Physical Environment

Lake Koshkonong lies within the Southeast Glacial Plains Ecological Landscape. The Southeast Glacial Plains Ecological Landscape makes up the bulk of the non-coastal land area in southeast Wisconsin. This Ecological Landscape is made up of glacial till plains and moraines. Most of this Ecological Landscape is composed of glacial materials deposited during the Wisconsin Ice Age, but the southwest portion consists of older, pre-Wisconsin till with a more dissected topography. Soils are lime-rich tills overlain in most areas by a silt-loam loess cap. Agricultural and residential interests throughout the landscape have significantly altered the historical vegetation.

Erosion

Lake Koshkonong was born with an irregular shoreline. The lake has been seeking a natural shoreline of rock, gravel or sand. Such names as Black Banks, and exposed, eroded peat bank typifies the problem. Threinen (1952) identified the problem over 50 years ago and stated, “Further evidence can found from the sight of uprooted trees and from duck hunters who will exclaim that what was their duck blink has now been claimed by the lake”. Due to the combined effects of ever-increasing water levels and the loss of aquatic plants, erosion of the wetlands and some adjacent uplands continues to date. Lake Koshkonong ranks 12th in the number of erosion control permits issued in the South Central Region (Table 1). Lake Koshkonong’s relatively low number of erosion control permits seemingly belies this environmental concern. This is due to the fact that over 35% of Lake Koshkonong’s shoreline is lowland and contains no adjacent residential development. Erosion control permits are typically the result of residential development along lakeshores.

The District has actively pursued this habitat protection strategy through a cooperative effort with the Department to ‘armor’ wetland shorelines to reduce wetland loss. The District considers this to be the most effective practical means of preventing further loss of wetland habitat on the lake. The Department, the District and private landowners have cooperated to construct these breakwater structures in order to protect exposed wetland shores. RKLD and WDNR are conducting a Cooperative Lake Study to assess the erosional conditions in the lake’s wetland areas.

Table 1. Number of Erosion Control Permits by lake issued in the South Central DNR Region. Lakes with 20 permits or less are not shown. Data are taken from the Waterway and Wetland Protection Database and reflect the years 1968-1998.

Lake Name	Number of Erosion Control Permits
Lake Wisconsin	648
Beaver Dam Lake	165
Lake Redstone	155
Lake Mendota	146
Lake Monona	113
Lake Kegonsa	103
Lake Waubesa	85
Green Lake [Big Green]	72
Rock Lake	59
Fox Lake	50
Park Lake	46
Lake Koshkonong	40
Lake Ripley	34
Swan Lake	33
Buffalo Lake	32
Puckaway Lake	30
Lake Delton	29
Little Green Lake	24
L Montello	23
Sinissippi L	22
Lawrence Lake	22
Lee Lake	20
Total	2144

Based on consultants recommendations, RKLD has sought grant programs and legislation to permit structures on the bed of Lake Koshkonong specifically to protect and restore aquatic habitat. RKLD has sponsored ten (10) $10,000 Wetland Restoration grants from the State of Wisconsin to limit erosion on many of the privately owned riparian wetlands of Lake Koshkonong. The majority of these projects included riprap armor of wetland shoreline areas that have been eroded and lost over time. Riprap armor has been used to reduce erosion loss and is actively supported by RKLD as a remedy for both upland and wetland shorelines.

During 2002 and 2003, the RKLD worked cooperatively with wetland owners to protect approximately 38% or 4.7 miles of the 12.5 miles of wetland shoreline. In 2001 Act 16, the Legislature granted authorization to the District for a Lake Koshkonong Comprehensive Project (Table 2). That legislation recognized the placement of breakwater structures was another suitable management approach to prevent wetland losses resulting from wind and seasonal flood conditions.

