51	0.002
139	14.8	94	9	12.46	139	14.8	93.855	9	12.46	0.002
140	14.8	94	9	12.47	140	14.8	93.855	9	12.47	0.002
141	14.8	94	9	12.48	141	14.8	93.855	9	12.48	0.002
142	14.8	94	9	12.49	142	14.8	93.855	9	12.49	0.002
143	14.7	94	9	12.44	143	14.7	93.855	9	12.44	0.002
144	14.7	94	9	12.45	144	14.7	93.855	9	12.45	0.002
145	14.7	94	9	12.46	145	14.7	93.855	9	12.46	0.002
146	14.7	94	9	12.47	146	14.7	93.855	9	12.47	0.002
147	14.6	94	9	12.42	147	14.6	93.855	9	12.42	0.002
148	14.6	94	9	12.42	148	14.6	93.855	9	12.43	0.002
149	14.6	94	9	12.43	149	14.6	93.855	9	12.44	0.002
150	14.6	94	9	12.44	150	14.6	93.855	9	12.44	0.002
151	14.5	94	9	12.39	151	14.5	93.855	9	12.39	0.002
152	14.5	94	9	12.40	152	14.5	93.855	9	12.40	0.002
153	14.5	94	9	12.41	153	14.5	93.855	9	12.41	0.002
154	14.5	94	9	12.42	154	14.5	93.855	9	12.42	0.002
155	14.5	94	9	12.42	155	14.5	93.855	9	12.43	0.002
156	14.4	94	9	12.37	156	14.4	93.855	9	12.37	0.002
157	14.4	94	9	12.38	157	14.4	93.855	9	12.38	0.002
158	14.4	94	9	12.39	158	14.4	93.855	9	12.39	0.002
159	14.4	94	9	12.39	159	14.4	93.855	9	12.40	0.002
160	14.3	94	9	12.34	160	14.3	93.855	9	12.34	0.002
161	14.3	94	9	12.35	161	14.3	93.855	9	12.35	0.002
162	14.3	94	9	12.35	162	14.3	93.855	9	12.36	0.002
163	14.3	94	9	12.36	163	14.3	93.855	9	12.36	0.002
164	14.3	94	9	12.37	164	14.3	93.855	9	12.37	0.002
165	14.2	94	9	12.31	165	14.2	93.855	9	12.31	0.002
166	14.2	94	9	12.32	166	14.2	93.855	9	12.32	0.002
167	14.2	94	9	12.33	167	14.2	93.855	9	12.33	0.002
168	14.2	94	9	12.33	168	14.2	93.855	9	12.34	0.002
169	14.2	94	9	12.34	169	14.2	93.855	9	12.34	0.002
170	14.1	94	9	12.28	170	14.1	93.855	9	12.29	0.002
171	14.1	94	9	12.29	171	14.1	93.855	9	12.29	0.002

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Mass Balance Calculation with 0.145 cfs Reduction to GW
Thornburgh Resort
Deschutes County, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO	Table 3 5-6
S. Yankey	S. Schenck	Oct 2015	1130-101	

LUBA NO. 2015-107

Mass Balance Calculations

Mass Balance Baseline: No Reduction to Groundwater Discharge					Mass Balance with 0.145 cfs Reduction to Groundwater Discharge					
Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	Stream Flow Just above lower Whychus (cfs) Data from FSR 6360	Stream Temp Just above lower Whychus (°C) Data from FSR 6360	Groundwater Discharge to Upper Reach lower Whychus (cfs)	Temp of Groundwater Discharge (°C)	Temp Downstream of lower Whychus (°C)	ΔT Immediately Downstream of Upper Reach lower Whychus (IMPACT)
172	14.1	94	9	12.30	172	14.1	93.855	9	12.30	0.002
173	14.1	94	9	12.30	173	14.1	93.855	9	12.31	0.002
174	14.1	94	9	12.31	174	14.1	93.855	9	12.31	0.002
175	14.0	94	9	12.25	175	14.0	93.855	9	12.25	0.002
176	14.0	94	9	12.26	176	14.0	93.855	9	12.26	0.002
177	14.0	94	9	12.27	177	14.0	93.855	9	12.27	0.002
178	14.0	94	9	12.27	178	14.0	93.855	9	12.27	0.002
179	14.0	94	9	12.28	179	14.0	93.855	9	12.28	0.002
180	13.9	94	9	12.22	180	13.9	93.855	9	12.22	0.002
181	13.9	94	9	12.23	181	13.9	93.855	9	12.23	0.002
182	13.9	94	9	12.23	182	13.9	93.855	9	12.23	0.002
183	13.9	94	9	12.24	183	13.9	93.855	9	12.24	0.002
184	13.9	94	9	12.24	184	13.9	93.855	9	12.24	0.002
185	13.9	94	9	12.25	185	13.9	93.855	9	12.25	0.002
186	13.8	94	9	12.19	186	13.8	93.855	9	12.19	0.002
187	13.8	94	9	12.19	187	13.8	93.855	9	12.20	0.002
188	13.8	94	9	12.20	188	13.8	93.855	9	12.20	0.002
189	13.8	94	9	12.21	189	13.8	93.855	9	12.21	0.002
190	13.8	94	9	12.21	190	13.8	93.855	9	12.21	0.002
191	13.8	94	9	12.22	191	13.8	93.855	9	12.22	0.002
192	13.7	94	9	12.16	192	13.7	93.855	9	12.16	0.002
193	13.7	94	9	12.16	193	13.7	93.855	9	12.16	0.002
194	13.7	94	9	12.17	194	13.7	93.855	9	12.17	0.002
195	13.7	94	9	12.17	195	13.7	93.855	9	12.17	0.002
196	13.7	94	9	12.18	196	13.7	93.855	9	12.18	0.002
197	13.7	94	9	12.18	197	13.7	93.855	9	12.18	0.002
198	13.6	94	9	12.12	198	13.6	93.855	9	12.12	0.002
199	13.6	94	9	12.12	199	13.6	93.855	9	12.13	0.002
200	13.6	94	9	12.13	200	13.6	93.855	9	12.13	0.002

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Mass Balance Calculation with 0.145 cfs Reduction to GW
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S. Yankey	S. Schenck	Oct 2015	1130-101	