DRAFT
Packwood Lake Drawdown Study
Wetland Hydrology Interim Report:
1st Year's Study Results
For
Energy Northwest's
Packwood Lake Hydroelectric Project
FERC No. 2244
Lewis County, Washington

Submitted to

ENERGY NORTHWEST
People · Vision · Solutions

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1.0 INTRODUCTION

Energy Northwest operates the Packwood Lake Hydroelectric Project (Project) near the town of Packwood in Lewis County, Washington. On November 12, 2004 Energy Northwest filed a Notice of Intent (NOI) to file an application for a new license to operate the hydroelectric project. Energy Northwest also concurrently filed with the Federal Energy Regulatory Commission (FERC) and the resource agencies, a Pre-Application Document (PAD), containing existing, relevant, and reasonably available information describing the existing environment and the potential effects of project facilities and operations. Additional studies of the potential effects of drawdown on wetlands and other natural resources were requested to supplement information contained in the PAD (WDFW 2005, USFS 2005).

Energy Northwest, in consultation with tribes and agencies, developed and is implementing a study plan to evaluate the potential effects of drawdown of Packwood Lake as part of Project operations (EES Consulting 2005). This report provides preliminary drawdown study results regarding Packwood Lake level, inflow and wetland hydrology monitored between September 2005 and April 2006.

1.1 Project Area and Study Area

1.1.1 Project Area

Packwood Lake lies within the Gifford Pinchot National Forest in the Cascade Mountains, east of the town of Packwood (Figure 1.1). The Project facilities at Packwood Lake include an intake canal, a concrete drop structure, and an intake building on Lake Creek located about 424 ft downstream from the outlet of Packwood Lake. The drop structure, located adjacent to the intake structure, extends 85 ft in width and is tied into impervious earth fill cutoff walls on each side extending to the natural embankment.

The total area drained by Lake Creek and Packwood Lake is approximately 19.2 square miles. The total surface area of the lake is 452 acres. The natural lake elevation (El.) is 2,857.0 ft Mean Sea Level (MSL). The Project seasonally regulates the lake level so that it is at El. 2,857.0 ft ±0.50 ft in summer recreation months and drawn down to no lower than El. 2,849.0 ft MSL during the winter months. This provides 8 ft of vertical storage usable by the Project. The Project is operated to achieve a lake elevation of 2,857 ±0.50 ft by May 1st of each year. This level is maintained until September 15 when drawdown may begin. When lake level rises above the drop structure crest elevation (El. 2858.50 ft), the flow passes over the drop structure into Lake Creek downstream of the lake. The influence on lake level exerted by the Project is approximately one-half inch per hour at maximum capacity (260 cfs), assuming no inflow. This effect can be easily reduced or offset by large inflows.

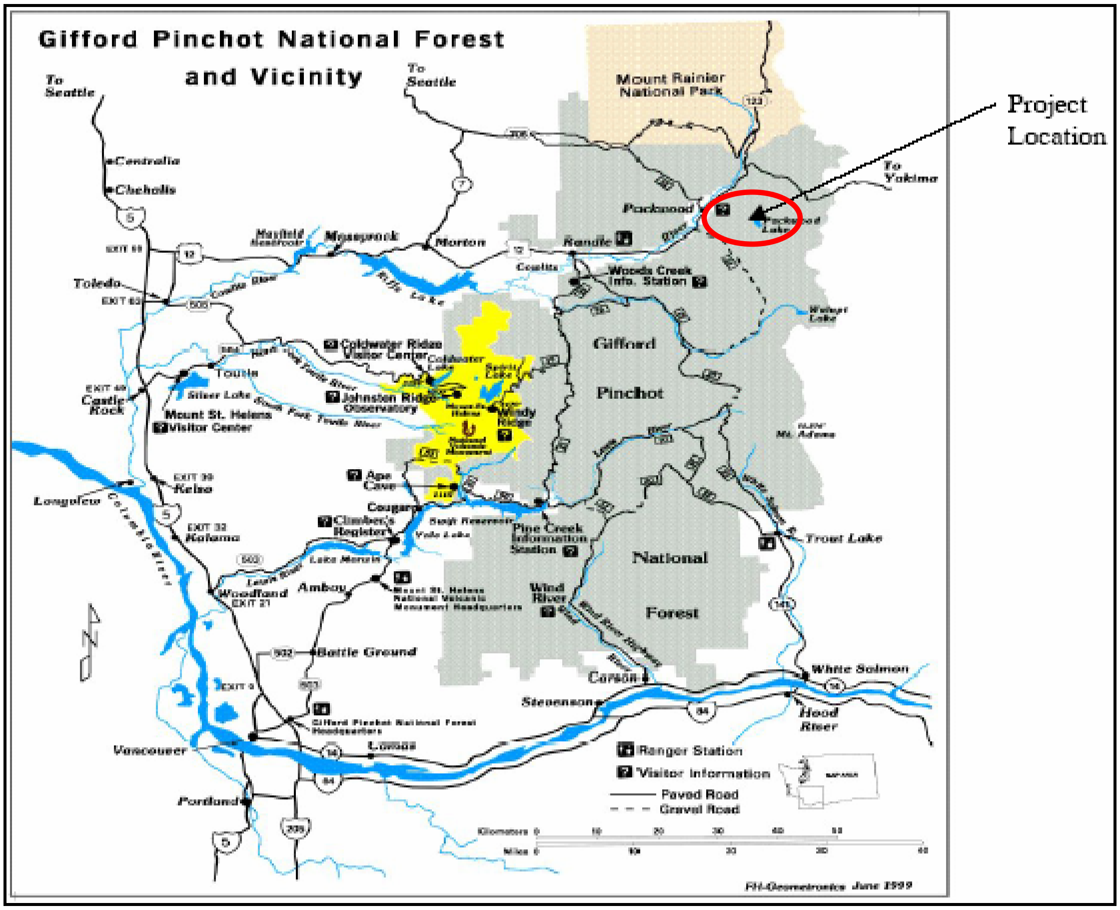

Figure 1.1 – Energy Northwest's Packwood Lake Hydroelectric Project is located in the Cowlitz River watershed, tributary to the Lower Columbia River in southwest Washington State (source Energy Northwest 2004).

1.1.2 Study Area

The study area includes Packwood Lake and two wetland complexes adjacent to the lake and tributaries (Figure 1.2). One wetland complex is located at the head of Packwood Lake and encompasses an area adjacent to Muller Creek and Upper Lake Creek. The second wetland complex is located along the southwest shoreline of Packwood Lake and includes an area adjacent to Osprey Creek.

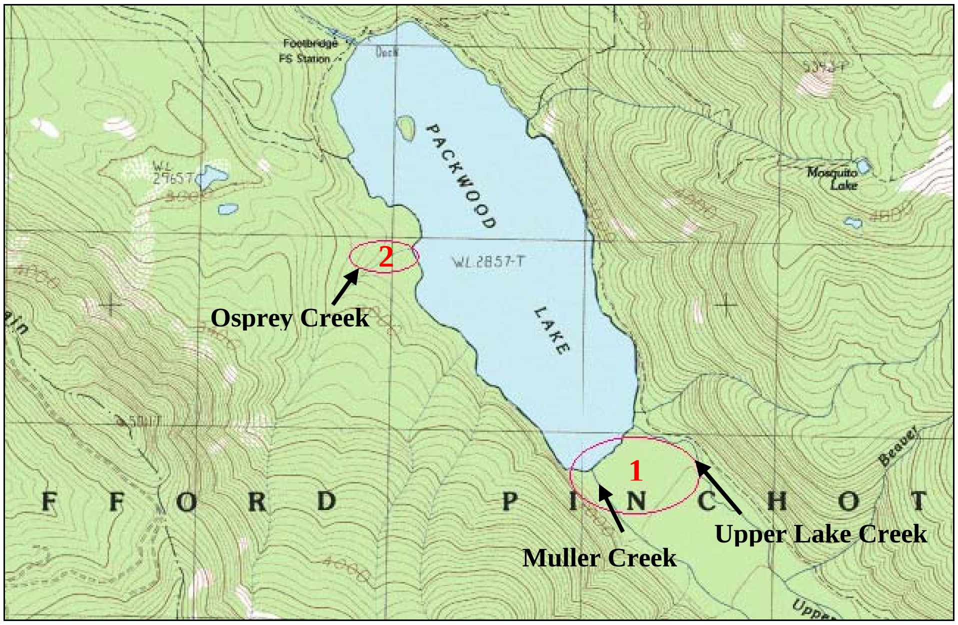

Figure 1.2 – The study area includes Packwood Lake and associated wetlands: (1) at the head of the lake adjacent to Upper Lake Creek and Muller Creek, and (2) on the southwest shore of the lake adjacent to Osprey Creek.

