Balance Hydrologics, Inc.

841 Folger Ave. • Berkeley, CA 94710-2800 • (510) 704-1000
224 Walnut Ave., Ste. E • Santa Cruz, CA 95060-3836 • (831) 457-9900
281 Nevada St. • Auburn, CA 95603-4617 • (530) 887-9988
www.balancehydro.com • email: office@balancehydro.com

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205203

Glen Spain, Northwest Regional Director
Pacific Coast Federation of Fisherman's Associations (PCFFA)
P.O. Box 11170
Eugene, OR 97440-3370

Dear Mr. Spain:

You have asked that we review the technical merit of selected testimonies given before the Public Utility Commission of Oregon related to the request for a general rate increase from Pacific Power & Light (Docket No. UE 170). The period allotted for our review has been less than 2 weeks, disproportionate to the time obviously spent in developing and polishing the testimony. Additionally, the materials which we have been asked to review are based fundamentally on other primary reports, which themselves require review, if only to assess whether the data taken from the primary documents are, in fact, reasonable and representative. Further complicating review, the testimony provided is primarily in the form of opinions, lacking computational backup and/or requiring considerable inquiry into other sources. Key elements are cited to tables in the ongoing Bureau of Reclamation 'Natural Flow Study' -- itself under frequent and radical revision – which may no longer be valid. We sympathize with the forthcoming decision deadlines of the Commission; in fairness, we must note that there has been literally not been quite enough time to do justice in this review, especially to check back to primary or confirmatory sources.

Given the limited time, our review has focused on the assumptions and methodologies used to arrive at the conclusions in the testimonies of Edward Bartell and Louis T. Rozaklis (on behalf of the Klamath Off-Project Water Users, Inc.). Other testimonies, in particular those of Marc Van Camp and Donald W. Schoenbeck (on behalf of the Klamath Water Users Association), are of great concern, but we are not able to provide a comprehensive review at this time.

1. Comments on Bartell Testimony

a. Lost River

Many of the limitations inherent in Mr. Bartell's testimony can be encapsulated from one of his statements:

"The fixed power rates also allow farmers to divert water out of closed drainage basins into the Klamath River. For example, the Pine Flat area is a closed basin. As a closed basin, precipitation or drainage from irrigation causes excess water. This water is pumped out of this closed basin and enters the Lost River System. In the wintertime, the entire flow of the Lost River and tributaries is diverted to the Klamath River via the Lost River Diversion Channel. In the summertime, water in the Lost River becomes part of the Klamath Project and thereby could lessen diversions out of Upper Klamath Lake or the Klamath River". Bartell, p.13

We find this testimony misleading in several respects:

1. He states that all of the water in the Lost River system during winter is diverted into the Klamath River. This is not correct.

2. He is implying that winter water in the Klamath River is equal in value to summer water. This is not correct in several respects. Narrowly, not all winter water goes through the power-generation system.[1] Narrowly, the demand for power is higher in summer. More broadly, summer water has high value for maintaining aquatic habitat (including for species of recognized national significance and for sustaining the culture of residents along the river below Iron Gate), as well as for maintaining water quality, in a manner allowing for both flexibility of power-pool management and environmental quality throughout the overall Klamath River system. In essence, he is confirming that most of the additional water coming in from the Lost River system enters in **winter,** when the flows are of limited or negative value for habitat or other traditional lower-river uses.

3. Bartell's statement claims additional summer water in the form of water whose diversion from the Klamath watershed is **avoided;** in fact, no additional water is created. He is inadvertently highlighting that agriculture within the Klamath Project area **removes many tens of thousands of acre feet each year** from the Klamath River for summer irrigation for use in the Lost River, Yonna and Swan Valley and other adjacent watersheds – a fact not mentioned in Mr. Bartell's or

[1] On an apples to apples basis, the probability that an acre foot of winter water on average will be able to generate power is a little more than 50 percent, based on Rozaklis' Table 15, and recognizing that Iron Gate is by far the largest of the facilities. Additionally, summer flow is more useful for generating peaking power.

Mr. Rozaklis' statements. Absent agriculture in the lower Lost River basin and Tule Lake, there would neither a need nor a means to divert this water out of the Klamath system**.** That it "could lessen diversion out of Upper Klamath Lake or the Klamath River" confirms and implies that water is being moved out of the Klamath watershed at the time of year when it is needed most for power and for aquatic and human habitat needs (including water quality) downstream, as noted above.

4. Bartell seems to be claiming all of the benefits realized in the powerhouses from Lost River diversions as attributable to agriculture. Yet we note that (a) water flowed from the Lost River system to the Klamath River system naturally at times prior to the Klamath project, and (b) diversion of Lost River flows to the Klamath River is so hydraulically simple and has such a high power-generation benefit that it would likely have been built simply to generate power -- even without the presence of agriculture. Interbasin diversions of similar magnitude and potential were constructed during the first half of the 20th century between watersheds where agricultural co-benefits were minimal or transitory – as witnessed by the Potter Valley Project (Mendocino County) or the Mono Lake tunnels (Eastern Sierra). In the case of the Klamath River, agriculture created substantial and central co-benefits for the Lost River diversions, but to claim all power-generation benefits as being created by agriculture is incorrect.

b. Hydrogeology

Bartell argues that water returning to the streams from lands irrigated from wells in areas upstream of Upper Klamath Lake is water 'added' by agricultural practices. Water can, in fact, be added by pumping deep water in some geologic settings, but not in those prevailing north and east of the lake, where (1) underlying rocks are permeable, where (2) the hydrogeologic setting is such that there is not a sharp downward gradient, and (3) where topographically lower points nearby where a local or regional aquifer can drain to the surface-water network. Each of these conditions are met upstream of Upper Klamath Lake. On these factors, we note:

(1) The volcanic rocks are generally permeable at the regional scale, as reflected in a summary document prepared by the Oregon State Engineer:

> *"The principal aquifer is a confined one in broken, cavernous or cindery lava and volcanic sediments. These permeable beds are overlain and confined by fine-grained laucstrine sediments and impervious volcanic rocks. In Sprague River, Swan Lake, and Yonna Valleys, irrigation wells that tap the confined aquifers yield a few hundred to 3,000 gpm (gallons per minute). Flowing wells occur in all areas except Swan Lake Valley. The most extensive area of flowing wells is in*

> *the Sprague River valley, where about 25 wells, some flowing more than 2,000 gpm, supply water for irrigation"* (Leonard and Harris, 1974, p. 2)

(2) The hydrogeologic setting is one where there is no sharp downward gradient that could convey water into deep basins where residence times can be centuries or longer – sometimes much longer, such as beneath the Great Plains, central Australia, or northern Africa. The presence of flowing ('artesian') wells indicates that regional gradient may actually be upward, implying that ground water cannot physically move into very deep zones; rather, it will flow to a topographic low where it enters the surface-water network. As noted by Leonard and Harris (1974, p. 17):

> *"Within Klamath Basin, the general circulation of ground water in the deeper zone is from north to south and from the uplands toward the valleys. All the lowlands are areas of discharge where ground water is discharged by upward seepage from confined aquifers. . ."*

With only very minor exceptions, there is nowhere in the Klamath Basin above Iron Gate other than the surface water network or wells for ground water to discharge. Substituting pumping for discharge to the streams, lakes and marshes does not make new water. It simply changes when the water arrives. And, in our opinion, for most of the water pumped, that change may be several years or even a number of months.2

(3) Flow can, and does move, to the surface-water network in the lowlands, as described by Leonard and Harris, 1974. The Sprague River Valley is about 200 feet above UKL, not far to the southwest. The aquifers of the upper Williamson watershed are even higher, and the Wood River Valley slopes steeply toward the lake, and to other intervening low points. The same dynamic also applies to adjacent portions of the Lost River watershed as well as downstream from UKL, where springs have been pouring into the lake and Klamath River over geologic time.

c. Bartell references

Portions of Mr. Bartell's testimony are based on his interpretation of work by USGS hydrologists John Risley and Antonin Laenen (1999). Bartell quotes Risley and Laenen as supporting the position that agricultural practices have increased the flows in the Williamson+Sprague system. This is not correct. These hydrologists conclude their report noting that:

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[2] In earlier work, we found (Hecht and Kamman, 1996, Appendix A, discussed further below) that the effects of a very wet year gradually diminishes over a period of several years, based on multiple-regression model results which decay below the threshold of discernment after 5 years.

> *"However,relating specific land-use activities to changes in runoff is impossible to assess using available data owing to the size and geologic complexity of the basin and to the paucityof historical land- and water-use data for local areas."* (p. 22; also, KOPWU 107/ Bartell 28)

A statement of this type does not seem to provide a basis for assigning 'added water' in any significant amount. Further, neither they nor other USGS staff have followed up with further work on the issues that they have left unresolved, among which are (a) differences in the number of high-recharge years between the two periods[3], (b) testing of alternative hydrologic explanations[4], (c) recently identified shifts in the timing of seasonal runoff[5], and other causes. As it turns out, each of these are in themselves sufficient to potentially negate the findings under further review. And the volumes of water involved are a small fraction of those claimed by Bartell and by others as allegedly added water. Further – as with all other winter water – not all such flows will actually enter the power-generation facilities, nor are they of equal value for power generation or environmental considerations and offsets; no difference in summer flow volume was found on the Sprague system, and only a small amount on the (upper) Williamson with neither (once again) found attributable to agriculture or any other specific land use. Any statement that these authors, or that USGS and affiliated agencies, support the theory of added water, let alone the volumes involved, is not correct.

We have included two graphics from an earlier report which show that the period from 1918 through 1950 was, in some important hydrologic respects, a period drier than normal, while the the subsequent period was wetter. Figure 1 uses USBR computations to show that long-term accumulated precipitation reached a minimum in 1950, and increased substantially since that time. Figure 2 uses the nearest record (Yreka) extending earlier than establishment of the Klamath Falls station in 1914. It suggest that

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[3] High-recharge or very wet years have a disproportionate effect on flows, one that can persist for several years. Balance Hydrologics staff (Hecht and Kamman, 1996, Appendix A) previously used a multiple-regression model to show that summer flows in the Klamath River at the outlet from the Klamath Basin (Keno gage) were discernibly elevated for up to 5 years following years of significantly above-average recharge. Since there are unequal numbers of high-recharge years during the two periods under inquiry (as one example, there were no years exceeding 20 inches at Klamath Falls from 1918 to 1950, but 5 such years from 1950 through 1996), this fact alone may account for much or all of the observed differences.

