Appendix 7

November 18, 2011 OWRD Technical Review of Aquifer and Interference Test (Application Question 8)

Oregon Water Resources Department Memorandum

Date: 18 November 2011

To: Swan Lake Valley Pump-Storage Project File

From: Jerry Grondin, OWRD Hydrogeologist

Subject: OWRD Groundwater Technical Review of the Swan Lake North Pumped-Storage Hydroelectric Project Aquifer and Interference Test Conducted by GeoDesign for Symbiotics for OWRD Permit Application HE 592

Introduction

A pumped-storage hydroelectric project is proposed to be sited in north Swan Lake Valley. The project seeks to flow water from an upper reservoir on Swan Lake Rim to a lower reservoir on the Swan Lake Valley floor during high electricity demand periods and generate electricity by having the water flow through turbines between the reservoirs. Then, the turbines will be used to return the water to the upper reservoir during low electricity demand periods. Groundwater pumped from north Swan Lake Valley wells is the proposed source of water for the reservoirs.

From late January to February 2011, GeoDesign collected pre-test data and then conducted two tests in Swan Lake Valley to assess the potential impact on the groundwater resource and existing water rights. The first test was an aquifer test using a single pumping well and multiple observation wells to obtain the hydraulic properties (transmissivity and storage coefficient) for the predominant basalt unit below the predominant "basin-fill" unit for the north Swan Lake Valley compartment. These values are needed to calculate the potential long term impact of the project. The second test was an interference test using multiple pumping wells concurrently (every proposed project pumping well) and multiple observation wells. This test is needed to assess the potential interference with wells in the area. For each test, the maximum pumping rate was used.

In May 2011, GeoDesign submitted a report titled "Groundwater Interference Testing Report" describing the test, the analyses conducted, and the test results. The report was resubmitted in October 2011 with some minor revisions. The report conclusions are:

1. The predominantly basalt unit below the "basin-fill" in northern Swan Lake Valley is highly transmissive. Depending on the well, the analytic technique used, and the time period considered, the hydraulic properties calculated ranged from 0.0029 to 0.105 for the storage coefficient and 49,400 to 8,823,500 ft^2/day for the transmissivity. The estimated effective transmissivity was from 300,000 to 900,000 ft^2/day.

2. The groundwater level response to both the single well aquifer test and the multiple well interference indicates the presence of a negative ("no or low-flow") boundary. The location appears to correlate with a boundary that Grondin (2004) postulates separates the north Swan Lake Valley compartment from the main portion of the Swan Lake Valley to Poe Valley sub-area.

3. Drawdowns and/or interferences were not observed in observation wells south of KLAM 2269. This means all the observed drawdown and interference observed was within the north Swan Lake Valley compartment.

4. The Theis equation was used to calculate the potential drawdown at different sites after pumping the proposed project wells at a pro-rated pumping rate for three years. The calculated drawdown ranged from 0.35 feet at well KLAM 2260 within the north Swan Lake Valley compartment to 0.13 feet at the southern-most observation well KLAM 12420 located in Pine Flat which is well outside the north Swan Lake Valley compartment.

OWRD Groundwater Section Review Conducted

The OWRD groundwater section review critically assessed the GeoDesign observations, analyses, and results by conducting its own analysis of the data for comparison purposes. The raw and barometrically corrected pre-test data was analyzed first to group apparently hydraulically connected wells; preliminarily identify wells inside versus outside the north Swan Lake Valley compartment; and to assess the barometric efficiency at the wells GeoDesign used. The barometrically corrected drawdown and recovery data from the aquifer test using a single pumping well with multiple observation wells was analyzed second. The analysis was not exhaustive. The data was plotted on semi-log graphs and analyzed to estimate the hydraulic properties (transmissivity and storage coefficient) of the predominantly basalt unit below the "basin-fill" using the Cooper-Jacob method and recovery method. Some analysis for flow boundaries was conducted, but not completed. It needs to be completed with corrections at another time. Lastly, the barometrically corrected drawdown data from the interference test using multiple pumping wells and multiple observation wells was analyzed. The analysis included assessing which wells responded to pumping and to which wells they responded, determining an "effective" transmissivity that includes boundary influences and determining an appropriate storage coefficient, and lastly determining the drawdown from the multiple pumping wells at different locations at different times using a graphical method and the Theis equation for both continuous pumping at the full rate as a worse case scenario and at a pro-rated pumping rate that is more consistent with the proposed project pumping limits.