1.2 Study Goals and Objectives

The goal of the drawdown study is to identify impacts to fish, wildlife, shorelines, and associated wetlands, due to Project-related drawdown and associated fluctuating reservoir levels. Objectives include:

1. Determine acres of drawdown zone exposed at various seasonal pool levels and evaluate impacts to fish and wildlife;

2. Determine if the wetlands are hydrologically connected to lake levels;

3. Determine if Project operations are impacting the wetland complex near Upper Lake Creek;

4. Investigate shoreline erosion associated with Project operations;

5. Evaluate the rate at which the reservoir is drawn down and if resources are being impacted; and,

6. Assess direct and indirect effects of Project drawdown on fish and wildlife.

A number of assessments are being conducted to respond to these study objectives. Wetland hydrology results will be integrated with these other assessments in the first and second draft Drawdown Study reports to be completed by June 30, 2006 and three months after the end of monitoring, respectively. This interim report focuses on preliminary results for Objective 2 –

"determine if the wetlands are hydrologically connected to lake levels." The purpose of this interim report is to provide information to Energy Northwest to decide, in consultation with agencies and tribes, if additional wetland hydrology monitoring is necessary to meet study objectives.

2.0 METHODS

2.1 Determine if Wetlands are Hydrologically Connected (Objective 2)

There are two known wetland complexes in close proximity to Packwood Lake. This study investigated the level of hydrologic connectivity between the lake level and groundwater in these two wetlands.

2.1.1 Wetland Water Level

On September 14, 2005 six piezometers were installed in monitoring wells in the two known wetlands. All monitoring wells were constructed within 500 linear ft of Packwood Lake. Monitoring wells were constructed in pairs, with one situated closer to the lake than the other. Four wells were established in the wetland complex at the head of Packwood Lake; two were located near Muller Creek, and two near Upper Lake Creek (Figure 2.1). Two monitoring wells were also installed in the wetland complex near Osprey Creek (Figure 2.2). Map locations for monitoring wells in Figures 2.1 and 2.2 are approximations as heavy forest canopy precluded the use of GPS to map planar position.

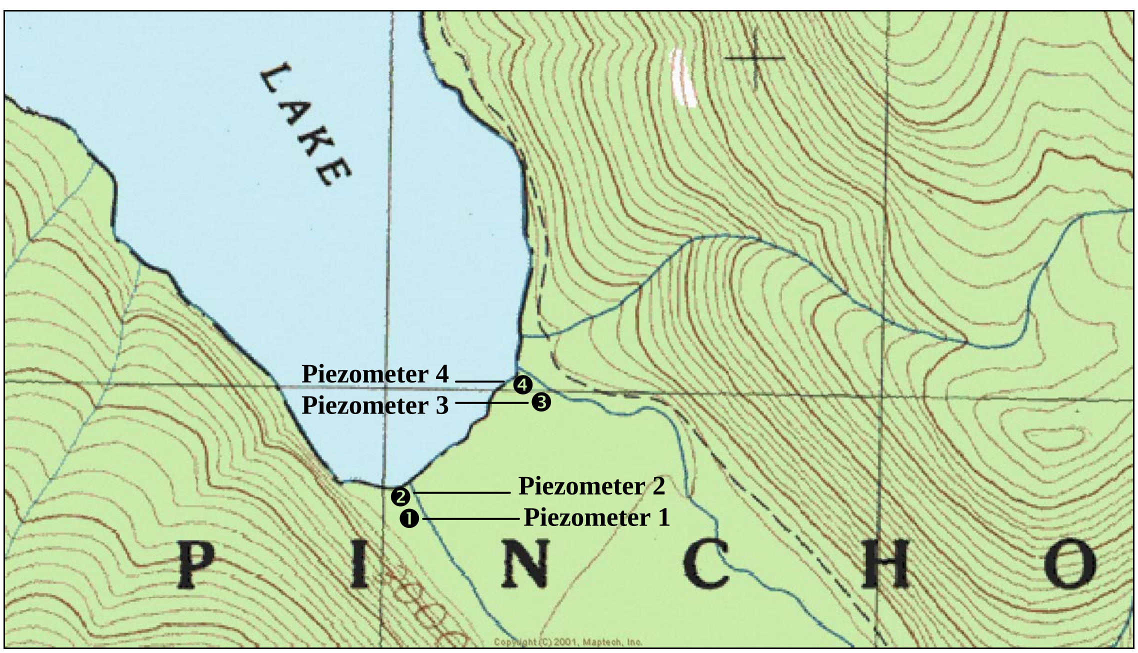

Figure 2.1 – Piezometers 1 and 2 installed at the head of Packwood Lake adjacent to Muller Creek. Piezometers 3 and 4 installed at the head of the lake adjacent to Upper Lake Creek.

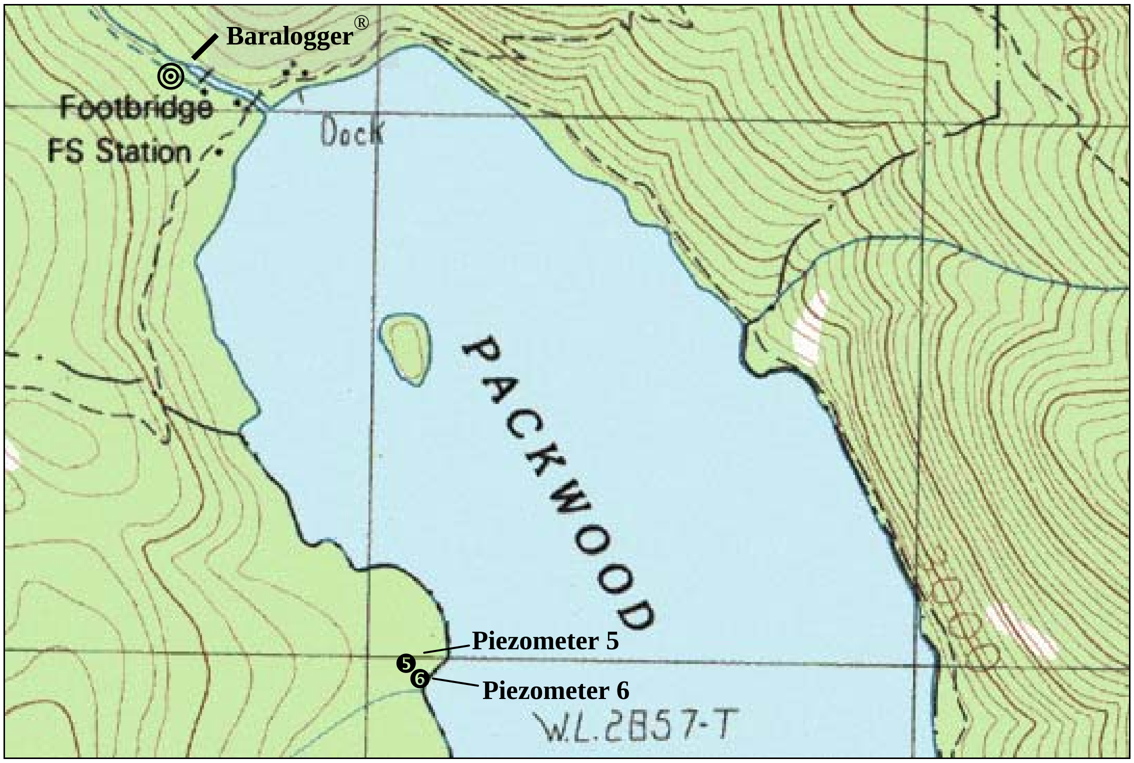

Figure 2.2 – Piezometers 5 and 6 installed in the Osprey Creek wetland complex on the south-west side of Packwood Lake. A Baralogger® was deployed at the existing weather station situated near the intake structure at the outlet of Packwood Lake.

Each monitoring well included a Campbell screened well point, associated 1.5 inch diameter steel piping, couplings and vented cap (see Appendix A for images). Elevation of each monitoring well head was surveyed relative to a benchmark and lake level using an autolevel and stadia rod. Well head elevations were calculated to within $\pm$0.01 ft accuracy, based on the known lake level and a benchmark reference at the time of survey. Well head elevation was referenced to estimate datalogger and initial water level elevation, relative to known lake level.

Initial water level within each piezometer was determined with the wetted tape method: a dip stick with gauging paste was used to measure the distance from the known elevation of the well head to the water level. The elevation of initial water level was estimated by subtracting the depth to water from the well head elevation.

A Solinst Levelogger® F30 (Levelogger®, electronic datalogger) suspended from the vented cap of each monitoring well recorded water level at 1 hour intervals. Dataloggers were suspended at a point close to the bottom of the well point. Datalogger elevation was estimated by subtracting the length of cable, used to suspend the datalogger, from the well head elevation.

2.1.2 Barometric Pressure and Altitude Correction

Water level data recorded with a Levelogger® must be corrected for atmospheric (barometric) pressure and altitude. These corrections are necessary because the dataloggers utilize pressure transducers to measure water level, and pressure varies with elevation and barometric pressure.

A Solinst Baralogger® (Baralogger®) was deployed at the Packwood intake site (Figure 2.2) at the same time the piezometers were installed. The Baralogger® was used to record barometric pressure and air temperature at the lake. Barometric correction was made by subtracting the atmospheric pressure, as measured by the Baralogger®, from the piezometer water level measured by each Levelogger®.