[4] The authors note that their work is solely a statistical exploration, and that no processes have been identified to account for differences found to be statistically significant but not understood. When dealing with small differences in large numbers, hydrologists normally proceed by testing a number of alternative hypotheses, and then identify specific processes which may be causes for such differences.

[5] In a recent report post-dating Risley and Laenen's work, ____ identified that snowmelt now is two weeks later than prior to 1950 in this part of Oregon, a process which could also explain much or all of the differences.

there is a long-term pattern of climatic fluctuations which may bear on claims of agriculturally-added water.

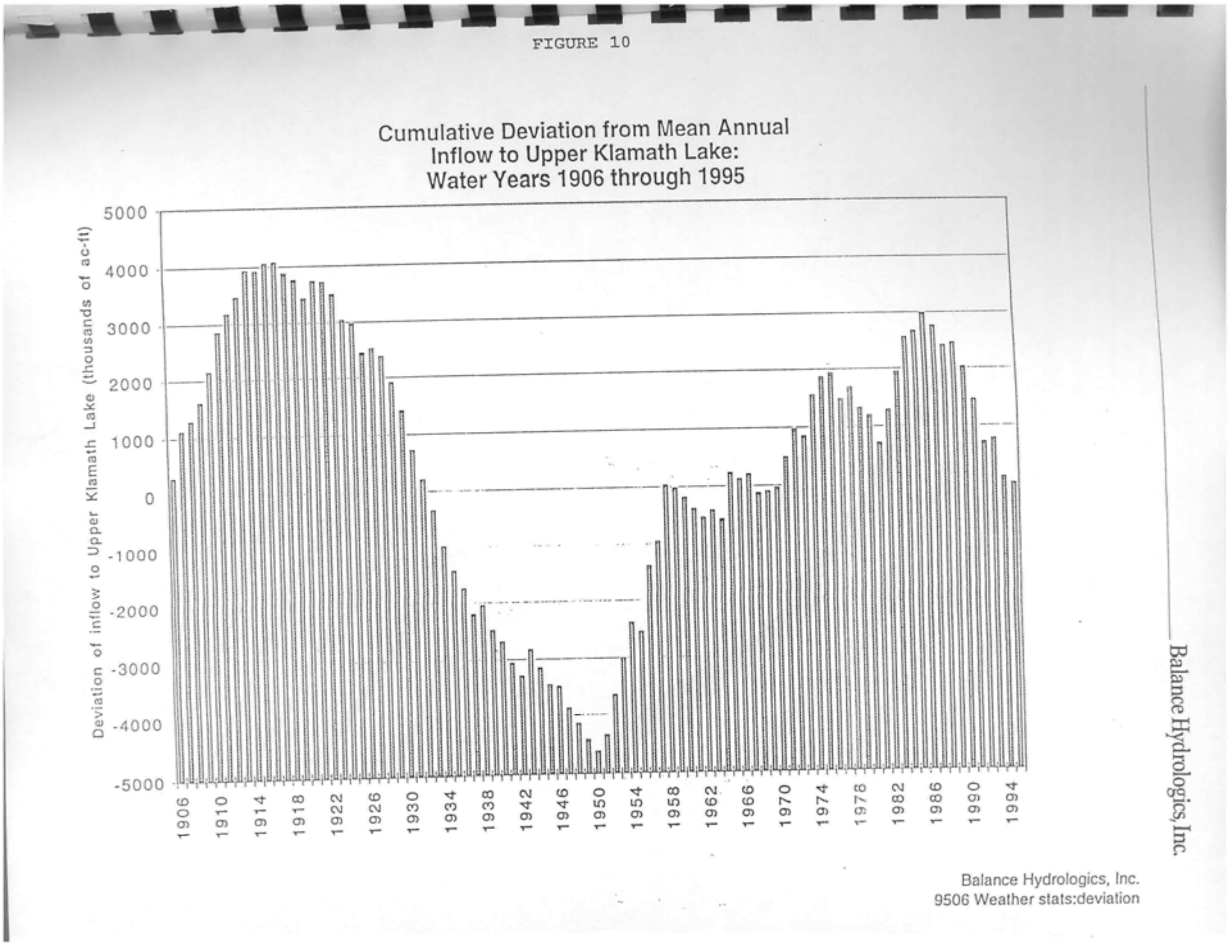

Figure 1. Cumulative deviation from mean annual inflow to Upper Klamath Lake

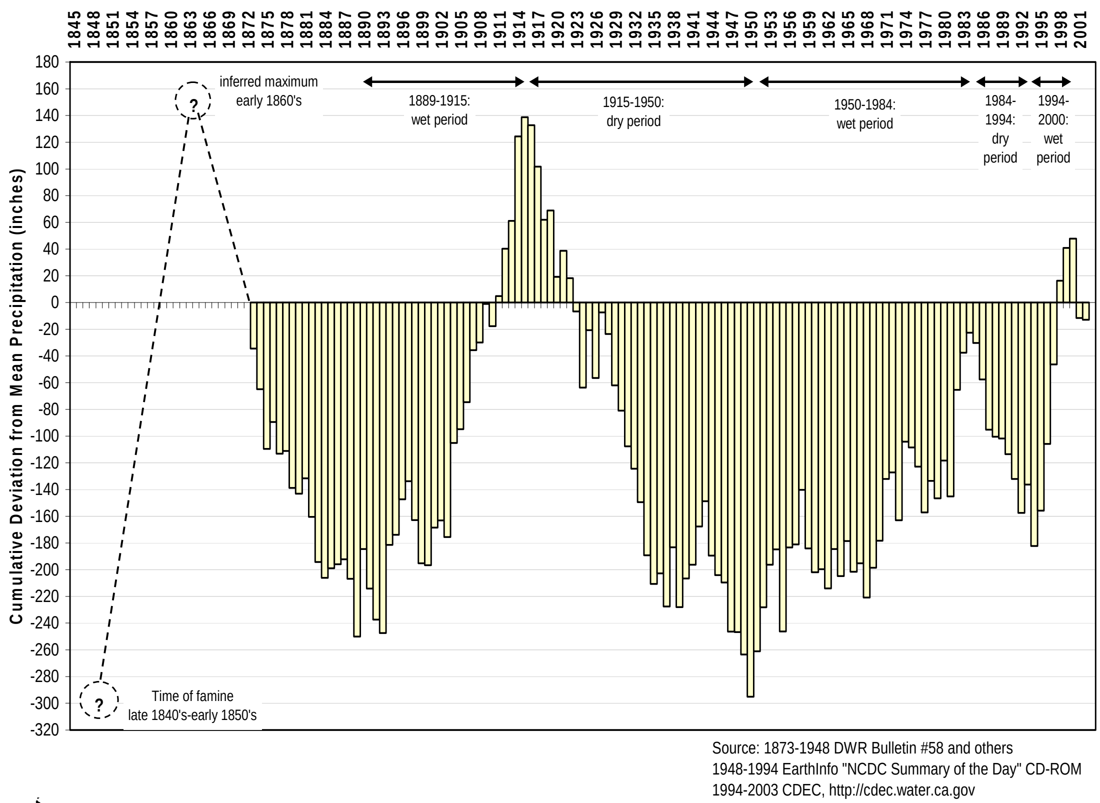

Figure 2. Cumulative deviation from mean annual precipitation at Yreka, California: rainfall years 1873 through 2003. Inferred 1840's to 1873.

2. Comments on Rozaklis Testimony

Mr. Rozaklis sponsors his report in which he estimates increased Klamath River flows/supplies from Off-Project lands on the order of 130,000 acre-feet per calendar year[6]. He proposes two primary increased supply sources: 1) agricultural return flows from lands irrigated with ground water (73,000 acre-feet per calendar year) and 2) differences between evapotranspiration from historical marshlands which were drained and converted to agricultural lands (58,000 acre-feet per calendar year). Rozaklis also suggests that draining of marshlands and clearing of forests for rangeland creation can increase annual stream flows.

a. Ground water

We make not of a number of assumptions made by Mr. Rozaklis to estimate increased supply from ground-water supplied off-project agricultural lands:

- He notes the presence of shallow and deep aquifers, and concludes that only the shallow aquifers are directly connected to the surface-water hydrologic system.

First, it merits mention that the extent of the shallow aquifers is relatively limited. They are prevalent mainly in the agricultural valleys, and even there they are discontinuous. Usefully generalized, the main aquifer(s) are the volcanic rocks to which Rozaklis refers as the deep aquifer, but which are exposed at the surface or are freely recharged from the surface over most of the topographic watersheds (c.f. Leonard and Harris, 1974, text and plates; USGS, 2005), most specifically in the Williamson+Sprague watershed.

In our comments on Mr. Bartell's testimony, the fundamental hydrogeologic linkage between ground water in the deep aquifer and the surface-water system of the Klamath basin was described. Prior to irrigated agriculture, the streams flowed, the springs sustaining the two endangered sucker species

[6] It is important to note that most hydrologic reporting occurs for a period defined as a water year, which begins on October 1 and ends on September 30 of the named year. In contrast, Rozaklis chose to use the calendar year as the basis for his annual estimates.

flowed at levels at least as high as at present, and the Klamath basin above the Shasta River or Iron Gate was a main source of summer or dry-year water to the entire Klamath watershed (Hecht and Kamman, 1996). This hydrologic system continues in the presence of agriculture and other human activities. The notion that it could be sustained by shallow aquifers of limited extent is not correct.