RKLD is currently involved with the U.S. Army Corps of Engineers (ACOE) in a Section 206 Ecosystem Restoration Program to further restore and protect wetlands and near-shore shallow water areas. The ACOE has identified several off shore breakwaters that if built would provide similar protected habitat to those structures constructed on the Lake Winnebago pool. ACOE's project has a focus of not only arresting waves but also excluding carp from shallow near shore areas. On the Lake Winnebago pool this concept has been effective in reestablishment of submergent vegetation. The status of this program is tenuous at this point. In Federal FY 04, a $112,000 congressional addition was placed within the Water Resources Development Act specifically allotting money to the ACOE to work on the Lake Koshkonong 206 project for planning and design of the Lake Koshkonong breakwater project. There is currently $160,000 of congressional additions within the House vision of the Water Resources Development Act for FY 05, which if enacted, would allow for continued funding of the Lake Koshkonong 206 project at the Feasibility level. ACOE officials have estimated that the report is approximately 40% to 50 % complete. However, the project manager has expressed great concern about moving forward with a project design until they are certain of the water level regime that will be established, and further that the new water level regime will yield the same environmental benefits from the off shore breakwaters. Accordingly, the ACOE project management team has decided to suspend all work on this project until the District's petition to raise water level is resolved.

It should be noted that the ACOE project includes structures that are substantial and engineered to withstand the forces from ice action and wave action that can reasonably be expected to occur on Lake Koshkonong. These proposed structures are substantially larger in size and scope than the structures built by RKLD in recent years.

Table 2 2001 Legislative Act 16 related to Lake Koshkonong.
30.2025 Lake Koshkonong comprehensive project.
(1) DEFINITION. In this section, “district” means the Rock–Koshkonong public inland lake protection and rehabilitation district.
(2) AUTHORIZATION. The district may implement a project developed and approved by the U.S. army corps of engineers to place structures, or fill, or both on the bed of Lake Koshkonong for any of the following purposes:
- (a) To improve navigation or to provide navigation aids.
- (b) To restore or protect wetland habitat or water quality.
- (c) To create, restore, or protect fish and wildlife habitat.
- (d) To enhance the natural aesthetic value or improve the recreational use of the lake.

(3) LOCATION OF STRUCTURES AND FILL. Any structure or fill placed as part of the project authorized under sub. (2) shall be located in Lake Koshkonong within the area that consists of Secs. 10, 13, 18, 19, 20, 24, 33, and 35, T 5 N., R 13.
(4) PRELIMINARY REQUIREMENTS. (a) Before beginning any activity involving the placement of a structure or fill as part of the project authorized under sub. (2), the district shall submit plans and specifications for the project to the department and obtain the department’s approval for the project.
(b) Before the department gives its approval for a project authorized under sub. (2), the department shall do all of the following: 1. Comply with the requirements under s. 1.11. 2. Review the plans and specifications submitted to the department under par. (a) and obtain any other information that it determines is necessary to effectively evaluate the structural and functional integrity of the structure or fill. 3. Hold a public informational meeting to discuss the plans and specifications submitted under par. (a). 4. Determine that the structure or fill is structurally and functionally sound and that the structure or fill will comply with the requirements under sub. (5).