Altitude correction was made by subtracting the elevation-corrected barometric offset value from the water level measured by each Levelogger®. Elevation-corrected barometric offset was calculated as follows:

(Barometric offset at MSL) – (Datalogger elevation/1000) = (Elevation-corrected Barometric Offset)

where the standard Barometric Offset value is 31.17 ft.

2.1.3 Lake Level and Inflow

Energy Northwest continuously records lake level (± 0.01 ft MSL) using a Stevens® strip chart for a Type A, Model 71 water level recorder. Project staff also manually record lake level and estimated total inflow (cfs) to Packwood Lake on a daily basis.

2.1.4 Precipitation

The weather station at Packwood Lake does not measure precipitation. Precipitation data collected by the National Climate Data Center (NCDC) will be used in future reports and analyses.

3.0 RESULTS

3.1 Piezometers

3.1.1 Piezometer Installation and Maintenance

All six piezometers were installed to a depth of at least 2.25 ft below ground surface (bgs), consistent with the study plan (EES Consulting 2005). Piezometers 1 (P-1) and 5 (P-5) were set at a slightly greater depth (approximately 5 and 6 ft bgs, respectively), but still within continuity of the shallow water table associated with the wetlands. Datalogger elevations were approximately 2 ft below mean lake level (2857 ft MSL) for all except Piezometer 3 (P-3). Construction of P-3 met the 2.25 ft bgs standard in the study plan, but was monitored at a higher elevation (2857.23 ft) than the other piezometers because it was constructed at a high point in the wetland. Please see the results section of P-3 for more details.

Piezometers filled with water at varying rates during construction with the exception of P-3, which was dry at the time of construction. Table 3.1 summarizes piezometer installation and setup.

Table 3.1 - Piezometer number, datalogger serial number, datalogger elevation, and manually measured initial water surface elevation.

Piezometer Number	Levelogger® Serial Number	Datalogger Elevation (feet above MSL)	Initial Water Level Elevation (feet above MSL)
1	71390	2855.17	2859.17
2	71355	2855.57	2857.77
3	71334	2857.23	n.a.[1]
4	71382	2855.42	2857.00
5	70844	2854.37	2860.37
6	71357	2855.75	2858.16

[1] Water level was not available (n.a.) as P-3 was dry at the time of construction. The piezometer well later filled with water as groundwater level rose with fall precipitation.

Initial water levels collected with the wetted tape method were compared with barometric-corrected water levels measured by Leveloggers®. Manual measurements of water level at the April 19, 2006 site visit were used to calibrate the previously recorded data. Dataloggers continuously recorded water level with a precision of ± 0.01 ft. As piezometer water levels were based on lake level and a benchmark reference, water levels are reliable for comparative analysis purposes in this report. They should not, however, be interpreted to represent true elevation with accuracy to ± 0.01 ft relative to a mean sea level (MSL) standard.

3.1.2 Piezometer Monitoring

Water levels in Packwood Lake wetlands have been monitored hourly since September 14, 2005. Dataloggers were downloaded on April 19, 2006 and all remain deployed. Table 3-2 identifies the number of observations, the mean water level, the minimum water level, and the maximum water level for all six piezometers.

Table 3.2 - Descriptive statistics for Packwood Lake piezometers including: count, median, minimum and maximum water level.

Piezometer Number	Number of Observations	Median Elevation (ft above MSL)	Min. Elevation (ft above MSL)	Max. Elevation (ft above MSL)
1	5182	2859.77	2858.09	2860.49
2	5182	2858.81	2856.50	2859.29
3	4451	2859.08	2857.25	2860.87
4	2756	2857.39	2855.82	2858.93
5	5186	2860.60	2859.86	2860.97
6	5187	2858.42	2857.14	2858.77

Data were checked following data retrieval and barometric and altitude correction. Following data retrieval, the Levelogger® serial number, filename and data were checked to assure that records were not mixed between piezometers. Data were also checked to make sure that there were no unexplained deviations in the data time series. Lastly, data were examined for outliers.

Some observations were eliminated from the record during quality control and quality assurance (QA/QC) data-checks. Data were not utilized when:

- A piezometer was dry,
- when data were affected by installation or retrieval,
- when the Baralogger® data were not available to properly calibrate piezometer data, or outlier data for a single hour indicated erroneous data.

Datasets most changed after QA/QC were those for P-3 and piezometer 4 (P-4), as illustrated by significantly fewer observations (Table 3.2). Over 700 observations were made but not utilized for P-3 because the monitoring well was dry. Similarly, over 2400 observations were made but not utilized for P-4 because the monitoring well was dry.

Piezometers 1 (P-1) and piezometer 2 (P-2) showed moderate range in water level fluctuation, 2.40 and 2.78 ft respectively, between minimum and maximum elevation. P-3 and P-4 showed the greatest range in water level with differences of 3.62 and 3.11 ft, respectively. Piezometers 5 (P-5) and piezometer 6 (P-6) showed the lowest range in water level, 1.11 and 1.63 ft, respectively.

3.2 Lake Level and Inflow

Energy Northwest continuously monitors lake level and inflow and records them daily at 7:00 AM. This study used daily values recorded between September 1, 2005 and April 1, 2006. The summertime standard lake level of 2857 $\pm$ 0.50 ft (MSL) was maintained through September 14, 2005 (Figure 3.1). Drawdown of Packwood Lake began on September 15, 2005, soon after installation of piezometers on September 14, 2005, as illustrated by rapid decrease in lake level through the end of September. A rapid increase in inflow to the lake beginning October 1st had little immediate effect on lake level. Lake level steadily increased through October to an average level of 2855.43 ft in November. At the end of November and early December, a smaller drawdown occurred just prior to significant inflow at the end of December and early January. Inflow peaked at approximately 439 cfs on January 10, 2006 concurrent with the lake level reaching the crest of the drop structure. Inflow decreased throughout the remainder of the sample period, resulting in a moderation of lake level and gradual decrease to 2856.05 ft on March 31, 2006.

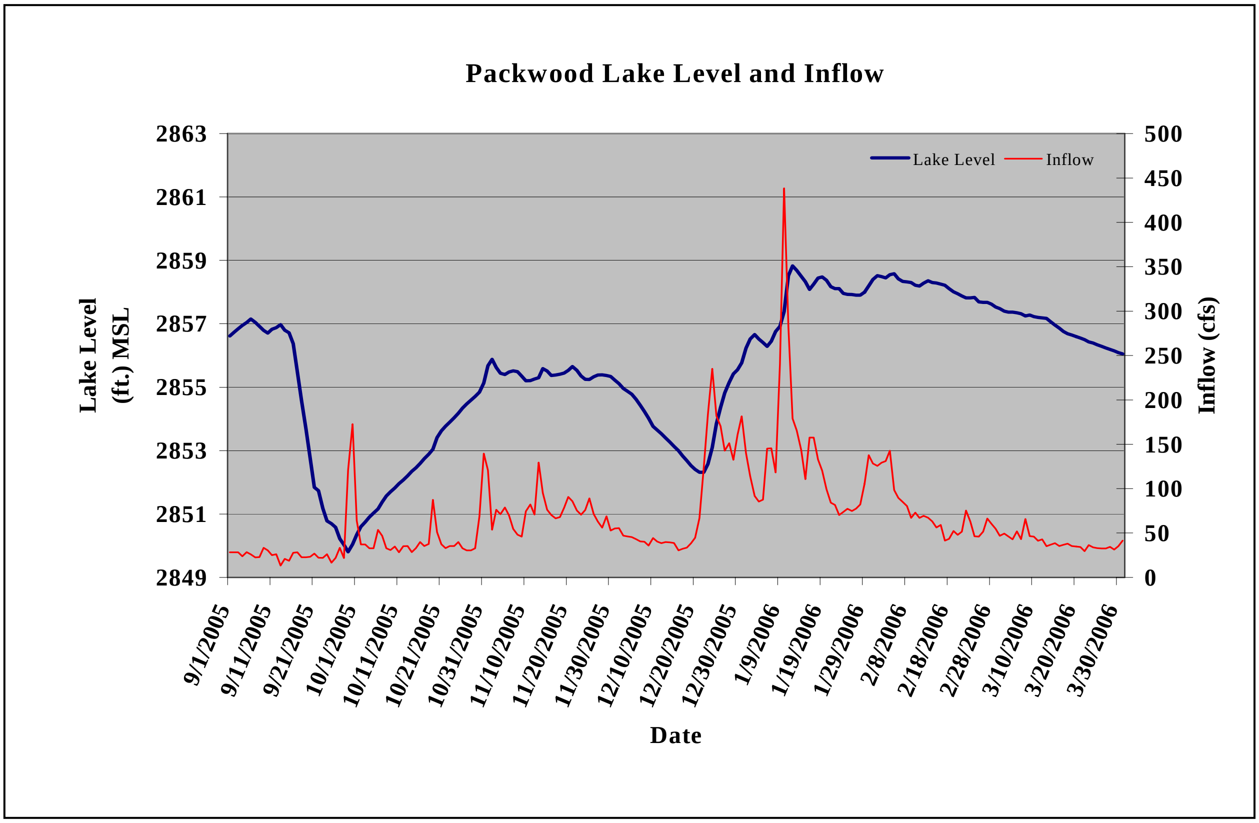

Figure 3.1 – Packwood Lake Level (ft) and inflow (cfs).