- Rozaklis assumes pumping ground water does not deplete stream flows, and that the irrigation (and return flows) come from aquifer storage, which is treated as inexhaustible. In his words:

"While the hydrogeology of the Upper Klamath Basin is complex and not completely understood, it is reasonable to conclude that the amounts of irrigation well pumping from this aquifer, as estimated above, generally do not affect surface stream flows in a direct and immediate manner. While irrigation wells developed in this lower basalt aquifer generally exhibit minor fluctuations in water levels associated with seasonal pumping, long-term water levels in these wells are generally declining, with periodic increases that correspond to extended regional climatic wet periods (USGS, 2005c). Well hydrographs for typical off-Project irrigation wells are shown in Figure 2 and Figure 3. These downward trends indicate that well pumping generally does not directly deplete stream flows; instead it reduces aquifer storage, which is in turn partially replenished during periods of unusually high precipitation, when stream flows are substantially above average. Therefore the return flows from groundwater supplied KOPWU lands are net gains to the stream system from the perspective of PacifiCorp's hydropower generation capacity." KOPWU / 202 Rozaklis / 15

If depletion from storage is the primary mechanism by which water is 'added' to the flows below Keno, then depletion should logically approach the 131,000 acre feet per year of claimed added water from the combined Williamson+Sprague watersheds. Using data from the well that he identified as representative (Fig. 2), we calculate the actual depletion as follows:

a. Assume entire ground water in the entire watershed (1,920,000 acres, or 3000 square miles) is lowered:
b. At the rate shown in his Figure 2 (approximately 0.25 ft / yr over the period shown)
c. With a storativity of 0.01 (or, one percent of aquifer is drainable water), as estimated by Leonard and Harris,

a depletion of 4800 acre feet per year (afa) for the 45-year record over the entire watershed may be computed. Realistically, this value is an overestimate, as it should be adjusted for 1) declines in water level associated with pumping in nearby wells and not related to depletion, 2) little likelihood of the entire watershed being depleted by pumpage in the small fraction of its area from which water is pumped, and 3) the likelihood that a lower mean storativity may prevail (since portions of the deep aquifer--including those most heavily pumped -- are confined, and a value of 0.01 is very high relative to those typical of confined aquifers), an actual depletion of 1000 to 3000 afa may be more reasonable. Assuming that the well he chose is representative, addition of 131,000 afa from the Williamson+Sprague watershed cannot be correct if aquifer depletion is considered by Mr. Rozaklis as a primary source of water claimed to be added for hydropower generation.

Use of deeper ground water sources can – and usually does -- significantly and persistently lower stream flows, especially late-summer and dry-year flows, which have particular value for habitat and bank stability, as well as power generation, factors not considered by Rozaklis. The links between pumping from the 'deep aquifer' and streams are considered above in our discussion of Mr. Bartell's testimony.

- He assumes that ***all*** excess water returns as stream flow either directly as surface returns (40%) or indirectly as subsurface returns (60%). He also may assume that no losses affect return flows as calculated at the field site during passage through ditches or by other means to the surface-water system and all the way downstream through Iron Gate.

Rozaklis does not include any estimation of water loss that occurs as a result of water transit or field application processes. Pumped ground water travels through an extensive array of irrigation canals, laterals, and drains in the Klamath Basin. Water is then applied to the fields via sprinkler systems or field flooding. Both water conveyance and application activities promote water loss through evaporation and evapotranspiration (ET). These losses, which can be quite significant, are not accounted for in Rozaklis' water budget.

Application losses

Burt and others (2002) conducted a review of evaporation research in order to compute evaporation amounts for irrigated agriculture in California. One of the key outcomes of their study was a compilation of work done to estimate spray losses from sprinklers, an important component of applied water which is neither consumed by crops nor captured as return flow in drainage systems. Spray droplet evaporation losses range from 1% to 4% for typical sprinkler systems and can be even higher in sprinkler systems with high pressures. Under high wind conditions spray droplet evaporation can be considerably higher on. Although the conversion from surface to spray irrigation reported by Mr. Rozaklis would likely increase irrigation efficiencies and decrease the amount of ground-water pumping, it is unlikely that it would have any impact on stream flows.

Conveyance losses

Excess water applied to croplands returns to the irrigation system and is often re-used for downgradient properties multiple times before finally reaching the main stream network. There are numerous ways in which water will be completely lost from the system during this transit process, including,

a) evaporation of water in open ditches and storage ponds,
b) evapotranspiration of water in ditches and tributaries that have vegetated banks or in-stream vegetation,
c) water loss to the deep ground water aquifer via leaks and seepage in the ditch system.

Estimates of transit loss can be quite substantial and should not be overlooked when calculating the amount of runoff generated from agricultural lands. Rozaklis assumes that all irrigation return flows and shallow, subsurface ground water are eventually returned to the creek, but makes no mention of evaporation and ET losses that occur when water is transported from the creek through the irrigation canal and drain systems, nor of potential losses to the deep aquifer. It is also important to note that because return flows are often re-used on multiple fields, the potential for total water loss is increased because the same water is subject to evaporation and ET losses with each application.

Kent (1905) conducted a study of irrigation losses from seepage, evaporation, and ET on the Adams ditches, the Ankeny, and the Mitchell lateral, located in the Klamath Basin. Kent measured discharge along sections of these irrigation ditches (from 1.5 to 6.5 miles apart), subtracted diversion flows, and calculated total water loss for a single irrigation application in July and August. Total water losses ranged from 10 to 20% of total discharge. These losses accounted for both evaporative processes and seepage during transit. Seepage losses do not necessarily equate to a complete loss to the system, as some seepage will eventually return to the creeks via subsurface pathways. However, this study emphasizes that losses do occur along irrigation ditches, canals, and drains, and can account for a significant amount of water that should be included in any water budget study of the Klamath Basin.

A more recent study conducted by Burt and Freeman (2003) addresses several hydrologic issues of the Upper Klamath Basin. In this study, estimates of evaporative loss during transit for irrigation purposes for several Project areas in the Klamath Basin were made. Evaporation and ET losses for three years, 1999 through 2001 were calculated. Average annual evaporation and ET losses in canals equaled 11,155 acre-feet per year. Using a GIS database and a number of supporting references, Burt and Freeman (2003)estimated the total canal and drain surface area within the Klamath Project as 3,543 acres, feeding and draining approximately 115,000 acres of irrigated fields. Thus, annual evaporative losses amount to 3.14 feet per acre of canal.

We did some simple calculations of potential water losses due to ET and evaporation of water transported in irrigation canals and ditches to support off-Project agriculture:

- We assumed a similar ratio of canal and drain surface area to irrigated fields as that measured by Burt and Freeman (2003). Burt and Freeman (2003) measured 3,543 acres of conveyance system supporting 115,000 acres of irrigated fields or 0.03:1. Rozaklis reports 70,736 acres of off-Project ground water-supplied agricultural fields and 65,665 acres of drained irrigated lands. A comparable irrigation network for the off-Project lands would be 2122 acres of canals and ditches supporting ground water-supplied fields and 1970 acres of canals and ditches supporting the drained irrigated fields.

- We used Burt and Freeman's (2003) calculated annual evaporative loss of 3.14 feet which accounts for evaporation and ET in canals and ditches.

The table below illustrates that irrigation transit loses to ET alone amount to approximately 12,849 acre-feet per year, or almost 10% of Rozaklis' estimate of annual flow increases resulting from off-Project lands. Our calculation does not account for water losses to the deep aquifer or compounded loss occurring due to re-use of return flows on multiple agricultural fields.

Table 1. Conveyance losses

	Total acreage of croplands (acres)	Ratio of Project conveyance system to irrigated acres	Estimated surface area of irrigation canalsand ditches (acres)	Total estimated annual ET (acre-feet)	Total annual water loss due to ET and evaporation (acre-feet)	Rozaklis estimates total annual increased flow (acre-feet)
Ground water-supplied off-Project agricultural lands	70,736	0.03:1	2122	6,663	12,849	130,000
Off-Project drained irrigation lands	65,665	0.03:1	1970	6,186		

b. Marshland conversion

Rozaklis suggests that conversion of 65,665 acres of marshlands adjacent to lakes and rivers to off-Project irrigated fields results in annual flow increases of over 58,000 acre-feet per calendar year. This is based on the overarching assumption that ET losses from agricultural lands are less than ET losses from wetlands. We question a number of the supporting assumptions go into his calculations:

- Rozaklis assumes that half (18,500 acres)of the drained wetland acreage in the off-Project lands located around Upper Klamath Lake and along the Klamath River near Keno was open water in pre-development conditions.

The rationale for this assumption is based on the current elevation of the agricultural field relative to adjacent lakes and rivers (see Rozaklis Section 4.2.1). No maps were provided as reference. In making this assumption, Rozaklis neglected consideration of an important consequence of farming in highly organic peat soils such as many of those of the Klamath Basin. When peat soils are drained and exposed to the atmosphere they oxidize and compact, and/or are reduced in thickness by wind erosion; thus, the land surface is permanently lowered with each yearly cycle. Prior to draining, these marshlands would have had a higher elevation than the water surface. Thus, it may be erroneous to factor open water surface evaporation from half of the acreage on the pre-development side of the equation. The revised tables (below) show that removing open-water surface evaporation reduces Rozaklis' monthly and annual increased flow estimates. In the Upper Klamath Lake area, increased annual flow is reduced from 38,982 acre-feet to 22,133 acre-feet. In the Klamath River near Keno area, increased annual flow is reduced from 5,166 acre-feet to 4,125 acre-feet. An important outcome is the decreased flows in October when competing uses for water are relatively high. Please note that we used Rozaklis' ET estimates in these tables which we feel overestimate wetland ET. A discussion of the ET loss estimates follows.