(5) REQUIREMENTS FOR STRUCTURES AND FILL. A structure or fill placed as part of a project authorized under sub. (2) shall meet all of the following requirements: (a) It may not materially affect the flood flow capacity of the Rock River. (b) It may not materially obstruct navigation. (c) It may not cause material injury to the rights of an owner of lands underlying the structure or fill or to the rights of a riparian owner who owns lands affected by the project. (d) It may not cause environmental pollution, as defined in s. 299.01 (4). (e) It may not be detrimental to the public interest. (f) It must further a purpose specified in sub. (2).
(6) MAINTENANCE BY THE DISTRICT. (a) The district shall maintain the structures and the fill that are part of the project authorized under sub. (2) to ensure that the structures and fill do not impair the safety of the public. (b) The district shall maintain the structures and the fill that are part of the project authorized under sub. (2) so that the structures and fill remain in compliance with the requirements listed under sub. (5).
(c) If the department determines that any structure orany fill that is part of the project authorized under sub. (2) does not comply with the requirements under sub. (5), the department may require the district to modify the structure or fill to bring it into compliance or to remove the structure or fill.
(7) USE OF STRUCTURES OR FILL. Any structure or fill placed as part of the project authorized under sub. (2) may be used only for any of the following:(a) As a site for the placement of navigation aids approved by the department.(b) Activities to protect or improve wildlife or fish habitat, including the placement of fish or wildlife habitat structures approved by the department. (c) Open space for recreational activities.
(8) OWNERSHIP. (a) The structures or fill that are part of the project authorized under sub. (2) are owned by the district. Except as provided in par. (b), the district may not transfer ownership of any structure or any fill that is part of the project authorized under sub. (2). (b) The district may transfer ownership of any structure or fill that is part of the project authorized under sub. (2) if all of the following apply: 1. The district transfers ownership of the structure or fill to a public entity, as defined by the department by rule. 2. Before transferring ownership of the structure or fill, the district obtains written approval of the transfer from the department.
(9) ACCESS TO PROPERTY. An employee or agent of the department shall have free access during reasonable hours to the structures or fill that are part of the project authorized under sub. (2) for the purpose of inspecting the structures or fill to ensure that the project is in compliance with the requirements of this section. If the department determines that any structure or any fill that is part of the project authorized under sub. (2) does not comply with the requirements of this section, the department may require the owner of the structure or fill to modify the structure or fill to bring it into compliance or to remove the structure or fill.
(10) EXEMPTIONS. Section 30.12 does not apply toactivities that are necessary for the implementation or maintenance of the project authorized under sub. (2).