3.3 Piezometer Water Level, Lake Level, and Inflow

Piezometer water levels were generally higher than Packwood Lake level throughout the monitoring period. The median lake level was 2855.55 ft MSL between September 14, 2005 and April 19, 2006. Median wetland water level was 2859.77, 2858.81, 2859.08, 2857.39, 2860.60, and 2858.42 as measured in P-1 through P-6 respectively (Figure 3.2). Piezometer water levels were also considerably less variable than lake level, as illustrated in Figure 3.2.

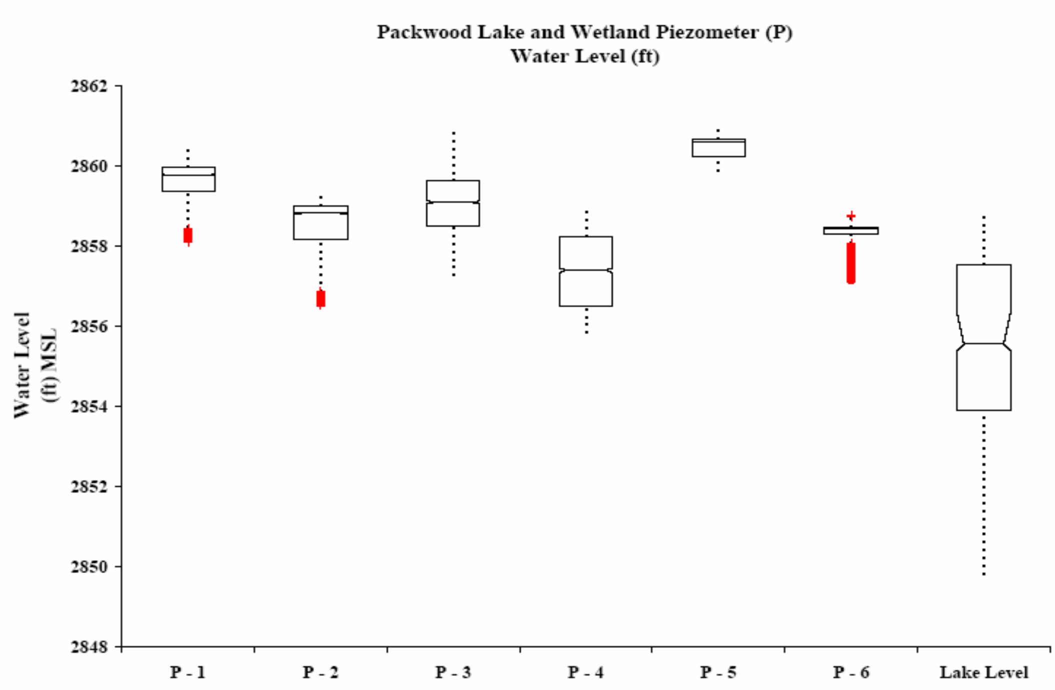

Figure 3.2 – Packwood Lake level (Lake) and wetland (piezometer, P) water levels[1] during the 2005-2006 drawdown period. Box-whisker diagrams illustrate minimum and maximum (dotted line), the 1st and 3rd quartile (box), median (line through box), and outlier (red plus symbol) values for each data distribution.

[1] *Wetland water levels are reliable for comparative analysis purposes as they were surveyed from known lake level and benchmark referenced; they do not represent true elevation.*

3.3.1 Piezometer 1 (P-1)

P-1 was installed as part of a paired set at the head of Packwood Lake, adjacent to Muller Creek. Of the pair, P-1 was located farthest from the lake. P-1 was constructed to a depth of 5 ft bgs, and in continuity with the shallow groundwater table associated with the wetland. The well point slowly began to fill with water at the time of construction.

Water level in P-1 was generally stable throughout the monitoring period. Changes in water level appear to be independent of changes in lake level (Figure 3.3) and inflow (Figure 3.4). Initial decreases in wetland water level during the last two weeks of September may at first appear to be associated with lake level. A closer examination of the data indicates that inflow or other upslope hydrologic forces have a stronger influence on wetland hydrology than does lake level. For example, on September 29th the wetland water level increased by over one foot (2858.14 ft and 2859.15 ft MSL) in a 13 hour period. Between September 28 and September 30 (a 48 hour period) lake level increased only 0.02 ft (2850.03 to 2850.05). Between September 28 and September 30, inflow changed from 22 cfs to 173 cfs. Sharp increases in both inflow and piezometer water level occurred at the time of storm events on October 1, November 1 and December 24 through 26. Timing of change in piezometer water level was more closely associated with inflow than lake level, but may also be associated with precipitation. Similar trends were observed throughout the monitoring period. Preliminary results suggest that water levels in P-1 are more likely associated with Muller Creek hydrology or other up-slope hydrology.

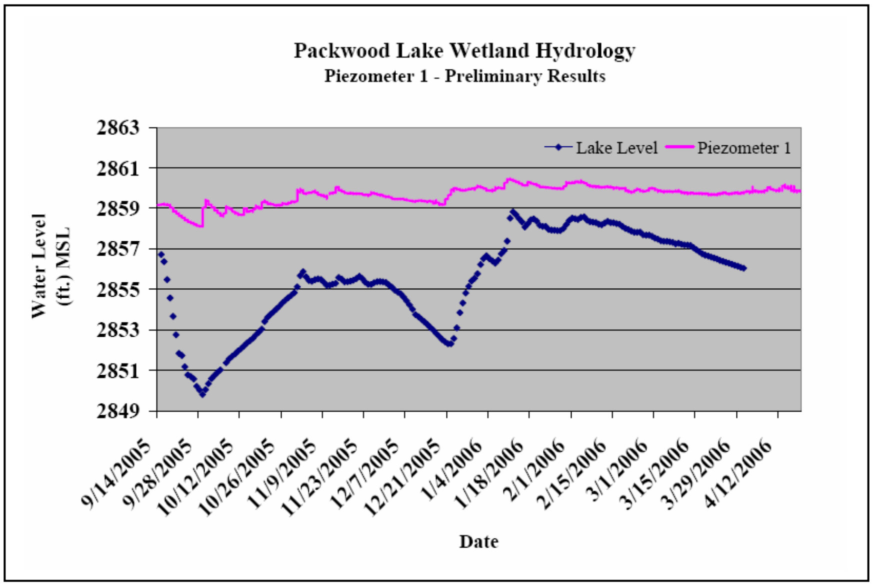

Figure 3.3 – Piezometer 1 water level (ft) and Packwood Lake Level (ft) during the 2005-2006 drawdown period.

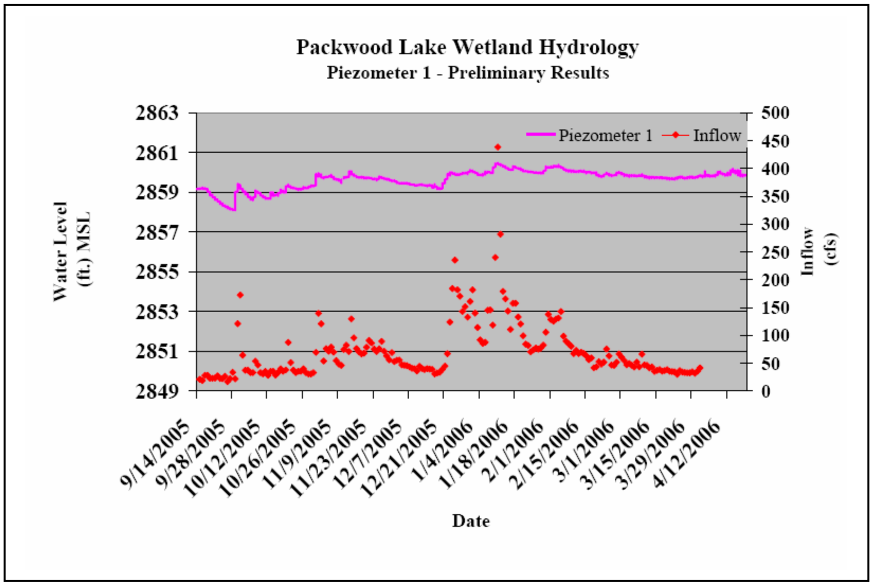

Figure 3.4 – Piezometer 1 water level (ft) and Packwood Lake inflow (cfs) during the 2005-2006 drawdown period.

3.3.2 Piezometer 2 (P-2)

P-2 was part of the paired set installed at the head of Packwood Lake, adjacent to Muller Creek. Of the pair, P-2 was closer to the lake. P-2 was constructed to a depth of approximately 2.5 ft bgs, and in continuity with the shallow groundwater table associated with the wetland. The well point slowly began to fill with water at the time of construction.

Water level in P-2 was very similar to P-1. As with P-1, water levels were generally stable throughout the monitoring period. Changes in P-2 water level appeared to be independent of changes in lake level (Figure 3.5) but appear to be associated with inflow and/or precipitation (Figure 3.6). As with P-1, rapid changes in P-2 water level coincided with rapid increase in inflow. Preliminary results suggest that water levels in P-2 are more likely associated with Muller Creek hydrology or other up-slope hydrology not characterized by inflow.