Table 2. Removal of open water from pre-development condition

Upper Klamath Lake Area (32,000 acres)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pre-Development ET													
marsh ET (inches)	0.4	0.7	1.2	1.3	3.8	5.5	7.2	5.9	3.5	0.6	0.6	0.4	31.1
ET losses (acre-feet)	1067	1867	3200	3467	10133	14667	19200	15733	9333	1600	1600	1067	82933
Post-Development ET													
ag ET (inches)	0	0	0	1	3	4.3	5.8	4.8	3.2	0.7	0	0	22.8
ET losses (acre-feet)	0	0	0	2667	8000	11467	15467	12800	8533	1867	0	0	60800
Increased flow	1067	1867	3200	800	2133	3200	3733	2933	800	**-267**	1600	1067	22133

Klamath River Near Keno Area (5,000 acres)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pre-Development ET													
marsh ET (inches)	0.4	0.7	1.2	2.1	4.8	6.7	8.9	7.3	4.3	1.2	0.6	0.4	38.6
ET losses (acre-feet)	167	292	500	875	2000	2792	3708	3042	1792	500	250	167	16083
Post-Development ET													
ag ET (inches)	0	0	0	1.8	3.9	5.1	6.9	5.7	3.9	1.4	0	0	28.7
ET losses (acre-feet)	0	0	0	750	1625	2125	2875	2375	1625	583	0	0	11958
Increased flow	167	292	500	125	375	667	833	667	167	**-83**	250	167	4125

Additionally, reviewers of the USBR Natural Flow study have provided data revealing that open water in the Upper Klamath Basin was heavily populated with wocus, a yellow pond lily (Gearheart, 2005). Wocus communities act to shade open water and have relatively low ET rates when compared to emergent aquatic plants such as tules and cattails. This fundamental fact is not incorporated in Rozaklis' analysis.

- Rozaklis bases his ET estimates on methods described in the November 2005 USBR "Natural Flow of the Upper Klamath River" study (USBR, 2005). ET for permanently flooded marshes are estimated using the modified Blaney-Criddle method, incorporating the USBR's monthly crop coefficients for tules and cattails, with ET results adjusted downward to reflect differences with work done by Bidlake and Payne.

There are a number of concerns with Rozaklis basing his wetland ET rates on the estimations made by the USBR's report that is still undergoing review by the National Academy of Science. Outlined below are some of the major flaws with the USBR's method of calculating wetland marsh evapotranspiration that bias the values toward increased wetland evapotranspiration and over-estimation of historical (pre-agriculture) water losses.

1. It is assumed in the USBR report and Rozaklis' testimony that the species composition for all of the wetland marsh areas were historically dominated by tules and cattails. This is an inaccurate assumption that does not take into account the diversity of the marsh areas of the Klamath Basin. For instance, Gearheart (2005) summarizes the historical importance of yellow pond lily (Woncus spp.), which has a much lower evapotranspiration rate than tule and cattail and actually reduces open water evaporation because it floats on the water surface.

2. It is also questionable to use the Blaney-Criddle method (which was developed for agricultural crops) for calculating evapotranspiration for aquatic macrophytes because wetland plant species respond to seasonality differently than crops. Crops are supplied with water via irrigation pathways during the dry, summer months when natural water sources are scarce to maximize consumptive use and growth, whereas wetland plants will uptake less water during their growth season when under moisture stress, such as occurs during dry years. Further, wetland plants senesce earlier in the season, curtailing late-summer ET. This is an important difference that is not addressed in Rozaklis' study.

3. Section 5 of Hecht and others (2005) describes in detail specific flaws with the USBR's estimated values for wetland ET. This section is attached as Appendix I.

As evidenced by the lack of confidence in the USBR ET estimates and summarized in the Gearheart (2005) memo, experts on wetland ET are still far from agreement on the appropriate method to employ (see for example Drexler and others, 2004). Unfortunately, wetland crop coefficients have not been developed for the species mix and climate characteristics which existed in the Upper Klamath Basin during pre-development conditions for simple substitution in the Rozaklis tables, and, it would be presumptuous for us to make such estimates.

c. Other considerations

It is not clear whether the tables included in his testimony include irrigation of lands with unadjudicated water rights. He may have noted these during his field work in the area. It appears that such lands are irrigated mainly with diversions of surface waters, many of which are not converted wetlands, which would logically diminish claims of added water.

3. Comments on Van Camp Testimony

We have a number of concerns with the testimony give by Mr. Van Camp:

a. "…all of the effects of Klamath Project facilities are experienced between Upper Klamath Lake and Keno"

   It may have been better to say 'from the shores of Upper Klamath Lake through Keno.'

   As it stands, this statement seems to conflict with that of Mr. Bartell -- who notes diversions from Upper Klamath Lake to Yonna Valley, among others -- and Mr. Rozaklis, who notes that a number of land owners within the Klamath Project, with lands with demands totaling several thousand acre per year, are becoming de-facto off-project irrigators due to decisions made by the Project.

   Equally, the Project makes many of the decisions how to operate UKL, which affects losses within the Klamath River surface-water system. We note, as well, that the Project accommodates its operation of the Lake to conform with water levels needed for listed species – further altering, and generally, reducing flows which might otherwise be claimed as added to power generation, but possibly adding value by delaying flows into the summer season.

b. Mr. Van Camp's analysis is based on water rights, and not on actual flows. It differs fundamentally from the basis used in comments on behalf of the off-Project users. As often happens when rights are emphasis rather than use, inconsistencies come into play. For example, Mr. Van Camp asserts rights both for consumptive use and for conveyance. The more losses during either, the larger he contends that the rights would be. If the Commission were to follow this logic, it would be rewarding the users and the Project for efforts not to diminish conveyance losses, which seems to us to be counter to the Project's objectives and to probably to public policy regarding water and water quality.

c. He bases his statement of rights on the period 1997-2000, an unusually wet period when more acreage would have been irrigated than during dry years such as 1992, 1994, 2001 and 2002.

d. Claiming that KWUA should benefit from all gains between Link River and Keno ignores the role of non-Klamath Project influences, among them:

   1) Much additional flow through Keno was created by construction of the railroad dike across the Klamath Straits, limiting many tens of thousands or hundreds of thousands of acre feet of winter overflow into Lower Klamath Lake. We emphasize that this change occurred two decades before Bureau of Reclamation irrigation commenced in Klamath Basin;
   2) Additional water enters this reach of the river from urban and industrial areas in and around Klamath Falls and the north shore of Lake Ewauna;
   3) Flows from the Lost River Diversion, discussed above in our discussion of Mr. Bartells analysis.
   4) Additional inflows from forested and other non-irrigated lands.

In summary, Mr. Van Camp's testimony is based on rights, rather than flows, resulting in claiming excessive benefits and not mentioning certain environmental obligations. It would be erroneous to use his estimates in energy value calculations such as those computed by in the testimony by Mr. Schoenbeck for the Klamath Water Users Association.

4. Conclusions

- Bartell:
    - Overemphasizes water 'added' by agriculture, but has yet to recognize that water is diverted from UKL to Yonna and Swan Valleys ("Pine Flat") and other de-facto off-Project areas, and to the Klamath River system, such summer flows to the Lost River, LKL and others.

- Attributes gains related to non-agricultural uses (such as the LKL railroad dike and the Lost River Diversion canals)

- Does not seem to recognize that summer water is more valuable.

▪ Rozaklis:
- Creates a distinction between the shallow and deeper aquifers that makes little difference in terms of the effects of using wells for water supply. It is the deep aquifer that drives the surface-water system of the Klamath Basin, and that always has done so. It makes little sense to act as if withdrawals from the deep aquifer do not diminish surface flows.

- Does not account for transit losses which can consume over 10% of irrigation return flows.

- Does not present a believable pre-development condition. It is unreasonable to assume that half of the converted acres in the Upper Klamath Lake area and along the Klamath River near Ken were historically open water.

- Uses wetland ET estimates taken from an ongoing study by the USBR which have not been questioned by the study work ground and are currently under review by the National Academy of Sciences.

▪ Van Camp

- Uses a water-right basis of computation, not compatible with other analyses.
- Claims incremental flows not ascribable to Project or KWUA operations.

None of these authors seem to fully recognize:

1. Not all water moving to Iron Gate actually gets there.
2. There are a number of legal constraints arising in recent years to the ability of the Bureau of Reclamation to provide any additional flows from the Project or off-

Project lands to PacifiCorp for power production. Among these legal constraints are ESA-mandated minimum Upper Klamath Lake levels now required under the U.S. Fish and Wildlife Biological Opinion for Lost River and Shortnosed Suckers, and minimum in-river target flows at Iron Gate Dam under the National Marine Fisheries Service Biological Opinion for Coho Salmon. These ESA-mandated constraints can considerably diminish any value from whatever additional flows might be provided by Project or off-Project irrigation water returns.

3. There are environmental and water-quality needs downstream of Iron Gate that are appropriately incorporated in this project, either because (a) most hydropower projects have environmental demands, and (b) the Oregon PUC may wish to meet moral or formal obligations to downstream uses and users.

Closing

Please feel free to contact us if you would like to discuss these concerns in further detail.

BALANCE HYDROLOGICS, Inc.

Barry Hecht
Hydrologist / Hydrogeologist

Bonnie Mallory
Hydrologist / Geochemist

Stacey Porter
Geomorphologist / Hydrologist

References

Burt, C. and Freeman, B., 2003, Hydrologic assessment of the Upper Klamath Basin, issues and opportunities (Draft Report): Consulting report prepared by Irrigation Training and Research Center for David Sabo, Klamath Basin Area Office, United States Bureau of Reclamation, 108 p. + appendices A-N.

Burt, C., Mutziger, A., Howes, D.J., and Solomon, K.H., 2002, Evaporation from irrigated agricultural land in California: Irrigation Training and Research Center Report R 02-001, 144 p. + appendices A-L.

Drexler, J.Z., Snyder, R.L., Spano, D., and U, K.T.P., 2004, A review of models and micrometerological methods used to estimate wetland evapotranspiration: Hydrological Processes, 18, p. 2071-2101.

Gearheart, R.A., 2005, Review of attachment A and D, Natural Flow of the Upper Klamath River: Technical memorandum dated August 30, 2005, 12 p. (included as Appendix II)

Hecht, B., and Kamman, G., 1996, Initial assessment of pre- and post-Klamath Project hydrology on the Klamath River and impacts of the project on instream flows and fishery habitat: Balance Hydrologics, Inc., consulting report prepared for The Yurok Tribe, 38 p., 2 tbls, 30 figs, 2 appendices.

Hecht, B., Mallory, B.J., and Porter, S.A., 2005, Comments on USBR's December 2004 report of modeling: "Undepleted natural flow of the Upper Klamath River," 47 p.