Winter Drawdown: Ice jacking, Ice Ridges, and Shoreline Alterations

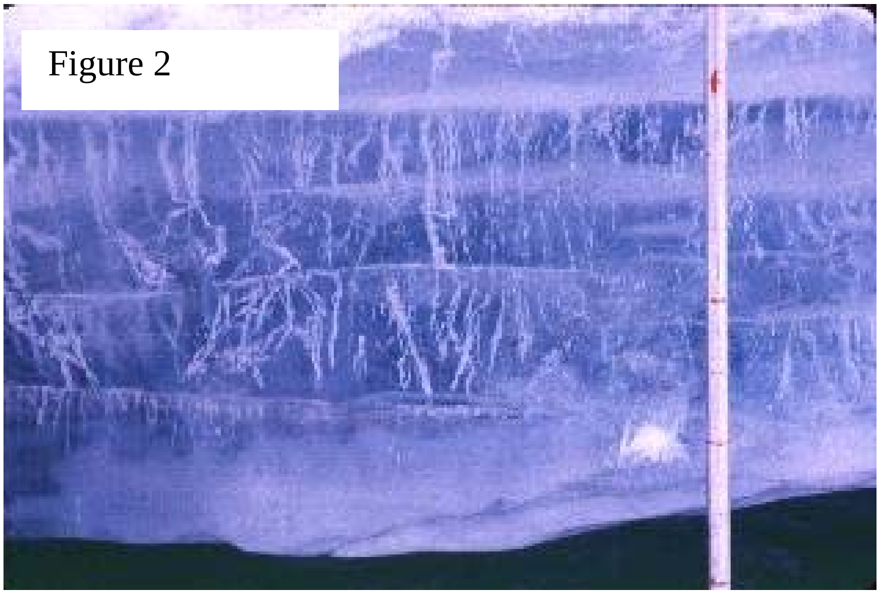


Figure 2

The expansion effect of lake ice, however, does not make itself felt until the ice layer is at least five inches thick. Lake shores are subjected to modification by ice action. The final result of the freezing process is a dense, water-tight sheet of floating ice ranging in temperature from a few degrees above freezing at its bottom surface to as low as –40 degrees F. at the top. The ice cover is normally in a state of almost complete flotation with the exception of its edges, which may be frozen solidly to the shores, projecting boulders, piers of bridges, dams, walls, or other objects to which it may have had an opportunity to attach itself. Ice on a lake surface expands or contracts with the rise and fall of the air temperature, and since air temperatures have a considerable range of fluctuation in winter, the ice changes in volume. What actually happens is that the ice sheet will expand a small amount during a temperature rise, with the resultant force of its compressive strength directed to its point of contact with the shoreline But as the temperature drops, the ice sheet then tries to shrink back to its original shape – like a piece of steel that expands when heated and contracts when cooled. The ice tries to pull its massive weight inward in a tensile force struggle within itself. But since the ice's tensile strength is weaker, than its compression strength, the ice literally ruptures itself, breaking open into shrinkage cracks (see Figure 2). Some cracks can be wide, others no more than "hairline cracks", but collectively their widths equal the amount that the ice sheet has contracted. The cracks subsequently refill with more ice (freezing water). When a subsequent rise in temperature produces an expansion of the whole ice mass, a tremendous force is exerted against the shore. As each successive expansion/contraction event occurs, the ice sheet creeps further, scraping, gouging and pushing as it goes. Some people call this process "ice-jacking" because of the ratcheting effect that each subsequent and cumulative push exerts upon the shore. The coefficient of linear expansion of ice is 0.000052 per degree of temperature rise, and thus for a 10º F variation in an ice sheet a mile long, the change in length would approximate 2.75 feet while the force exerted is probably not less than 30,000 pounds per square foot. If the shore is of such a nature that the ice cannot shove, it may buckle. Buckling is not uncommon, even in very thick ice sheets (see Figure 3). If the ice is weaker than the friction on shore it heaves and cracks near the center of the lake, resulting in ice plates that slide past each other and rest one atop the other, leaving open water. If this occurred now the pressure of the ice on shore would be relieved.


Figure 3

Figure 4

Whether or not expanding ice will push up the shore or buckle (Figure 4) depends on whether weak spots in the ice sheet permit the release of this pressure by the buckling of the sheet or crumbling of its edges, both of these conditions being somewhat dependent on the water depth near the shore. If the shores are gently sloping, the expanding ice overrides them, but if the shore materials are of a yielding sort, an irregular ridge called an ICE RAMPART is likely to be formed by shoving a portion of the marginal material to a higher level, and leaving it in the form of a ridge (Figures 5 and 6). Such ice ramparts may be several feet in height, and may contain large boulders. Where conditions are such that ice ramparts once formed become permanent, successive shoves may build up a considerable accumulation of displaced materials, thus forming an ICE-PUSH TERRACE. Shorelines resist the outward movement of expanding ice.

Ice-jacking and the formation of ice ridges is most dramatic during winters with extreme temperature fluctuations and little snow cover. A dense layer of snow on top of the ice not only reduces the freezing rate, but also forms an insulation blanket that reduces temperature changes in the ice, and subsequent frequency of ice-jacking events. In conclusion, it appears that the effects of the "jacking" action of ice are most severe during those periods when there is little or no snow-cover, and temperatures fluctuate greatly. One intent of winter drawdown is to purposely move the zone of ice-jacking offshore; in the interest of minimizing shoreline alterations and the formation of ices ridges at the bank.