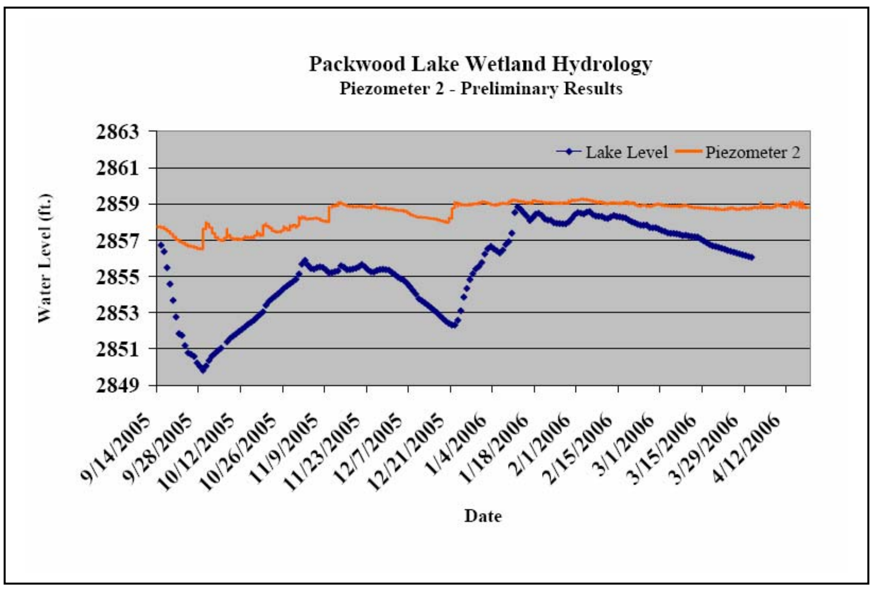

Figure 3.5 – Piezometer 2 water level (ft) and Packwood Lake Level (ft) during the 2005-2006 drawdown period.

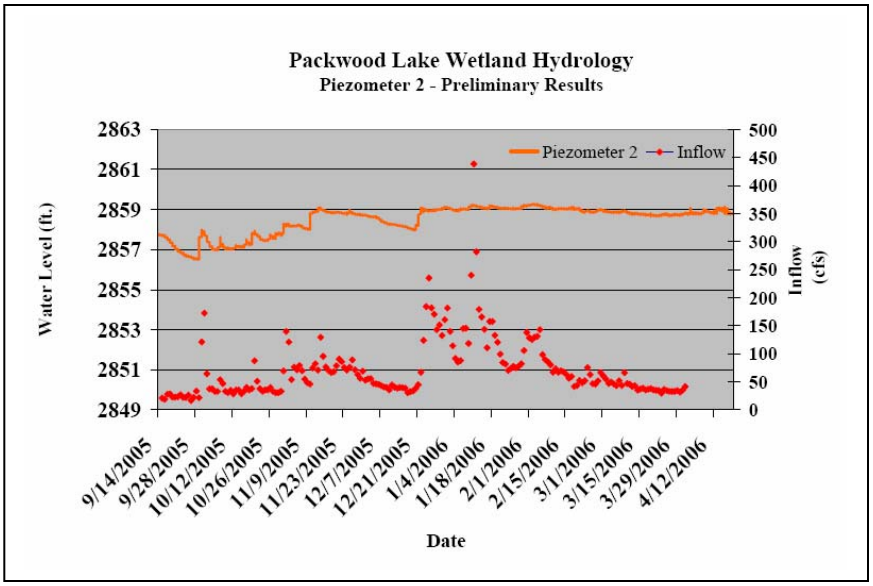

Figure 3.6 – Piezometer 2 water level (ft) and Packwood Lake inflow (cfs) during the 2005-2006 drawdown period.

3.3.3 Piezometer 3 (P-3)

P-3 was part of a paired set installed at the head of Packwood Lake adjacent to Upper Lake Creek. Of this pair, P-3 was farthest from the lake. P-3 was constructed to a depth of 2.5 ft bgs, and in continuity with the shallow groundwater table associated with the wetland. Unlike P-1 that was constructed to a greater depth because it was farther from the lake and farther upslope, P-3 was kept to the minimum construction depth to avoid perforating a clay layer found during construction of P-4 (see Section 3.3.4). As a result, P-3 met construction criteria in the study plan (EES Consulting 2005), but was monitored at an elevation higher than the other wells (Table 3.1). The well point remained dry throughout construction. Over 700 observations were not utilized for P-3 because the well was dry.

Water levels in P-3 were highly variable. Neither the variability nor the trends in water level closely followed lake level (Figure 3.7). There appears to be a relationship between changes in piezometer water level and changes in inflow (Figure 3.8). For instance, spikes in piezometer water level on October 1, November 1, November 13, and December 23 corresponded with significant increases in inflow to levels over 100 cfs. These corresponding events imply that water level in P-3 may be associated with groundwater in continuity with Upper Lake Creek. Variability in P-3 water level may be most closely associated with precipitation. Results of further analyses of relationships with inflow and precipitation will be reported in the first and second draft drawdown reports.

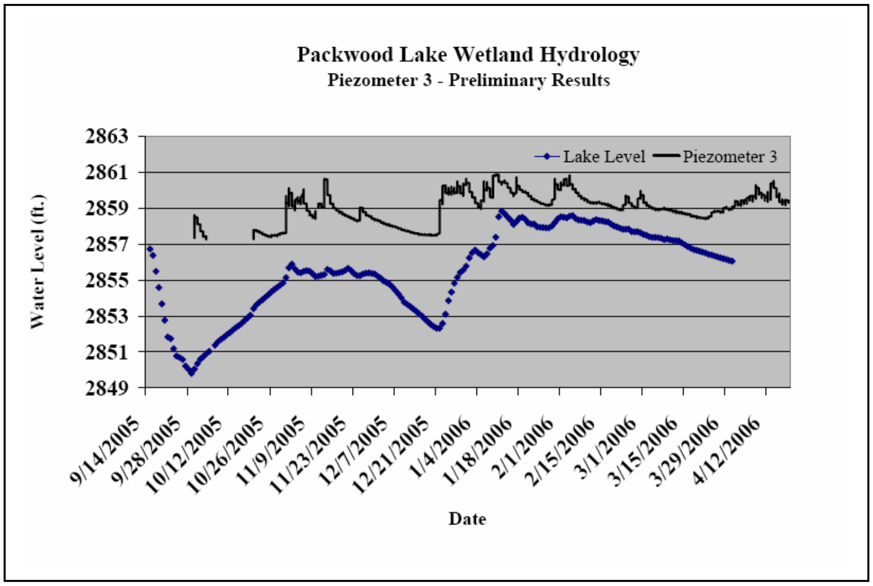

Figure 3.7 – Piezometer 3 water level (ft) and Packwood Lake Level (ft) during the 2005-2006 drawdown period.

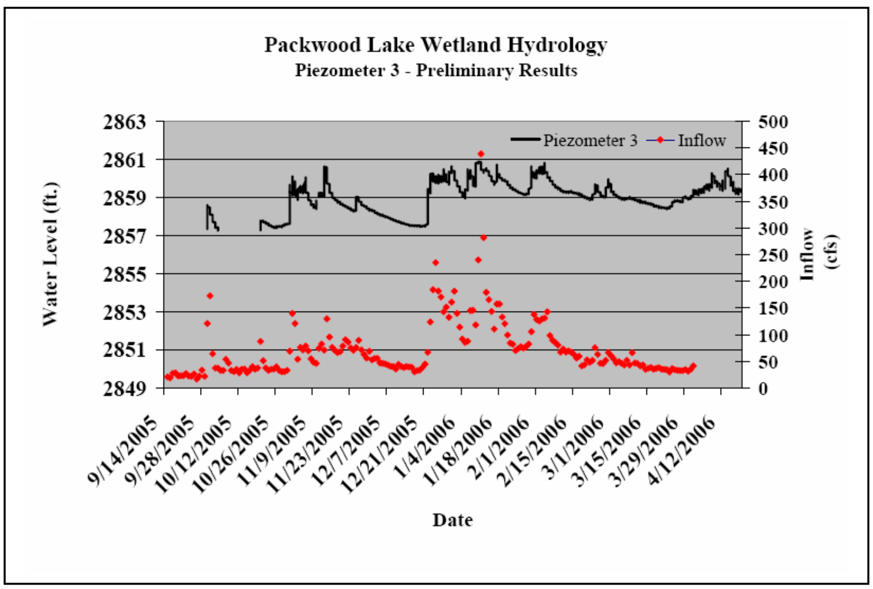

Figure 3.8 – Piezometer 3 water level (ft) and Packwood Lake inflow (cfs) during the 2005-2006 drawdown period.