Kent, F.L., 1905, Irrigation in Klamath County, Oregon - Annual report of irrigation and drainage investigations, 1904: U.S. Department of Agriculture, Office of Experiment Stations Bulletin No. 158, p. 257-266.

Leonard, A.R., and Harris, A.B., 1974, Ground water in selected areas in the Klamath Basin, Oregon: Oregon State Engineer Ground Water Report No. 21, 104 p.

Risley, J.C., and Laenen, A., 1999, Upper Klamath Lake Basin Nutrient-Loading Study -- Assessment of Historic Flows in the Williamson and Sprague Rivers: U.S. Geol. Survey Water-Resources Investigations Report 98-4198, 22 p. [Appear in UE-170 as KOPWU/107 Bartels/3 ff]

U. S. Department of Interior, Geological Survey http://or.water.usgs.gov/projs_dir/or180/background.html

U. S. Department of Interior, Water and Power Resources Service, 1981, Butte Valley Division, Klamath Project, Oregon-California. Concluding report. 56 p.

Appendices

I. Hecht and others (2005), Section 5
II. Gearheart (2005), memorandum

5. Comments on evapotranspiration and evaporation estimates

5.1 Evapotranspiration Adjustments

The conceptual model for determining ET losses due to natural marshes, riparian areas, and croplands is well developed but it is deficient in certain parameter estimations and basic assumptions. The critical considerations for determining ET losses from wetlands and riparian areas in the Lower and Upper Klamath Lake (LKL, UKL) undepleted natural flow study area are listed below:

- Representative wetland ET model with wetland plant coefficients
- Statistically valid mass transfer ET values-multiple sites
- ET values representative of various types of wetland plants
- Inundated in-lake wetland areas and wetland areas in LKL and contributing watersheds to UKL
- Historic extent and composition of wetlands adjacent to UKL, LKL, and upstream watersheds
- Change in the in-lake wetland acreage during periods of unregulated lake levels
- Role of saturated soils in the wetland areas in terms of ET losses

Understanding that it is difficult to reconstruct vegetative patterns, extent of lake and wetland inundation, and missing climatological data, it, therefore, is critical to be able to test the variance in estimating these factors. The approach taken in the cropland ET losses is a good example of non-parity in the model. As an example, crop coefficients for agricultural crops are distributed in sub-components of the model (for example the Sprague watershed) based upon the types of crops irrigated. On the other hand the wetlands ET equivalent factor (see Table 3 of Attachment A in USBR Report) is generalized to the dominant species in the wetlands (tules-cattail, salt grass, etc). There are other wetland plant communities along with open water sections that are included in these "designated areas". There are several issues related to this observation:

1) does it make a difference in the estimated ET losses for marshes and riparian areas, and,

2) is it a biased analysis if the level of detail in assigning ET losses from wetlands is different than irrigated agricultural land?

Another assumption to be evaluated in the model is the extent to which the in-lake wetland areas increased due to the lower lake elevation and its hydroperiod variation (Figure 5.2). It is an established fact that wetland plant coverage is enhanced by 1) lower hydroperiods and / or 2) seasonal varying hydroperiods. Other species such as Wocus spp., for example, were known to dominate certain in-lake wetland areas. This raises the question of whether the Wocus plant community and perhaps other plant communities might be found in the now existing open water sections of the regulated lake.

5.1.1 Wetland Crop Coefficients

The value of the crop coefficient for various plants during various periods of the growing season for a particular plant appears to be divided into three phases; 1) initial stage, 2) mid-season stage and, 3) late season stage. For agricultural crops, specific values are given for various climate zones. There is not an equivalent table of coefficients for wetland plants. The model assumes that the shape of the crop coefficient curve over the growing period is the same for both agricultural and wetland plants. This assumption needs to be evaluated both in terms of the length of the growing period and the changes in the crop coefficient during mid-season to late season stages. In the case of wetlands plants that are not water limited, the rate of transpiration is reduced as the plants enter into their physiological senescence. The shape of the crop coefficient curve for wetland plants does not follow the same shape as the crop coefficient for agricultural crops.

5.1.2 The Concept of 'Methodology'

Attachment A of the Report deals with the assumptions and methodologies used to determine evaporation and evapotranspiration from the various historic and project affected land uses, vegetated coverings, and water surfaces within the scope of the study. At the top of page A-2 a conclusion is reached which is unsubstantiated and without reference, "…marshes around UKL and LKL transpire significant amounts of water by photosynthesis." While it is well known that plants transpire water by photosynthesis it is a bit premature in a methodology section of a water balance to come to a conclusion. A suggestion would be to simply state what the model will do and how it will do it. The next sentence suffers from a different deficiency in that the sentence structure makes it appear that riparian and marsh vegetation along river corridors and irrigated agriculture are similar. It is my understanding that this is a methodology section, which should simply state, without assessment, the sources of water loss by E and ET. A suggestion would be to rewrite this section as objectively as possible. The last sentence should be broadened to include lake, marsh, and riparian areas that E and ET was estimated to include in the water balance.

5.1.3 Blaney-Criddle

The Blaney-Criddle (no wind or humidity) method, developed by SCS (now NRCS), provides seasonal crop consumptive use estimates and may be used for monthlies.

U = K Sfi

f-tp / 100

U = seasonal consumptive use in inches

t = mean monthly temp

p = mean monthly percent of daytime hrs

K = seasonal consumptive use for a crop

Stand density, height, and areal extent have been reported by many investigators to have a great deal of influence on the rate of water loss from a vegetated water body (Anderson and Idso 1985, Hammer 1989, Idso and Anderson 1988, Kadlec et al. 1988). These vegetative characteristics are probably the most important and least quantifiable factors when relating ET to ETo and comparing ET rates between different species.

Hammer (1989) states that "evapotranspiration losses from dense emergent stands are generally lower than evaporative losses from open water surfaces because of plant influences on the microclimate near the water surface within a stand of vegetation." Higher losses may be the case for limited periods during the growing season, however, plant structure substantially reduces evaporation losses from exposed water surfaces by shading the surface, and by occupying a substantial portion of surface area. Dense emergent stands also obstruct air movement near the waters surface such that relative humidity is near saturation for some distance above the water surface and the saturated air is not exchanged with drier air. This process can reduce wetland ET. Transpiration losses are also reduced by limited air movement around plant stems and leaves, maintaining high humidities near plant surfaces.

In our previous review of the Undepleted Flow study we stated the known shortcomings of the Blaney-Criddle method with respect to estimating wetland vegetation ET (Hecht and others, 2004). The discussion will not be repeated in this review but we recommend that the USBR review that section in the report. The importance of data availability for a model is recognized as important, but the accuracy of the model to estimate the marsh ET is the overriding criteria. For example, the evaporation component of marsh ET is not developed in a manner that allows for a careful review.

The evaporation of the water from a marsh follows different processes than evaporation from soil in irrigated agriculture. Variation in ET from different plant species has primarily been attributed to vegetative structure (linear-erect vs. broadleaf and emergent vs. floating) and to differences in stomatal conductance to water vapor. The type of vegetative cover greatly influences shading and wind effects which in turn affect air and water temperatures, humidity, and solar radiation reaching the water surface (Otis 1914, Kadlec et al. 1988, Snyder and Boyd 1987). These factors influence the evaporation component of ET. Snyder and Boyd (1987) reported a reduction in water temperature of 2 to 4°C in vegetated tanks compared to open water tanks due to daytime shading. Kadlec et al. (1988) found that free surface evaporation from evaporation pans placed within the vegetation is strongly influenced by plant cover type due to its shading effects. The greatest water losses in their study occurred in areas with the most open cover (meadow) and the lowest losses were from the densest (Leatherleaf).

Cover type also influences the degree of daily and seasonal variation of evapotranspiration (Otis 1914). The importance of water temperature in a marsh and within the area of marsh water advection should not be discounted as an insignificant factor. For example, the wetlands of the Klamath Lake Wildlife Refuge are fed to some extent by springs both on the edges and within the wetlands (Figure 5.3). This upwelling of spring water is much cooler than the lake open water temperature in the summer. This internally loaded cold water volume along with the waters in the wetland cooled shading effect of the wetland plants makes the water temperature within the wetlands cooler than the lake water temperature. To some extent the spring addition of cooler water might have existed in the wetlands at the mouth of the Williamson River. In the case of all wetlands in the basin the summer water temperature in the wetlands could have been 3 to 5 degrees cooler than the open water lake temperature (Gearheart, 1999).

It is recognized that within the last few years the accuracy for estimating evapotranspiration have improved due to methods which are more complex. In spite of these methods and the large number of older methods, wetland ET estimates remain poorly characterized. This is partly due to the variability and complexity of wetlands. Most of the methods used to estimate ET assume uniform vegetation and adequate fetch.

- **Recommendation: The plant coefficient for wetland plants should be adjusted monthly based on wetland transpiration (ET) rates. It has been observed that wetland plant crop ET rates (crop coefficient) diminish faster in the late season than irrigated crop late season crop coefficients. BOR should identify monthly wetland plant crop coefficients for those aquatic plants commonly found in the basin and compare these results with the results found in the first draft. If crop coefficient can not be found then BOR should develop a rational for estimating these monthly ETc values.**

5.1.4 Capillary Rise

The value of 1.8 feet of capillary rise used in the model to extend wetland ET as the lake level decreases is reportedly based upon hydraulic characteristics of peat soils. The question is if this value is derived from peat soils which have already been drained, oxidized, and perhaps compressed or do they represent the soil-sediment-detrital layer below the wetland communities under condition of seasonal and or annual inundation. General understanding of capillary action as a function of particle size suggests that the capillary rise would be less than 1.8 feet under conditions normally found in the wetlands.

- **Recommendation: The USBR should verify and reference the use of 1.8 feet for determining the capillary rise in the wetlands during periods of lake level decrease. If 1.8 feet is deemed appropriate, then full justification should support the capillary rise value used in the model. There are several general soil types found in the Upper**

Klamath Lake historic wetland areas. The USBR should justify using one value for capillary rise based upon the known soil types.