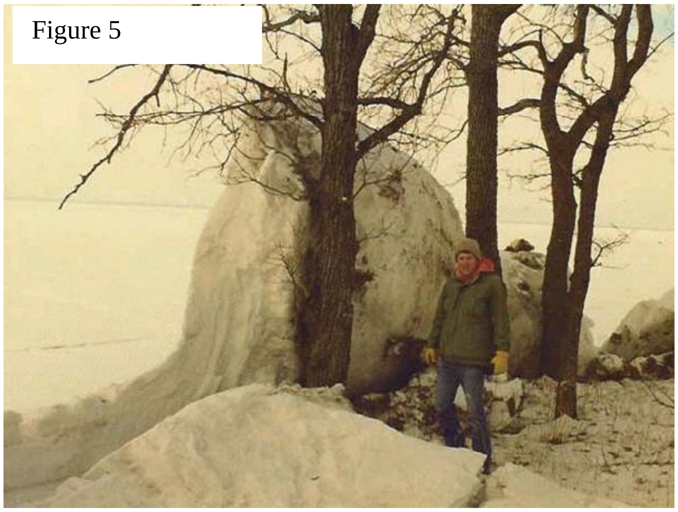


Figure 5

Figure 6

Flooding

Flooding has historically been a concern on Lake Koshkonong and on the Rock River upstream of the Lake. There have been three studies in recent history that speak to the effects of dam operation on flood flows. USGS studied the relationship of the Indianford dam and flood levels on Lake Ksohkonong in a report dated March 1983 and titled ***Evaluation of Alternative Reservoir-Management Practices In The Rock River Basin, Wisconsin.*** USGS studied 12 different operating rules and concluded that "There are some significant differences at certain flow rates among some of the rules. At other times, the different rules produce no detectable difference in stage." With regard to the winter drawdown USGS concluded that "winter drawdown had very little effect on the peak stages the following spring." The Rock Koshkonong Lake District commissioned Montgomery Association Resource Solutions to conduct a hydraulic analysis in 2003. Their January 2003 report titled ***Hydraulic Analysis of Indianford Dam and***

Lake Koshkonong had similar conclusion regarding the operation of the dam and Lake flooding as the earlier USGS report. Specifically Montgomery concluded, “ Comparison of Rock River discharge data from gages at Fort Atkinson and Indianford indicate that Lake Koshkonong, as large as it is, has relatively little effect on attenuating flood peaks that move through Lake Koshkonong.” And Further “ ...changes to Indianford Dam operational procedures may be able to produce noticeable effects on Lake Koshkonong at relatively low flow conditions, but the control of large water fluctuations during major floods or attenuation of flood flows downstream of Indianford Dam were not likely to be possible.”

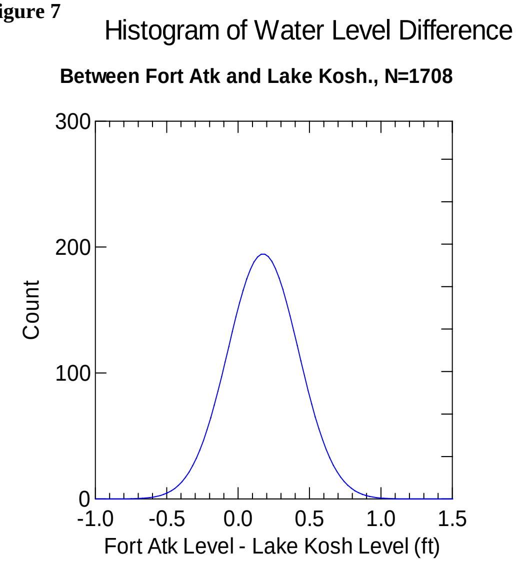
Low flow The Department’s last order, 3-SD-82-809, reaffirmed the minimum release from the Indianford Dam as 64 CFS. Wis. Stats., Section 31.34 requires that all dams release at least 25% of the normal low flow “except as otherwise required by law.” Normal low flow has not been statutorily or administratively defined. It has been the long standing practice of the Department to interpret the requirement’s of Section 31.34 as the same as the $Q_{7/10}$. The $Q_{7/10}$ is a statistical representation of normal low flow used routinely in the WPDES program when applying discharge limits. It represents the 10 year recurrence interval for a 7 day cumulative low flow. It has been the experience of the Department that requiring discharges of $Q_{7/10}$ as the minimum dam release is generally protective of downstream water quality, but fails to fully consider impairments on in-stream habitat. The Department has used more sophisticated Incremental In-stream Flow Analyses at several hydroelectric sites around the state to help establish more scientifically protective discharges. However, due to cost and needed time to perform these analyses the Department has only applied this technology in situations where there is demonstrated need. The most recent determination of $Q_{7/10}$ at Fort Atkinson for the discharge from the Fort Atkinson WPDES permit was 53 CFS and was based upon the flow records from 1953 to 1992. The current minimum release of 64 CFS appears to be protective of down stream resources, and consistent with the $Q_{7/10}$ on the Rock River at Fort Atkinson. The petition from RKLD does not propose a change in the minimum release from the dam and it is unlikely that a change in water levels will alter the $Q_{7/10}$ in the future.