OWRD Groundwater Section Observations and Analysis Results

The work conducted by GeoDesign was very thorough and competent. Most of the OWRD observations and results presented below are similar to the GeoDesign observations and results. Differences are explained. They do not change the conclusion.

The wells used by GeoDesign can be divided into three groups based on the pre-test data and is confirmed by the aquifer test data and interference test data. The first group has the wells inside the north Swan Lake Valley compartment: KLAM 2259, KLAM 2260, KLAM 2262, KLAM 2263, and KLAM 2269. The wells south and "outside" of the north Swan Lake Valley compartment can be divided into two groups. One is the west valley group of wells which show consistent recovery for the data period: KLAM 12186 and KLAM 2289. The source of local groundwater recovery could not be determined. The other group is the east and south valley wells: KLAM 2265, KLAM 12203, KLAM 12420, and KLAM 50362. OWRD data currently suggest these two "outside" groups are hydraulically connected within the main portion of the Swan Lake Valley to Poe Valley sub-area. Notable is the finding that KLAM 2265 is "outside" of the north Swan Lake Valley compartment. The well has been recognized as being close the undefined boundary between the north Swan Lake compartment and the main portion of the sub-area, and was previously assumed by OWRD to be inside the compartment. Being "outside" the compartment means pumping at that well directly affects wells within the main portion of the Swan Lake Valley to Poe Valley sub-area. This is confirmed by the GeoDesign interference test data (see below).

The barometric pressure varied significantly and almost constantly throughout the 27 January to 24 February 2011 period. This barometric pressure change was a significant non-pumping influence on the groundwater levels observed, but it was not the only non-pumping influence. Apparent recharge dominated the groundwater level at wells KLAM 2289 and KLAM 12186. The barometric pressure influence needed to be removed from the groundwater level data to make the data intelligible and suitable for analysis. GeoDesign calculated from the pre-test data a barometric efficiency for each test project well using a graphical method and an analytic method (BETCO). The range of barometric efficiency values in the report's Table 8 (0.15 to 0.88) seemed unusually large. A smaller range is more common for wells in similar geologic materials in a limited geographic area. This prompted this review to conduct its own barometric efficiency estimate for each well using a graphical method and a spreadsheet method of comparing incremental and cumulative changes in barometric pressure to changes in groundwater levels. In the past, these methods have been very successful. This time, they were most unsuccessful and inconsistent. This is likely due to the additional non-pumping influences on the groundwater level at each well. While this review thinks, but can not confirm, that the range of barometric efficiency values is likely narrower than shown in Table 8, the values in the table were sufficiently adequate to make the groundwater level data intelligible and useful for analysis. GeoDesign deserves high credit for obtaining useful barometric efficiency values given the complexity of other non-pumping influences on the groundwater levels.

The OWRD observation and review of the aquifer test finds the groundwater level at all the wells inside the north Swan Lake Valley compartment (KLAM 2260, KLAM 2262, KLAM 2263, and KLAM 2269) responded to the 48 hour pumping at well KLAM 2259. The response at KLAM 2263 is quite small (0.02 to 0.05 feet) due to distance and can be easily missed.

Nearly 3.5 hours prior to the 48 hour pumping, well KLAM 2259 pumped for 7 minutes. This was supposed to start the 48 hour pumping period, but the electrical system failed. The groundwater level at wells closest to KLAM 2259 (KLAM 2262 and KLAM 2269) clearly show a response. The groundwater level at KLAM 2260 may have responded 0.01 feet.