3.3.4 Piezometer 4 (P-4)

P-4 was installed as part of a paired set at the head of Packwood Lake, adjacent to Upper Lake Creek. Of this pair, P-4 was closest to the lake. P-4 was constructed to a depth of 2.5 ft bgs. A popping and gurgling sound was clearly audible when the auger used to drill the monitoring well perforated a clay layer at approximately 2 ft bgs indicating that a natural groundwater barrier was penetrated. The well point rapidly filled with water. At the time of construction there was no way to determine if the water in the monitoring well was anything other than that associated with the wetland, so well construction was completed and a piezometer was installed.

Water level has been continuously recorded at P-4, since September 14, 2005. Water level at P-4 was highly variable, but closely tracked lake level during the monitoring period (Figure 3.9). P-4 water levels did not appear associated with inflow (Figure 3.10). Over 2400 observations were not utilized in the analysis because the monitoring well was dry. These dry well periods corresponded closely with the time periods when lake level was lower than the Levelogger® elevation in P-4 (2855.42 ft). Results suggest a high level of continuity between lake level and water level below the clay layer perforated by P-4. Results do not, however, provide a clear understanding of the hydrology associated with the wetlands around P-4. Results of monitoring at P-3 and P-4, when interpreted together, suggest that there may be a shallow layer of groundwater associated with the wetland. This shallow groundwater layer appears to be separated from groundwater in continuity with lake level by a clay layer.

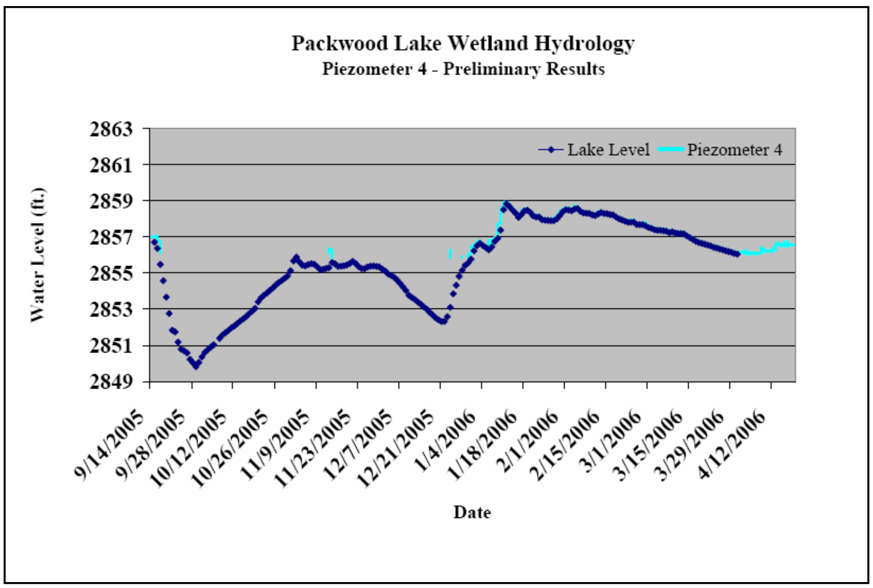

Figure 3.9 – Piezometer 4 water level (ft) and Packwood Lake Level (ft) during the 2005-2006 drawdown period.

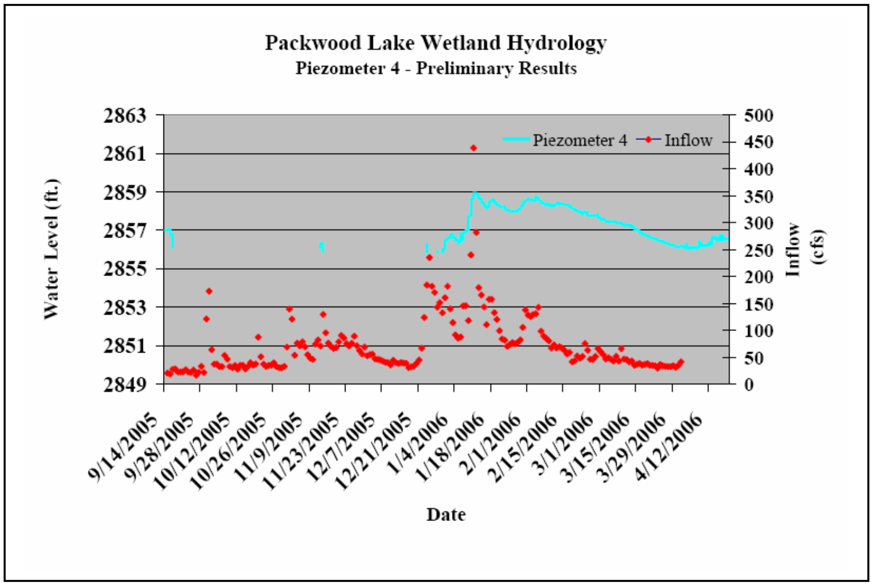

Figure 3.10 – Piezometer 4 water level (ft) and Packwood Lake inflow (cfs) during the 2005-2006 drawdown period.

3.3.5 Piezometer 5 (P-5)

P-5 was installed as part of a paired set adjacent to Osprey Creek on the southwest shoreline of Packwood Lake. Of this pair, P-5 was farthest from the lake. P-5 was constructed to a depth of approximately 6 ft bgs, and in continuity with the shallow groundwater table associated with the wetland. The well point slowly began to fill with water at the time of construction.

Water level in P-5 was very stable throughout the monitoring period. A shift may have occurred in P-5 when data were retrieved from all piezometers on November 10, 2005 (Figure 3.11). Field notes indicate mud was attached to the P-5 datalogger when data were downloaded. When the datalogger was returned to the monitoring well, it may not have returned to the original depth, causing the stair-step appearance of the graph in November.

Water level at P-5 appears to be independent of lake level (Figure 3.12) and inflow (Figure 3.13). Lake level ranged 9.02 ft (2849.81 ft to 2858.83.ft) during the monitoring period, while P-5 water level varied by just over 1 ft. Water levels in P-5 seem to reflect a stable groundwater hydrology, most likely associated with upslope hydrology rather than lake level. Figure 3.14 is a scatter diagram illustrating P-5 water level versus Packwood Lake level during the monitoring period. If there was continuity between lake level and P-5 water level, we would expect to see very similar water levels in the lake and wetland throughout the monitoring period. We do not. Instead we see a scatter of points, generally following the median P-5 elevation of 2860.60 ft across all lake levels. Initial analysis of lake level versus mean daily P-5 water level produced a coefficient of determination (r^2, the proportion of the variance in P-5 water level attributable to the variance in lake level) of 0.44. An r^2 of 0.44 suggests a weak relationship, at most, between the datasets. We also found the relationship to have a slope of 0.08, meaning that for every 10 ft of change in lake level one might expect to see 0.08 ft of change in P-5 water level. Additional regression analyses will be completed for P-5 and the other piezometers, and reported in the first and second draft drawdown reports.

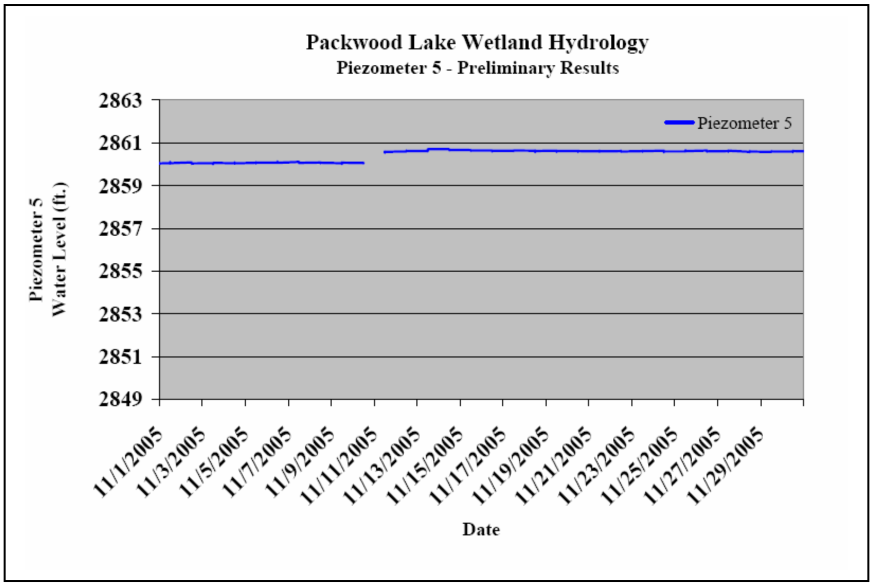

Figure 3.11 – Piezometer 5 water level (ft) in November, 2005.