Koshkonong Water Level Time Series Analysis

The USGS in cooperation with Rock County operates a water-stage recorder for Lake Koshkonong (USGS 05427235 LAKE KOSHKONONG NEAR NEWVILLE). However, the period of record for this station is limited to recent years (July 1987 to current).

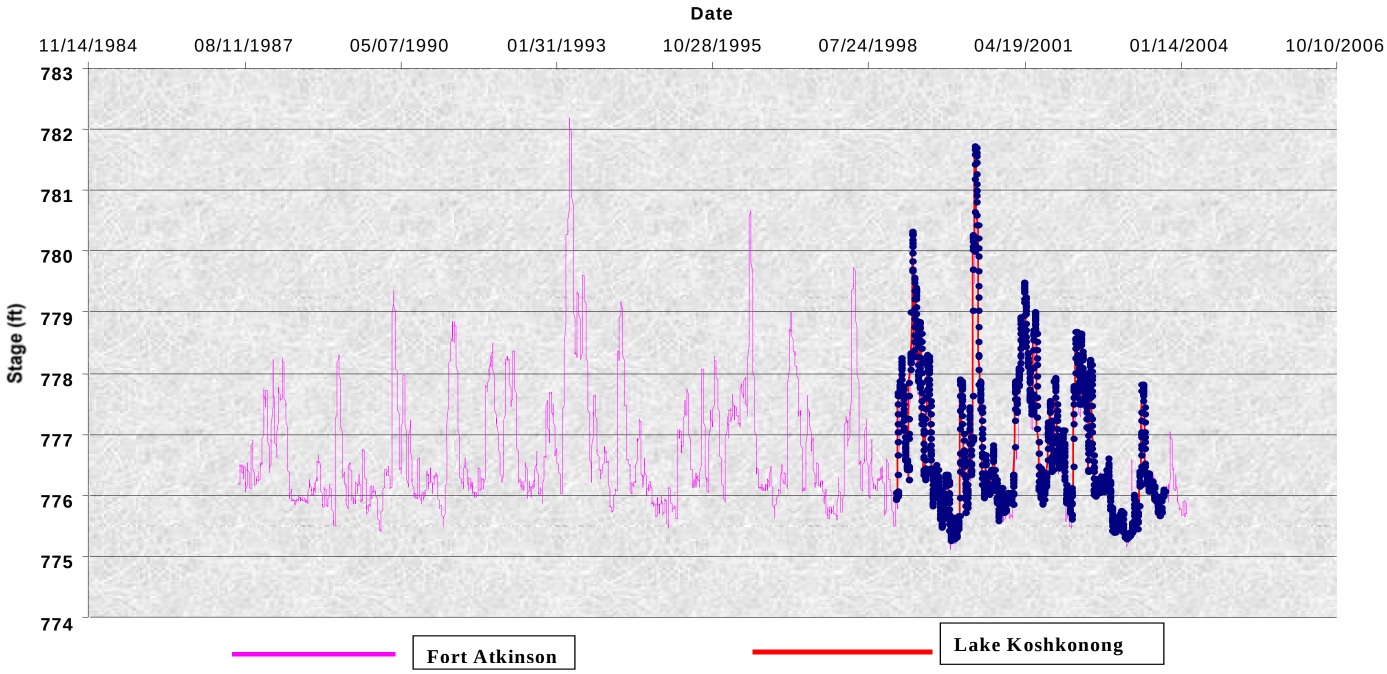
Fort Atkinson Water Plant staff has recorded daily water levels of the river adjacent to the plant since 1932. DNR staff received detailed annual graphs (1932-1998) of these water level records (Attachment 3). The reach of river between the water plant and Lake Koshkonong is very low gradient. Because of its extremely low gradient, changes in water levels recorded upstream at Fort Atkinson reflect lake levels and accurately track annual trends in water levels of the lake (Figs. 7 and 8).