The aquifer test data was plotted on semi-log graphs and analyzed to estimate the hydraulic properties (transmissivity and storage coefficient) of the predominantly basalt unit below the "basin-fill" using the Cooper-Jacob method and recovery method. The drawdown data at the pumping well KLAM 2259 was not analyzed due to a 40 to 60 minute rise in the water level in the well after the initial drawdown (possibly due to changes in pump performance that may relate to the discharge system pressurizing) and a 0.25 foot variability in the data (possibly due to disturbances in the well related to the pumping). Table 1 shows the transmissivity and storage coefficient values calculated by this review.

Table 1. OWRD Calculated Transmissivity and Storage Coefficient Values Using GeoDesign Barometric Efficiency Corrected Aquifer Test Data

Well	Analysis Method	Data Period	Transmissivity feet^2 per day	Storage Coefficient
KLAM 2259 Pumping well	Cooper-Jacob	Not calculated	Not calculated	Not calculated
	Recovery	Early time	4,602,000	Not calculated
	Recovery	Middle time	1,764,000	Not calculated
KLAM 2260 4,150 feet to pumping well	Cooper-Jacob	Early time	5,292,000	0.0010
	Cooper-Jacob	Middle time	1,411,000	0.0051
	Cooper-Jacob	Late time	833,000	0.0060
	Recovery	Early time	10,584,000	Error
	Recovery	Middle time	4,233,000	Error
	Recovery	Late time	1,7634,000	0.0002
KLAM 2262 1,940 feet to pumping well	Cooper-Jacob	Early time	4,811,000	0.0040
	Cooper-Jacob	Middle time	1,857,000	0.0153
	Cooper-Jacob	Late time	1,058,000	0.0238
	Recovery	Early time	7,056,000	Error
	Recovery	Late time	1,058,000	0.0003
KLAM 2263 8,660 feet to pumping well	Cooper-Jacob	Early time	2,646,000	Error
	Cooper-Jacob	Late time	962,000	Error
	Recovery	Early time	7,056,000	0.00004
KLAM 2269 2,190 feet to pumping well	Cooper-Jacob	Early time	5,292,000	0.0053
	Cooper-Jacob	Middle time	2,352,000	0.0196
	Cooper-Jacob	Late time	132,000	0.0024
	Recovery	Early time	10,584,000	Error
	Recovery	Late time	4,233,000	0.00003

The transmissivity and storage coefficient values calculated by this review are in general agreement with the values calculated with GeoDesign. As can be seen in Table 1, the transmissivity values decrease as later time data is analyzed. This is due to negative ("no-flow") boundary affect influences coming into play as time progresses. This is noticeable on the semi-log graphs by an approximately doubling of the drawdown or recovery slope each time a negative boundary affect influence begins. The larger transmissivity represents the actual property of the predominantly basalt unit below the "basin-fill" unit. The smaller transmissivity can be considered the "effective" transmissivity that incorporates the boundary conditions to be used when the Theis equation is used for calculating drawdowns.

As previously noted, some analysis was conducted to locate the flow boundaries, but not completed. It needs to be completed with corrections at another time.