5.2 *Effective Wetland Surface Areas for Estimates*

An assumption is made by the USBR (which is neither referenced nor justified) that the effect of lake lowering on the effective level of the water under the wetlands can be accounted for by lagging, by one month, the water levels under the wetlands. This assumption does not include any consideration for the slope of the wetland. For example, if the slope of the wetland is 0.5 %, then a 1.8 ft reduction in distance from the plant roots to subsurface water level would occur within 360 feet of the lake / wetland margin[7]. At 1 % slope, the 1.8 foot difference would occur with in 180 feet of the lake / wetland margin. The slope of the marginal wetlands surrounding UKL increases in the upper reaches of the watershed. The techniques used in this study do not account for this slope factor, which consequently results in an over estimation of the ET from these wetlands.

A second factor not considered or not fully justified is the reduction in physiological need for water by these plants (photosynthetic process) during the period in which lake levels are decreasing. Even at the assumed 1.8 foot effective lake elevation correction, the plants could be reducing their need for water. If the 80% adjustment to the Blaney-Criddle crop factor is to account for this reduced plant need, then justification needs to be included in the report. It is highly probable that the plant physiological need for water is considerable less in the mid- to late growing season, while at the same time, normal plant senescence, which is genetically determined (see Section 5.4), is increasing.

A question also arises when partitioning the lake areas (UKL and LKL) into inlake wetlands and open water as to the amount of open water in the wetland areas. As can be seen in IR photographs (Figure 5.4) open water exists in the Klamath Lake Wildlife Refuge. Whether this condition is significant in the pre and post conditions that are modeled in this study is a question the model developers should address.

[7] The model uses 1.8 feet as the capillary rise factor.

5.3 Evaporation Considerations

The evaporation component of the model uses the Hargreaves Method, an acceptable method commonly used in water resource management when only temperature incident radiation data are available. This method requires a minimum of information and has proven to be accurate enough for lake and irrigation management applications. The Kimberly-Penman Method is generally considered to provide more accurate evaporation estimates but requires a higher level of data inputs. Work conducted in India by Moges and others (2002) attempted to compare PET estimates using six available evaporation models, one of which was a modified Hargreaves Method. They found that the Penman-equivalent method can be estimated using a modified Hargreaves Method with an efficiency of 28 to 96%. This highlights the extreme variability that is inherent to the Hargreaves Method and suggests the need for further calibration and sensitivity analysis of the USBR evaporation estimates. Typically, the longer the daily moving average used, the closer the Hargreaves Method estimates come to the more complicated Kimberly-Penman method.

Several correction factors were applied to the Hargreaves Method by the USBR in an effort to estimate evaporation from the open waters of the lakes. The comparison of the Hargreaves to the Kimberly-Penman daily values from the AgriMet station is one example. For the period March 31, 1999 to December 1, 2001, the Hargreaves method gave a lower estimate of open water evaporation than the Kimberly-Penman. The adjustment in the form of an extended polynomial equation (4^{th} order) brought the overall difference to an R^2 of 0.92. With only a visual observation it appears (comparison of Figure D-2 graphs) that the fourth order equation is generally underestimating evaporation during the warmer months (growing season period). There is neither discussion of this seasonal effect in the report nor any attempt to apply a correction. The polynomial fit is essentially trading off “good fit” fall and winter evaporation with poorer fit spring and summer evaporation. The important information to know for the use in the model’s sensitivity analysis is the error in the USBR-developed methodology during the period of concern (late spring and summer).

- **Recommendation: The USBR should test the condition of open water sections within the wetland in terms of trading off evaporation from the open water and evapotranspiration in the wetlands to see if there is a significant difference. A correlation relationship should be developed between the Kimberly-Penman and Hargreaves for the growing period/summer months. The results of this new**

correlation should be use to adjust values of evaporation. The independent parameters used in the Kimberly-Penman and Hargreaves should then be used to determine the error range to be used in the sensitivity analysis and or Monte Carlo simulation.

5.4 Definition of Senescence

Plant senescence is a highly regulated and complex process during which the plant reclaims as many mobilizable nutrients as possible from the senescing tissues. Plant senescence is the final event in the growth and development of a plant which ultimately leads to the death of a particular organ or whole plant. The senescence in plants is a highly regulated, genetically programmed and developmentally controlled process. Genetic and molecular analyses suggest that the cell death associated with senescence is a form of programmed cell death, however, little is known about the senescence signal and its detection. Clearly aquatic macrophytes detect the onset of short days in the autumn and the whole plant senesces to reroute materials into the seeds representing the next generation. In other plants or in individual plant organs, the signal and its transduction are not as well understood.

The leaves of aquatic macrphytes senesce in a seasonal manner to survive harsh winters or severe droughts. Annual plants undergo leaf senescence mainly during their reproductive stage. Leaf senescence is highly predictable and essential for plant survival. It is a programmed, active process that enables the plant to use the nutrients from photosynthetic tissue for the development seeds or for growth in the next season. While genetically programmed conditions in aquatic macrophyes are the primary signal for senescence, water stressed conditions can accelerate the process within the natural life cycle of the plant. Normally water stressing of aquatic macrophytes by processes such as: lowering of lake elevation, drought conditions, or wetland drainage can initiate the programmed senescing process. In other cases water stressing of plants leads to limited to no reproduction of the plant.

- **Recommendation: The USBR should incorporate wetland plant senescence in the model for both UKL and LKL. There seems to be some confusion in the December 2004 draft as to how plant senescence operates. For example, the USBR considers senescence to occur only when the environment is water-limited. However, plant senescence is a physiological occurrence that can be independent from the physical**

setting, meaning that even in wet years the plants will not transpire as much water during the summer/autumn months.

TO:	John Hicks Bureau of Reclamation, Klamath Falls Oregon	Date 8/30/2005
SUBJECT:	Review of Attachment A and D Natural Flow of the Upper Klamath River	
FROM:	R.A. Gearheart, Ph.D., P.E. Hydro Resources International, Arcata, California Consultant for Yurok Tribe	

I appreciate the opportunity to submit these review comments on Natural Flow of the Upper Klamath River's Attachment A and D dealing with evapotranspiration assumptions and methods. These comments to the latest Attachements A and D (August 2, 2002) include information that has been forwarded to BOR personnel over the summer, some information submitted previously, and new review comments.

- **Aquatic Plant ET Rates**

This review attempted to present a methodology to estimate wetland plant ET by considering the plant community diversity in the Klamath Lake wetlands. An example of the range of aquatic plant coverage was determined for Hank's Marsh by using an aerial photograph and a planimeter. Three general plant community categories were measured for Hank's Marsh. Three categories cattail/bulrushes, and wocus coverage's were measured. This reviewer also sent under previous reviews a color infrared plate from Klamath Lake Marshes. It was this reviewer's understanding that either USFW or BOR perform an on the ground spectral analysis which could be used to determine aquatic plant community coverage and the extent of open water (Reference Mark Buettner- Ecological Restoration Office)

Below is an example of how a calculated ET rate (Blaney Criddle Method) can vary. This example has not been normalized to the data collected by Bidlake for local wetland species. This is shown only for the purpose of 1) showing that and agricultural engineering method is questionable when applied to aquatic macrophytes and 2) if wetland plant species have the range of variation found in terrestrial plants than plant coverage and specie specific ET rates need to be used. The full development of this example has been sent to Mark Spears earlier in the summer.

An example of the ET losses from a mixed aquatic community (including a percent of open water as seen in infra-red photos) is shown in Table A. A comparison of three aquatic plant communities and open water for a 1,000-acre site showed a significantly lower value than using cattail/tules and spike rush. The implication of this assumption is that using only two high to moderate plant types over estimated water losses from in-lake Klamath Lake marshes. This statement of only “moderate to high” consumptive uses marsh plant consumptives needs to be modified to include wocus and open water. It is a poor assumption that the wocus community “would not change the overall marsh consumption use values appreciably”. The combination of lower ET rates along with percent distribution should be considered prior to arriving at a conclusion.

Table A-Example of Using Various Aquatic Plants ET Using Hank’s Marsh Plant Coverage for an Example (1000 acre wetland)

	Rushes & sedges	**Tules & cattails**	**Wocus**				
Precipitation (Ac-ft)	**ET Blaney - Criddle (inches)**	**ET Blaney - Criddle (inches)**	**ET Blaney - Criddle (inches)**	**Open water ET**	**ET (Ac-ft)**	**Storage (Ac-ft)**	**Water Balance Monthly (Ac-ft)**
66.80	6.60	3.08	1.92	3.36	360.55	6562.699	6268.95
153.47	1.33	1.18	0.74	1.22	106.33	6562.699	6609.83
145.34	0.94	0.94	0.59	0.60	73.62	6562.699	6634.42
170.62	1.00	1.00	0.62	0.80	81.60	6562.699	6651.71
103.82	1.09	1.09	0.68	1.42	100.21	6562.699	6566.30

109.23	1.55	1.55	0.97	2.90	161.35	6562.699	6510.58
84.86	2.50	4.31	2.69	4.22	322.02	6562.699	6325.54
106.52	8.70	8.47	5.30	7.38	710.82	6562.699	5958.40
68.61	11.98	10.12	6.32	8.68	886.70	6562.699	5744.61
35.21	14.37	11.29	7.06	9.71	1015.70	6562.699	5582.20
45.14	14.19	9.88	6.18	8.28	925.70	6562.699	5682.13
65.00	11.29	7.32	4.58	5.51	692.59	6562.699	5935.11
						Total/year	

Total ET	**5437.20**

The use of the Blaney Griddle method is not an appropriate method for determining the consumptive losses for aquatic macrophytes. This reviewer has not been able to verify the “antidotal information”, 1983 data (Ch2M-Hill), relating to aquatic macrophyte ET rates. It could be that plant coverage distribution is more important than the monthly ET rates. I have interacted with BOR hydrologist on this matter and did not received acknowledgement of an attempt to test a different approach. BOR hydrologist Mark Spears did state that he thought the Blaney-Criddle Method is not an appropriate method for estimating aquatic plant ET rates. Mark Spears also stated that BOR is working with USGS to perform a more exact ET method, surface energy/water balance technique (Bowen Ratio) for a different aquatic plants in the Upper Klamath Lake marshes (Bidlake 2000).