Figure 7



Our primary objective is to examine long term trends in water level during the summer period, when flow is reflective of base levels and is not so strongly affected by the extreme runoff events that occur in spring. Data points from the Fort Atkinson Water Plant graphs were systematically interpolated on days 1,5,10, 15,20, and 25 of each month and entered into a database for analysis. For data after 1998, daily water level records were electronically available. Mean water levels were calculated by month and by season (spring, summer, fall winter) for each year. **For a complete description of the methods and results please refer to Attachment 5.**

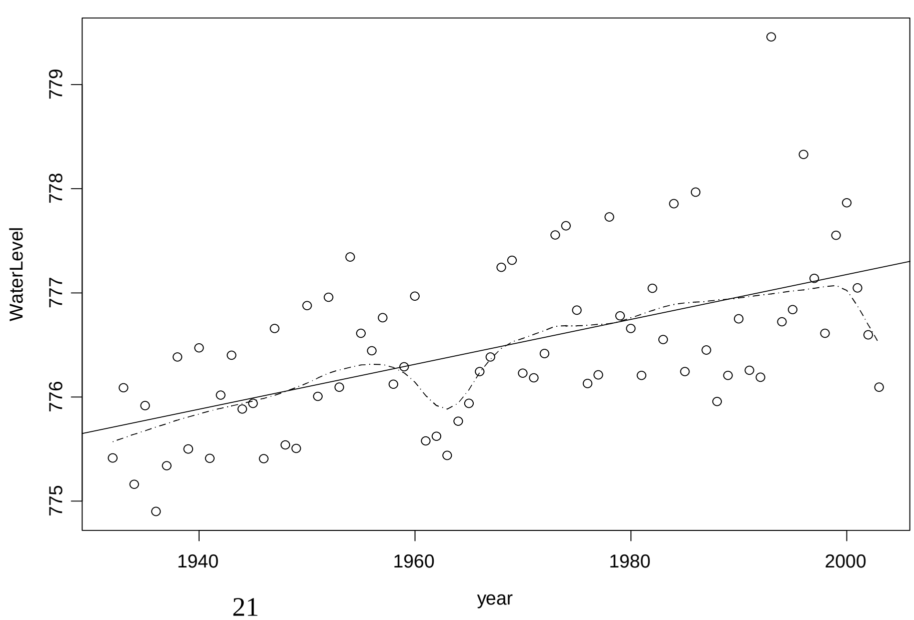
Figure 8 **1987-2004 Rock River, Water Level Data from Fort Atkinson and Lake Koshkonong**



Annual Trends in Summer Water Levels

Mean summer water levels have markedly increased through the years 1932-2003 by 1.532 feet. Mean summer water levels for the period 1932-2003 is shown in figure 9. The solid line in figure 9 is the simple linear regression line (water level = 734.0195 + 0.02158*year, SE of the intercept is 7.506, SE of the slope is 0.00381, $P < 0.001$ for both, residual standard error is 0.6727). The change in water level predicted by this model for the period 1932-2003 is 1.5 feet (predicted level of 775.709 in 1932 and of 777.241 in 2003).

Figure 9.



Annual Trends in Spring, Fall, and Winter Water Levels

Water levels have significantly increased through the years 1932-2003 (Figure 10-13; $P<0.001$) for all seasons. Trends for spring, fall, and winter mean water levels are somewhat similar to summer water-levels trends, although less variance is explained by year. Annual variation in water levels is greatest in the spring, followed by fall, winter, and summer (Figures 10-13). R^2 values for the seasonal relationships were 0.099 for spring, 0.314 for summer, 0.179 for fall, and 0.236 for winter.