The OWRD observation and review of the multiple pumping well interference test finds the groundwater level at all the observation wells inside the north Swan Lake Valley compartment (KLAM 2260 and KLAM 2269) clearly responded to the 213 hour pumping at wells KLAM 2259, KLAM 2262, and KLAM 2263. Additionally, OWRD finds the groundwater level at observation wells KLAM 12203 and KLAM 50362 in the main portion of the Swan Lake Valley to Poe Valley sub-area responded to the 213.5 hour pumping at well KLAM 2265. The response at KLAM 12203 and KLAM 50362 is quite small (about 0.04 feet and 0.06 feet respectively) due to distance and can be easily missed. The drawdown occurs just before a groundwater level rise at each well and could be interpreted as part of the non-pumping influence leading to the water level rise. However, OWRD finds it is a drawdown related to the pumping at KLAM 2265 given the following. First, the groundwater level well KLAM 12420 further away from well KLAM 2265 shows the same water level trend during the interference test as seen at KLAM 12420 and KLAM 50362, but it is missing the drawdown component, most likely due to distance. Second, the decline slope for KLAM 12420 and KLAM 50362 are similar and can be reproduced using the Theis equation. Lastly, OWRD finds the groundwater level at observation wells KLAM 2289 and KLAM 12186 was dominated by local recovery that likely overwhelmed any observable drawdown.

Next, the OWRD review used the observed interference test groundwater level drawdown slope (semi-log graph, late time data) for well KLAM 2260 and the Theis equation to iteratively estimate a usable "effective" transmissivity and storage coefficient for calculating potential drawdowns related to the proposed Swan Lake north pump-storage hydroelectric project. That effort found using an "effective" transmissivity of 501,300 ft^2/day and a storage coefficient of 0.005 in the Theis equation adequately reproduced the interference test related late time drawdown slope at KLAM 2260 inside the north Swan Lake Valley compartment and at wells KLAM 12203 and KLAM 50362 in the main portion of the Swan Lake Valley to Poe Valley sub-area. Table 2 shows the comparison. The drawdowns in table 2 represent continuous pumping. The "effective" transmissivity and storage coefficient values are within the value range noted by GeoDesign.

Table 2. Comparison of OWRD Observed Interference Test Related Drawdown Slopes to Calculated Drawdown Using the Theis Equation and "Effective" Transmissivity and Storage Coefficient Values

Well	Time (days)	OWRD Observed Drawdown on Late Time Slope (feet)	OWRD Calculated Drawdown Using the Theis Equation (feet)
KLAM 2260 Inside the north Swan Lake Valley compartment	1.11 3.47 365.00 1095.00	0.38 0.75 2.35 2.78	0.78 1.08 2.33 2.63
KLAM 12203 Main portion of the Swan Lake Valley to Poe Valley sub-area	3.47 365.00 1095.00	0.06 0.33 0.39	0.05 0.49 0.60
KLAM 50362 Main portion of the Swan Lake Valley to Poe Valley sub-area	1.11 3.47 365.00 1095.00	0.03 0.09 0.33 0.39	0.03 0.10 0.56 0.67

Lastly, the OWRD review estimated the one-year and three-year drawdown the proposed Swan Lake north pumped-storage hydroelectric project may cause inside the north Swan Lake Valley compartment by pumping wells KLAM 2259, KLAM 2262, and KLAM 2263 and in the main portion of the Swan Lake Valley to Poe Valley sub-area by pumping well KLAM 2265. The drawdown estimate for the main portion includes the closest reach of the Lost River and springs along the Lost River in west Poe Valley. The drawdowns were estimated using the Theis equation and a graphical method, both using a pro-rated pumping rate. The graphical method involved using the observed slope noted in Table 2 and multiplying the drawdown on that slope by the pro-rated pumping rate versus continuous pumping rate ratio. This works, because drawdown is directly proportional to the pumping rate. Using the pro-rated pumping rate is appropriate due to a likely permit required limitation on water use (duty).

Table 3 shows the drawdown estimates. It needs to be emphasized that the proposed pumping for the proposed Swan Lake north pumped-storage hydroelectric project is <u>not</u> new pumping given the project intends to "transfer" existing permitted groundwater use to the project. That includes limitations on the maximum pumping rate(s) and the maximum amount of water allowed to be pumped annually (duty). Rather than concentrate the pumping during the irrigation season, the project anticipates spreading the pumping out over the year. The result should be shallower drawdown spread out over three years rather than deeper seasonal drawdowns.