It is this reviewer’s observation that specific plant coverage could be as important as the specific ET rate in determining water losses from wetlands. Both these factors plant coverage and specific plant ET rates need to be considered when altering inundations coverage due to lake level variation

This review attempted to present a methodology to estimate plant community diversity ET rates in the Klamath Lake marshes. Three general plant community categories were measured for Hank’s Marsh.

Three categories cattail/bulrushes, and wocus coverage's were measured; Table A This reviewer also sent under previous reviews a color infrared plate from Klamath Lake Marshes. It was this reviewer's understanding that either USFW or BOR perform on the ground spectral analysis library was performed. Reference Mark Buettner Ecolgical Restoration Office.

An example of the ET losses from a mixed aquatic community (including a percent of open water as seen in infra-red photos) is shown in Table A A comparison of three aquatic plant communities and open water for a 1,000 acre site showed a significantly lower value than using cattail/tules and spike rush. The implication of this assumption is that using only two high to moderate plant types over estimated water losses from in-lake Klamath Lake marshes. This statement of only "moderate to high" consumptive uses marsh plant consumptives needs to be modified to include wocus and open water. It is a poor assumption that the *Wocus spp.* community would not significantly change the overall marsh ET consumption by reducing the wetland water consumptive use. The combination of lower ET rates along with percent distribution should be considered prior to arriving at a conclusion.

Recommendation- BOR should contact ERO and USFWS to obtain data on aquatic plant distribution to be used to estimate ET rate for the distribution and coverage of various wetland plants prior to the implementation of the BOR irrigation project. Plant specific ET rates should be used for the major aquatic plants found in the wetlands of Upper Klamath Lower Klamath Lake wetlands.

- **Historic occurrence of yellow pond lily (Wocus spp.) and other UKL wetland references**

One of the most important food sources for all the Klamath's was the wocus, or yellow pond lily, as evidenced by the fact that the month in which the wocus is harvested, August, marks the beginning of the Klamath year (Stern 1965). Wocus grow on open, shallow water within marshlands, and the Klamath's' reliance on the wocus would seem to indicate the presence of a substantial amount of appropriate wetland habitat in the upper Williamson. Some estimates run as high as 10,000 acres of wocus-dominated wetland in the Klamath Marsh area alone. The wocus ripened in late summer and early fall, and often-different tribal communities would come together to harvest the wocus in reed or dugout canoes. The wocus could be eaten in a variety of ways, but much of it was ground into flour and stored for winter use.

Klamath Marsh has always been a dynamic system, changing in size in response to local climate changes. There is clear evidence in the historic record that the hydrology of Upper Klamath Marsh and its associated effects on marsh plant communities was notably different during the late 1800s from what it is today. Historically (i.e. late 1800s), water levels were higher, there was a greater area of open water, willow thickets were more prevalent, and the extent of the deep water wocus plant community was much greater than is the case in present times (USFS 1998, USFS 1997, Weddel et al 1998). It is readily accepted that human intervention with the landscape has played a role in these changes. What is less clear is the extent to which natural climate cycles have played a participating role in this change.

Many hypotheses have been put forth regarding One of the earliest descriptions of the marsh, by Williamson and Abbot in August 1857, described the marsh as "a strip of half submerged land, about twelve miles long and seven miles broad … covered by clumps of tule and other aquatic plants separated by sheets of water" (approximately 52,000 acres) (USFS 1997). Map 3-1 illustrates the areas of the Upper Williamson River sub basin that were covered by Government Land Office (GLO) notes and maps in 1892 and 1893. Map 3-2 and Map 3-3 show the historic GLO maps overlain onto current day USGS quadrangle maps (Military Crossing and Wildhorse Ridge quadrangles). GLO notes associated with these maps indicate the edge of open water at an elevation of 4,515 feet in the vicinity of Military Crossing, where water depths were observed to be between 2 to 4 feet (USFS 1997). The GLO information was recorded when water levels were at their lowest during the course of the year, suggesting that this area of open water was
permanent. Coville estimated that in 1902 the marsh contained a solid growth of 10,000 acres of wocus (Coville 1904 from Weddell et al 1998). This is indicative of a large area of water too deep for emergent vegetation to develop, as wocus prefer water depths from approximately 3 to 8 feet (USFS 1997). An example of a wocus plant community is shown in Photo 3-2, a historic photo of the wocus harvest. Coville provided the following description of the wocus plant community. "The plant is so vigorous and has such a habit of growth as usually to occupy an area suited to it to the complete exclusion of other characteristics and conspicuous marsh plants, such as tule and cattail. but these plants are for the most part submerged in the water, are inconspicuous, and subsidiary in their relationship to the waterlily, and in no effective or important way contest its spread. The principal of these latter plants are bladderwort (*Utricularia vulgaris*), mare's tail (*Hippuris vulgaris*), and pondweed (*Potamogetan natans*) and other species."

Coville 1904 from Weddell et al 1998

A 1912-1913 report prepared by the Bureau of Indian Affairs (BIA) estimated the area of the marsh at 30,000 acres and described it as being "engulfed with water at all times" and covered with tule, slough grass (*Beckmanniasyzigachne*), and wocus growths (BIA in Clyde-Criddle-Woodward, Inc. 1976 as cited in Weddell et al 1998). Average water depths in tule and wocus areas were estimated at less than two feet, with channels of greater depth located throughout the marsh. A ring of wet meadow community dominated by sour marsh grass was also observed (BIA in Clyde-Criddle-Woodward, Inc. 1976 as cited in Weddell et al 1998). Map 3-2 and Map 3-3 show that the marsh of the late nineteenth century, in many places, extended far beyond its current boundaries. The GLO maps also show sizeable willow thickets, particularly where streams enter into the marsh. According to climatic records (described in detail in Section 2), many of the historic descriptions were recorded during a cool/wet climate cycle, which began in the early 1900s and lasted until approximately 1916). In contrast, the period between 1916 and 1931 was a warm/dry climate cycle characterized by drought. The effects of this drought period on the marsh are telling. For example, USFS (1997) reported that Big Springs Creek completely dried up during a drought in the early twentieth century. A narrative report during this time period (circa 1930) describes the drought as follows: [The marsh is in] a sad state. Ranchers and livestock men were compelled to put down wells and otherwise provide water. Grasshoppers and rodents plagued the then dry marsh. It was possible to travel by saddle horse and automobile over much of the present marsh area.
USDI Fish and Wildlife Service 1960 as cited in
Weddell et al 1998

From the mid-1920s to 1930 (during the known period of drought) the quantity of permitted irrigated land acreage in the Upper Williamson River basin (i.e., above confluence with the Sprague River) increased from less than 1,000 acres to approximately 10,000 acres (Risley and Laenen 1999). This significant increase in irrigation may have been a result of an increase in land available for agriculture due to the

Extent of Wetland Inundation UKL

Some sources describe Kirk Reef as a natural control structure for water levels in Upper Klamath Marsh (USFS 1998, USFS 1995a) and there is some debate as to whether it was lowered in the past with the intent of lowering water levels in the marsh. In their Big Bill Watershed Analysis, USFS (1998) indicated the reef was lowered around 1908 by an estimated 5 to 10 feet from its estimated historic elevation of 4,528 feet mean sea level (USFS 1995a). However, in a separate Watershed Analysis, USFS (1997) states that "channel morphology upstream from the control point at Kirk does not support the idea that any potential modification of the Kirk Reef had affected marsh surface elevation." Whether or not Kirk Reef was intentionally lowered is still a question; however, there is no readily observable evidence to support the idea that modifications to the Kirk Reef have affected water levels in the marsh.

Following this period of drought, there was a long wet/cool climate cycle that extended from the early 1930s to the mid-1960s. A 1955 USFWS report described the marsh as containing 9,900 acres of shallow marsh and 15,000 acres of deep marsh (USDI Fish and Wildlife Service 1955, as cited in Weddell et al 1998). This description of marsh conditions is very similar to those for the marsh at the beginning of the 1900s, both in overall acreage and habitat types. The comparison between these two time periods is notable because the period from the early 1900s through the 1940s was a period of substantial agricultural development within the marsh area (USFS 1998). This agricultural development included the construction of the Kittredge Canal, major water

diversion feature that was dug during the 1940s (Walt Ford pers. comm. 2004). This canal was used to pump water from the north end of the marsh to the south end of the marsh during the spring high water season. This allowed for cattle grazing of the north marsh area. Later in the year, when water levels were naturally lower, a secondary canal diverted water back to the north end in order to irrigate pasture grasses and provide water for cattle (Walt Ford pers. comm. 2004). Although the refuge stopped this practice in the1990s and the pumps have since been removed, the ditch system still remains (Walt Ford, pers. comm 2004). A new warm/dry cycle began in the mid-1960s and has been a brief cool/wet cycle during the late 1990s). As in previous years, it appears this climate trend may be affecting water levels in the marsh. A 1975 Draft Conceptual Plan for the Klamath Forest Wildlife Refuge provided the following description of refuge lands:

…present refuge vegetation is dominated by dense stands of hard stem bulrush, [while] open water vegetation interspersion is virtually non-existent with an estimated 10 percent of the marsh Consisting of open water.

Anon. 1975 as cited by Weddell 1998

"Tules growing in the lakes and marshes gave the *maklaks* a versatile material. They made canoes of tules, built homes with tules arranged on a framework of poles, covered communal storage pits with tule mats, wore tule leggings and tule sandals, and wove tules into baskets to sift wocus through. Shells of dried wocus seeds yielded a dye for tules used in basket-making.