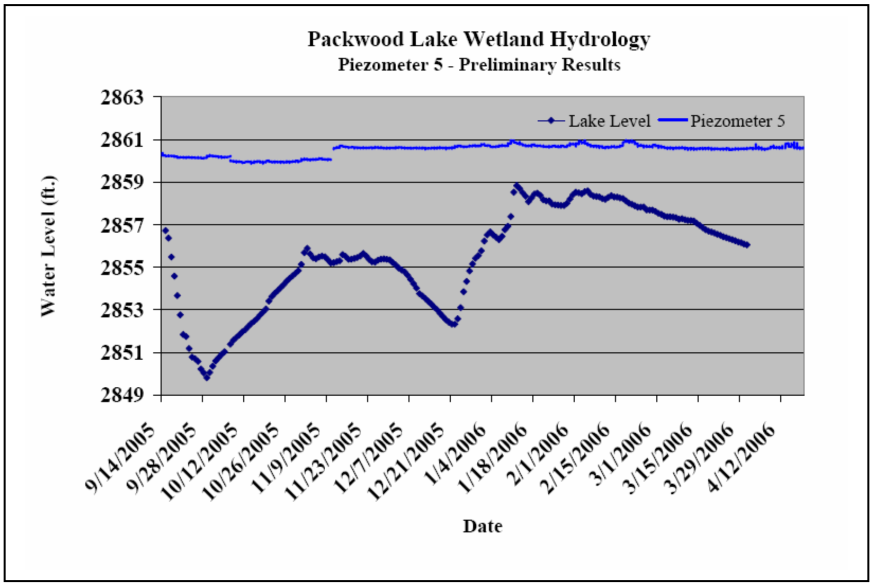

Figure 3.12 – Piezometer 5 water level (ft) and Packwood Lake Level (ft) during the 2005-2006 drawdown period.

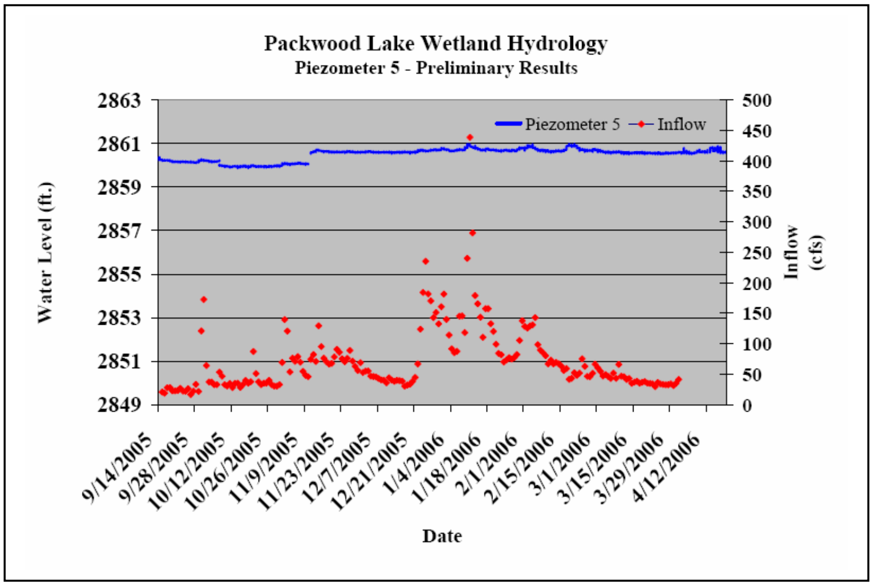

Figure 3.13 – Piezometer 5 water level (ft) and Packwood Lake inflow (cfs) during the 2005-2006 drawdown period.

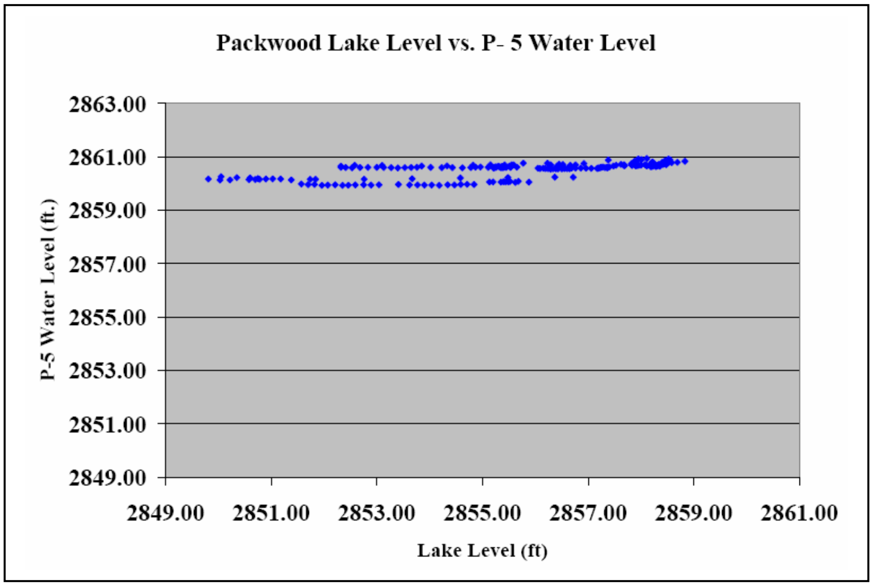

Figure 3.14 – A scatter diagram of Piezometer 5 water level (ft) versus Packwood Lake Level during the monitoring period. The appearance of two lines on this chart is the result of a stage shift.

3.3.6 Piezometer 6 (P-6)

P-6 was installed as part of a paired set adjacent to Osprey Creek on the southwest shoreline of Packwood Lake. Of this pair, P-6 was closest to the lake. P-6 was constructed to a depth of 2.5 ft bgs, and in continuity with the shallow groundwater table associated with the wetland. The well point slowly began to fill with water at the time of construction.

Figures 3.15 and 3.16 illustrate changes in P-6 water level as compared with lake level and inflow, respectively. Water levels in the lake and piezometer both gradually decreased between September 14 and September 29. Between September 29 and September 30, however, piezometer water levels rapidly changed over 1 ft (from 2857.15 ft to 2858.59 ft). This change corresponded with a change of lake level of only 0.02 ft (from 2850.03 to 2850.05) between September 28 and September 30. The rapid change in piezometer water level seems to be associated with a spike in inflow or a precipitation event (Figure 3.15). Inflow changed from 22 cfs to 173 cfs between September 28 and September 30.

Following this event, piezometer water levels stabilized for the remainder of the monitoring period. The relatively constant P-6 water level suggests no association between P-6 water level and lake level or inflow (Figures 3.15 and 3.16) during this portion of the monitoring period. It is possible that the early, apparent association between P-6 water level and lake level may result from a dewatering of the wetland groundwater during the dry summer or early fall time period. Then, when rains saturated the ground in later September, relatively stable water levels persisted.

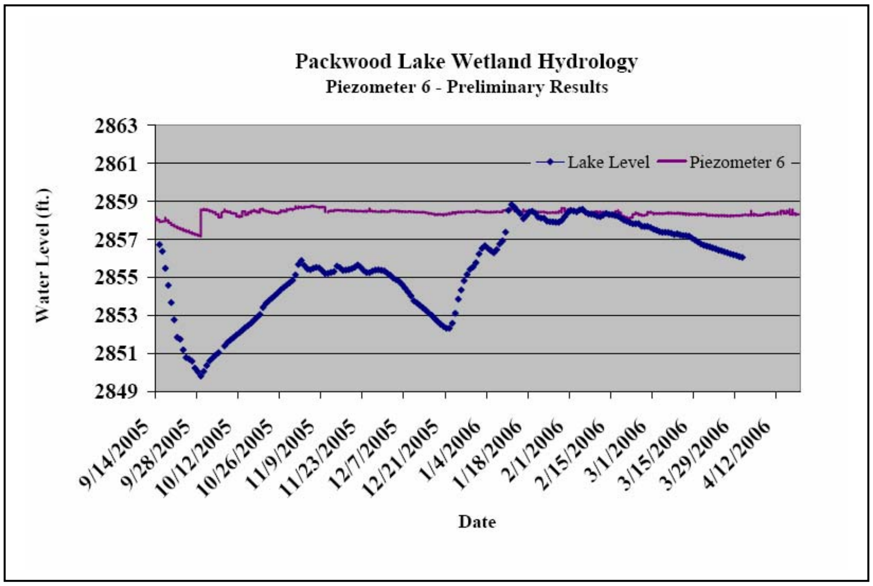

Figure 3.15 – Piezometer 6 water level (ft) and Packwood Lake Level (ft) during the 2005-2006 drawdown period.

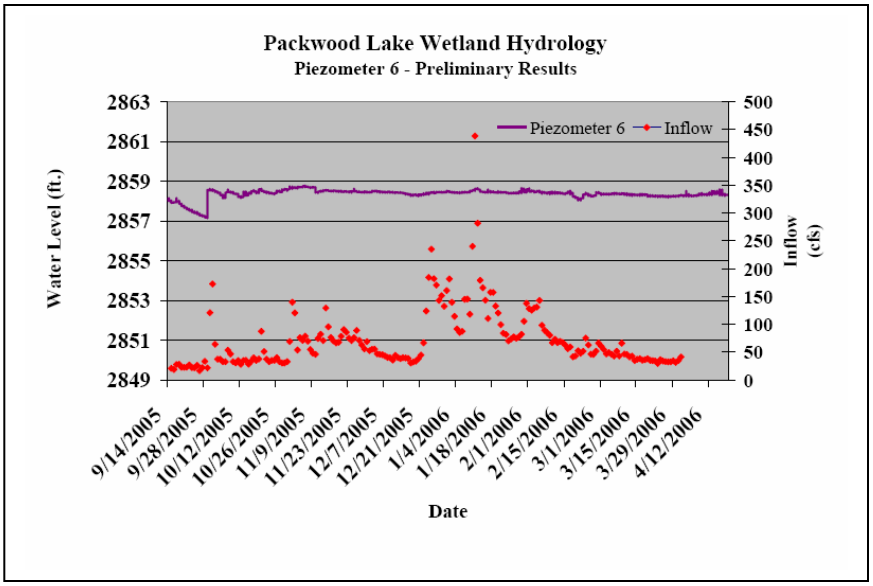

Figure 3.16 – Piezometer 6 water level (ft) and Packwood Lake inflow (cfs) during the 2005-2006 drawdown period.