Table 3. OWRD Estimated One-Year and Three-Year Drawdown Related to the Proposed Swan Lake North Pumped-Storage Hydroelectric Project

Well	**Time (days)**	**OWRD Drawdown Graphically Derived (feet)**	**OWRD Drawdown Calculated Using the Theis Equation (feet)**
Inside the North Swan Lake Valley Compartment			
KLAM 2260	365.00 1095.00	0.80 0.95	0.79 0.89
Main Portion of the Swan Lake Valley to Poe Valley Sub-Area			
KLAM 12203	365.00 1095.00	0.11 0.14	0.17 0.21
KLAM 50362	365.00 1095.00	0.11 0.13	0.20 0.24
Lost River (nearest reach)	365.00 1095.00	No graph	0.12 0.16
"High Spring" (west Poe Valley)	365.00 1095.00	No graph	0.11 0.15

GeoDesign calculated three-year drawdowns of 0.35 feet at well KLAM 2260 within the north Swan Lake Valley compartment and 0.13 feet at the southern-most observation well KLAM 12420 located south of KLAM 12203 and KLAM 50362 (further away from pumping well KLAM 2265). The GeoDesign and OWRD calculated drawdowns are similar.

OWRD finds these drawdowns should not injure existing groundwater or surface water rights given the following. First, the drawdown impact on the neighboring wells and surface water should be the same or less than currently experienced during the irrigation season. Second, the drawdown at the neighboring wells should not affect the operation of those wells.

OWRD Conclusions

1. The work conducted by GeoDesign was very thorough and competent.

2. Most of the OWRD observations and results presented above are similar to the GeoDesign observations and results. Any difference can be explained and does not change the main conclusion: groundwater level drawdowns related to the project should not injure existing groundwater or surface water rights.

3. The OWRD analyses found the proposed project well KLAM 2265 is in the main portion of the Swan Lake Valley to Poe Valley sub-area, not inside the north Swan Lake Valley compartment.

4. The OWRD analyses found that well KLAM 2263 did respond to the single pumping well aquifer test.

5. The OWRD analyses found that wells KLAM 12203 and KLAM 50362 did respond to the pumping of well KLAM 2265 during the interference test.

6. The OWRD analyses concurs that the transmissivity of the predominantly basalt unit is very high, likely 1,000,000 ft^2/day or greater.

7. The OWRD analyses of the aquifer test data observed two likely negative ("no-flow) boundaries.

8. An "effective" transmissivity that incorporates the boundary influences needs to be used when using the Theis equation to calculate drawdowns. OWRD analyses derived an "effective" transmissivity of 501,300 ft^2/day and a storage coefficient of 0.005 for the Theis equation that adequately reproduced the observed multiple pumping well interference test related late time drawdown slopes.

9. It needs to be emphasized that the proposed pumping for the proposed Swan Lake north pumped-storage hydroelectric project is <u>not</u> new pumping given the project intends to "transfer" existing permitted groundwater use to the project. Rather than concentrate the pumping during the irrigation season, the project anticipates spreading the pumping out over the year. The result should be shallower drawdown spread out over three years rather than deeper seasonal drawdowns.

10. OWRD was able to calculate possible drawdowns related to the proposed Swan Lake north pumped-storage hydroelectric project. OWRD finds these drawdowns should not injure existing groundwater or surface water rights given the following. First, the drawdown impact on the neighboring wells and surface water should be the same or less than currently experienced during the irrigation season. Second, the drawdown at the neighboring wells should not affect the operation of those wells.

11. OWRD accepts the GeoDesign report and its conclusions in general except for conclusion 3 (see the introduction section of this review). OWRD analyses indicate two wells south of well KLAM 2269 did respond to the multiple pumping well interference test. To GeoDesign's credit, they acknowledged likely drawdown south of those wells in response to the proposed Swan Lake north pumped-storage hydroelectric project.