Great quantities of wocus were stored in those mat-covered pits. Ten thousand acres of the lily grew in Klamath Marsh alone, providing a food so abundant that *maklaks* depended on it to survive when other foods were not available. Also helping the *maklaks* to survive harsh winters at 4,000 feet, with fierce winds and heavy snows, was the faith that their creator had provided them everything they needed." One of the most important food sources for all the Klamaths was the wocus, or yellow pond lily, as evidenced by the fact that the month in which the wocus is harvested, August, marks the beginning of the Klamath year (Stern 1965). Wocus grow on open,
shallow water within marshlands, and the Klamaths' reliance on the wocus would seem
to indicate the presence of a substantial amount of appropriate wetland habitat in the upper Williamson. Some estimates run as high as 10,000 acres of wocus-dominated wetland in the Klamath Marsh area alone. The wocus ripened in late summer and early fall, and often different tribal communities would come together to harvest the wocus in reed or dugout canoes. The wocus could be eaten in a variety of ways, but much of it was ground into flour and stored for winter use.
Ref.-The Oregon History Project, Oregon Historical Society, Subtopic: Inhabiting the Land: Life on the Waters, Stephen Most, 2003

Some reported ratios evapotranspiration losses over evaporation losses (Numbers less than 1.0 mean that those plants actually reduce water loss.) On the other hand, floating-leaved plants, such as duckweeds and lotus, that have flat, often overlapping leaves, reduces evaporation, because there is less exposed water for evaporation, but also, because the structure and habit is different from immersed and floating plants, do not
transpire as much water as would evaporate in the same area. Therefore, lakes with many floating-leaved plants will lose less water than will open water lakes. Lakes covered with duckweed will hold water for a longer time than will open water lakes. Below is a list of aquatic plants with their respective relative ET rate compared to open water. Generally the data shows that the taller the plant the greater the ET rate, using open water as reference (0.0 datum), Table B.

Table B-Example of Aquatic Plant ET rates normalized to openwater evaporation

Eichhornia crassipes (water hyacinth) transpires 1.26, 1.62, and 2.7 times the amount of water as would evaporate over open water

Typha latifolia (cattail) 1.75, 1.8, 2.5, 2.0

Acorus calamus 2.0

Scirpus validus (bulrush) 1.9

Panicum rigidulum (panic grass) 1.58

Juncus effusus (rush) 1.52

Carex lurida 1.33

Alternanthera philoxeroides (alligatorweed) 1.26

Pontederia cordata (pickerelweed) 1.2

Justicia americana 1.17

Nymphaea odorata (water lily) 1.0

Lemna minor (small duckweed) 0.9

Wolffia columbiana (water meal) 0.89

Spirodela polyrhiza (giant duckweed) 0.85

Recommendation-For purposes of review of the model a weighted average ET rate for aquatic plants and openwater should be tested in a model run to determine the sensitivity of this approach compared to the existing assumptions. This method has been demonstrated in an example sent earlier to BOR.

Recommendation-The Wocus plant (yellow water lily) found in Upper Klamath Lakes and environs needs to be considered in these analysis due to its wide distribution and coverage during the period of natural flows. It is this reviewers assumption, that due to its low ET rate compared to emergent aquatic plants such as tules and cattails, that inclusion of Wocus plant coverage and its associated realistic ET rate could be a significant factor in the water balance of the Upper Klamath Lake. Documentation for this recommendations and historic narratives concerning its distribution and wetland coverage around Upper Klamath Lake is found in the following paragraphs.

ET References

Price, J.S., J.M. Waddington. 2000. Advances in Canadian Wetland Hydrology and Biogeochemistry. Hydrological Processes, Hydrol. Process. 14, 1579-1589.

Eitzinger, J., D. Marinkovic, J. Hosch. Sensitivity of Different Evapotranspiration Calculation Methods in Different Crop-Weather Models.

Lott, Brandon R., Randall J. Hunt. 2001. Estimating Evapotranspiration in Natural and Constructed Wetlands. Wetlands: Vol. 21, No. 4, pp. 614-628.

Bidlake, William R. 2000. Evapotranspiration from a Bulrush-Dominated Wetland in the Klamath Basin, Oregon. Journal of the American Water Resources Association, Vol. 36, No. 6.

Hellsten, Seppo. 2000. Environmental Factors and Aquatic Macrophytes in the Littoral Zone of Regulated Lakes. Dissertation presented to the Faculty orf Science, University of Oulu.

- **<u>Pore Water/Capillary Groundwater Availability for Rooted Aquatic Plants</u>**

The pore water in the wetland peat material is extracted by the wetland plants as transpiration and any surface water is subjected to evaporation losses. As the lake level goes down the replacement water that flows into the wetlands could be water that has not been accounted for the water balance i.e., inflow, precipitation, and stored volume. It appears that the conceptual model does include or justify a ground water connection to the upland wetlands that were historically connected to the lake. The replacement water in the peat sediment that support the wetland plants could be coming from upgradient groundwater/peat storage elements. Horizontal wetland/ peat horizontal velocities have been estimated to be 0.01 to 1 meter per day (Baird, et.al., 2004; McKenzie, et.al. 2002; Wisem W., 2000). This upgradient replacement volume to the wetland peat storage appears to have either not been accounted for the water balance or considered to be insignificant. Some proportion of this replacement could have come from the lake storage but a significant quantity could have been supplied by upgradient shallow seepage/groundwater sources. Implication of this processes on the water balance is that the ET volume calculated for fringe wetlands ET during the period of lake drawdown might be overstated.
It seems to this reviewer that the slope of groundwater/saturated sediments should be considered when determining the effect of lake level drawdown when estimating the transpiration (ET I guess) of the rooted aquatic macrophytes. The suggest method for showing that effect is start at considering that effect.

Saturated soils, which would have existed in the historic wetland and riparian areas of the Upper Klamath Basin, are a storage component in the water balance of a system. For example the drained lake bed muck (found in the Williamson River Delta) can hold 6.84 inch per foot of soil and 2.04 hydroscopic inch per foot of soil (NCRS Soil Survey for Klamath County). This is opposed to saturated soils in the Poe Valley which can hold 1.35 ft. per foot of soil and 1.09 hydroscopic inches per foot. In other words the lake bed mucks can hold about 5 times more water in a saturated condition than the Poe Valley soils. This amounts to about 25,000 ft^3 of water per acre ft. or $25x10^6 ft^3$ of water per 1,000 acre-ft. This is water available for transpiration by the rooted aquatic macrophytes and for lateral drainage to rivers, streams, and lake as the lake elevation falls. The water that moves as inter-flow in the wetland detritus and soil could at a rate of between 1 to 200 ft./day depending on the bulk density of the detrital mat and soils. Hydraulic conductivities have been measured in the vegetated mat of wetland systems in Florida that are on the order of 50 to 100 ft./day.

In the case of the lake-head mucks at the mouth of the Williamson, approximately 7,000 acres there would be approximately $175x10^6$ ft^3 of water in the top one foot of soil under saturated condition. At a lateral flow rate of 50 ft/day it would take about 100 days for the flow originating one mile away, given sufficient slope, to reach the lake and about 20 days for the flow originating 1,000 feet from the river/lake. This slow release of water from the vegetated could serve as a significant desynchronization of inflow into a lake if sufficient lake margin wetland exist

This saturated pore water and detrital water serves as a significant storage component in the system that meters stored runoff water slowly into the lake over he growing season. It appears that this desynchronization of stored water has not been considered in the BOR Undepleted Natural Flow Study of the Upper Klamath Basin.

Recommendation:

BOR should include and evaluate processes in their conceptual model that utilizes upgradient replacement volume for a proportion of the fringe wetlands ET demand during the low lake level conditions. This process should be evaluated as to its significant in the overall water budget. This would require estimating horizontal hydraulic conductivities of the peat/wetland detritus layer in those wetland areas not inundated by surface lake volume (references are included that might serve as a starting point in estimating horizontal conductivities in peat soil).

References for Pore Water Recommendation

Baird, A.J. et. al., Special Issue of *Hydrological Processes* Wetland Hydrology and Eco-Hydology, Hydrological Processes, 18, 211-212 (2004), John Wiley Interscience, 2004.

McKenzie, J.M., et.al., Heuristic numerical models of the hydrological controls over vertical solute transport in a domed peat bog, Jura Mountatins, Switzerland, Hydrological Processes, 16, 1047-1064 (2002), John Wiley Interscience, 2002.

SOFIA, Ground Water Recharge and Discharge in the Central Everglades, USGS

Wisem W.R., et. al. A wetland-aquifer interaction test, Journal of Hydrology, 221 (2000) 257-272, Elsevier

General References Dealing with Aquatic Plant Inlake Distribution and ET Rates

Anderson, J.E. 1994. Spectral Reflectance Properties of Wetland Plants, in proceedings International Symposium for Spectral Sensing Research (ISSSR), STC Norfolk, Virginia.

Price, J.S., J.M. Waddington. 2000. Advances in Canadian Wetland Hydrology and Biogeochemistry. Hydrological Processes, Hydrological Processes, 14, 1579-1589.

Eitzinger, J., D. Marinkovic, J. Hosch. Sensitivity of Different Evapotranspiration Calculation Methods in Different Crop-Weather Models.

Lott, Brandon R., Randall J. Hunt. 2001. Estimating Evapotranspiration in Natural and Constructed Wetlands. Wetlands: Vol. 21, No. 4, pp. 614-628.

Bidlake, William R. 2000. Evapotranspiration from a Bulrush-Dominated Wetland in the Klamath Basin, Oregon. Journal of the American Water Resources Association, Vol. 36, No. 6.

Hellsten, Seppo. 2000. Environmental Factors and Aquatic Macrophytes in the Littoral Zone of Regulated Lakes. Dissertation presented to the Faculty orf Science, University of Oulu.

Baird, A,J, et. al,, Special Issue of *Hydrological Processes* Wetland Hydrology and Eco-Hydology, Hydrological Processes, 18, 211-212 (2004), John Wiley Interscience, 2004.

McKenzie, J.M., et.al, Heuristic Numerical models of the hydrological controls over vertical solute transpost ina domed peat bog, Jura Mountatins, Switzerland, Hydrological Processes, 16, 1047-1064 (2002), John Wiley Interscience, 2002.

Wisem W.R., et.al., A wetland-aquifer interaction test, Journal of Hydrology, 221 (2000) pp. 257-272, Elsevier

SOFIA, Ground Water Recharge and Discharge in the Central Everglades, USGS