3.4 Piezometer Level and Precipitation

Precipitation data have not been analyzed for this preliminary report.

4.0 DISCUSSION AND RECOMMENDATIONS

Hydrology is critical to the structure and function of wetlands. Hydrology and timing can influence species composition and richness, primary productivity, accumulation of organic matter, and nutrient cycling in wetlands (Mitsch and Gosselink 1986). Therefore, understanding wetland hydrology is central to characterizing any potential effects of Project operations on wetlands and associated fish and wildlife.

Based on review and interpretation of preliminary drawdown study results, there are very different hydrologic processes influencing the hydrology of wetlands in the Packwood Lake study area. Water levels in the six monitoring points showed markedly different patterns.

The portion of the wetland complex at the head of Packwood Lake, monitored by P-1 and P-2, seem to be primarily supported by a shallow groundwater source other than Packwood Lake. This local area may be influenced by Muller Creek hydrology or upslope hydrological processes, but shows little association with lake level. Monitoring should continue at P-1 and P-2 through October 31, 2006 to further evaluate relationships between piezometer water level, lake level, inflow, and precipitation through the summer dry period and into the September/October 2006 drawdown period.

The portion of the wetland at the head of the lake monitored by P-3 and P-4 showed markedly different patterns from P-1 and P-2. P-3 appears to show some association with inflow, and P-4 showed direct and immediate association with lake level, perhaps as a result of penetrating the clay layer. Since Upper Lake Creek is a major tributary to Packwood Lake, it is possible that there would be some association between water level in P-3 and estimates of inflow, if the wetland ground water near P-3 was associated with Upper Lake Creek hydrology. Further statistical analyses will be conducted to determine if this is the case. Of the six piezometers installed, P-4 water levels were most clearly associated with lake level. Additional analyses are necessary to determine if water levels in P-4 reflect wetland groundwater or groundwater levels below a confining clay layer out of immediate continuity with the wetland. When P-4 was installed it perforated a clay layer that may separate the shallow groundwater in this area of the wetland from water levels below the clay layer that appear to be in continuity with the lake. In addition to continuing monitoring at P-3 and P-4, a new piezometer should be installed near P-4. The new piezometer should be constructed in a manner that does not perforate the clay layer found during construction of P-4. We recommend moving the datalogger from P-5 to this location and monitoring through October 31, 2006.

Shallow groundwater hydrology supporting wetlands adjacent to Osprey Creek was very stable throughout the monitoring period. Water levels in P-5 remained stable, in spite of significant changes in lake level and inflow. Initial correlation analyses show a weak relationship (r^2 =0.44) between lake level and P-5 water level, and a slope of 0.08 suggesting that a lake level change of 10 ft might result in a change in the P-5 water level of 0.08 ft. These results show a low likelihood of lake level changes resulting in very minor changes in P-5 water level. For these reasons, we recommend that there be no further monitoring at P-5, and that analyses be completed with existing data.

Water levels in P-6 also were stable throughout a majority of the monitoring period. Fluctuations in P-6 water levels during the last 2 weeks of September may have been a result of the local groundwater hydrology reaching an equilibrium point following well construction, or may reflect dewatering of the wetland groundwater table during the typically hot, dry summer and early fall. Additional monitoring through the September/October 2006 drawdown could provide data to support one or the other of these possible scenarios. The wetland complex in the vicinity of Osprey Creek appears to have significant ground water level controls. These controls result in very stable groundwater levels around P-5, and relatively stable groundwater levels around P-6. P-6 was located closest to the lake, and may not have the same level of control as the area around P-5. Fluctuations in P-6 water levels may be limited to the hot, dry period of the year. Therefore, we recommend continuing monitoring at P-6 through October 31, 2006.

Results presented in this wetland hydrology report are preliminary. Additional assessments are being completed as part of the drawdown study that will supplement the information presented in this report. The drawdown study includes an analysis of the littoral zone, shoreline erosion, wetland hydrology and function, and vegetation mapping. Analyses should be completed before any conclusions are drawn about the potential effects of Project operations on wetland hydrology and associated natural resources.

Preliminary results suggest there is limited hydrologic continuity between lake level and wetlands around Packwood Lake. Rather, preliminary results suggest that wetland hydrology is more directly associated with localized upslope hydrology.

At this point in the study we have collected sufficient information to formulate hypotheses about wetland hydrology and recommend changes to monitoring at two points. We recommend that monitoring continue through the summer and next drawdown period in September/October 2006 to test hypotheses of relationships between wetland water level, Packwood Lake level, inflow, and other hydrologic processes. Data collected throughout the summer would provide a valuable opportunity to test a number of these hypotheses because lake levels are held relatively constant while other hydrology varies. Monitoring during a second drawdown period would be valuable to assure that results of the first drawdown study period are representative.

We recommend that monitoring be conducted through October 31, 2006 as follows:

(1) Continue monitoring at P-1, P-2, P-3, P-4, and P-6;

(2) Supplement monitoring of wetland groundwater levels near P-4 with a new piezometer constructed in a manner that meets the 2.25 ft bgs standard without perforating the clay layer found at P-4; and,

(3) Discontinue monitoring at P-5.

The following hypotheses would be tested from monitoring through October 31, 2006.

***H_1**: Hydrology supporting P-1 is associated with Muller Creek or other upslope hydrologic influence.*

If this hypothesis is correct, we would expect to see a moderate decrease in the water level of P-1 throughout the summer associated with the natural dry season. We might expect to see increases associated with the spring snowmelt, in spite of lake levels being held at 2857 ± 0.50 ft. We would need to stratify analyses to differentiate between potential association with increased lake level during overflow studies and other factors. Also, we would expect to see only moderate changes in piezometer water level in the fall during the next drawdown period despite much larger changes in lake level.

***H_2**: Hydrology supporting P-2 is associated with Muller Creek or other upslope hydrology.*

As with P-1, if this hypothesis is correct, we would expect to see moderate changes in the water level of P-2 throughout the summer. We might expect to see increases associated with the spring snowmelt, in spite of lake levels being held at 2857 ± 0.50 ft. We would need to tease out, during analyses, any potential association with increased lake level during overflow studies. Also, we would expect to see only moderate changes in piezometer water level in the fall during the next drawdown period despite much larger changes in lake level.

***H_3**: Hydrology supporting P-3 is associated with Upper Lake Creek or other upslope hydrology.*

We should expect to continue to see a high level of variability in the water level of P-3 throughout the summer and next drawdown period. P-3 should continue to show significant increases and decreases in water level concurrent with significant changes in inflow. Although lake level should be relatively constant through the summer, P-3 should have highly variable water levels as snowmelt, rain on snow, rainfall, and the dry period of the summer cause fluctuations in inflow. We would expect P-3 to have no significant decrease in water level when drawdown occurs in the fall; rather, we might again see increases in P-3 water levels concurrent with rainfall events.

***H_4**: Hydrology supporting P-4 is associated with Packwood Lake.*

If this hypothesis is correct, we should continue to see changes in P-4 water level closely tracking lake level. A second piezometer should be installed in the vicinity of P-4 to determine if there is a shallow, perched water table associated with the wetland that is not in direct continuity with the lake.

***H_5**: Hydrology supporting P-5 is associated with Osprey Creek or other upslope hydrology.*

We believe this hypothesis is adequately supported by existing data to warrant discontinuing monitoring at this point

***H_6**: Hydrology supporting P-6 is associated with Osprey Creek or other upslope hydrology.*

If this hypothesis is correct, we will continue to see little or no association between lake level and piezometer water level. We should continue to see stable water levels in P-6 throughout the summer and next period of drawdown.

5.0 LEVEL OF EFFORT AND COST

The estimated level of effort to extend monitoring through October 31, 2006 includes materials and labor to install an additional piezometer, summer and fall data collection, data analysis, report preparation and consultation. The estimate of total cost is $ 12,000.

6.0 LITERATURE CITED

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APPENDIX A
Piezometer Images

Piezometer 1 – April 19, 2006
Adjacent Muller Creek (off-lake)

Piezometer 2 – November 9, 2005
Adjacent Muller Creek (near lake)

Piezometer 3 – November 9, 2005
Adjacent Lake Creek (off-lake)

Piezometer 4 – April 19, 2006
Adjacent Lake Creek (nearest lake)

Piezometer 5 – November 9, 2005
Adjacent Osprey Creek (off-lake)

Piezometer 6 – April 19, 2006
Adjacent Osprey Creek (nearest lake)