Figure 10 Spring (Mar, Apr, May)

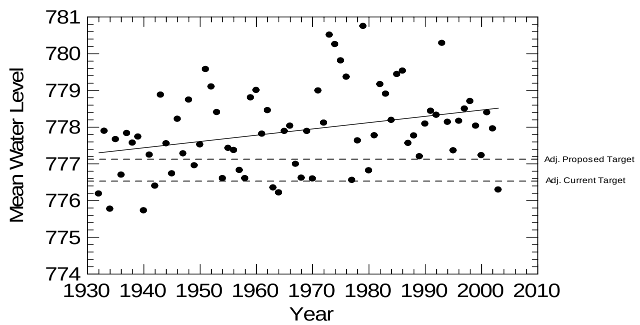


Figure 11 Summer (June, July, Aug)

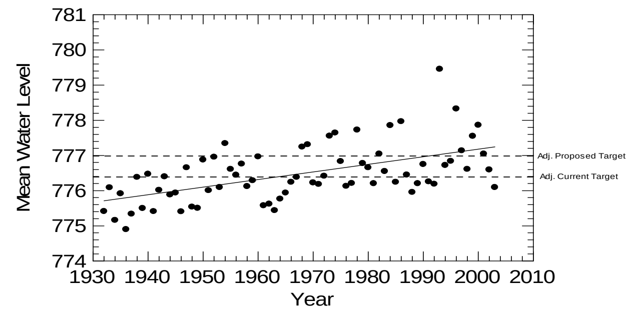


Figure 12 Fall (Sept, Oct, Nov)

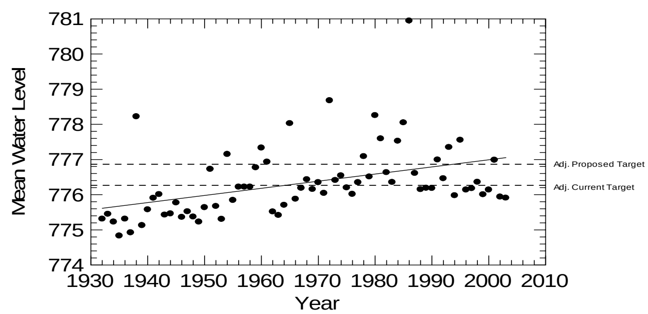
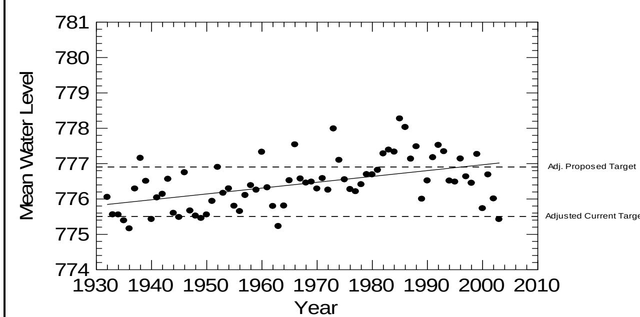


Figure 13 Winter (Dec, Jan, Feb)



Summary of Koshkonong Water Level Time Series Analysis

- Average summer water levels of Lake Koshkonong (as recorded at Fort Atkinson) has increased by approximately 1.5 feet between 1932 and 2003.

- Linear regression results of time series data of water levels predicts (after Fort vs. Lake differential adjustments) a mean summer water level of 775.52 ft in year 1932, which is 0.68 feet below the water level target in the current order and a mean summer water level of 777.05 ft in year 2003, which is 0.8 feet above the water level target in the current order.

- Trend analysis of summers typified by “base-flow” conditions (Elimination of Wet and Variable Summers--data Subset Method) predicts a peak summer level of 775.19 in 1932 and a peak summer level of 776.56 in 1998; an increase of 1.37 ft. in summer water levels during the period.

- After upstream flow was accounted for, there was still an increase in summer water levels of Lake Koshkonong over time (slope = 0.00854, $P < 0.001$).

- A comparison of the slopes of the time series among seasons indicates that water level increases during the summer and fall has been greater than those for spring and winter periods.

Ordinary High Water Mark Determinations

The Ordinary High Water Mark (OHWM) has a long history in Wisconsin Water law. Probably the most famous case defining the OHWM was Diana Shooting Club v. Husting in 1914. The definition used in Diana Shooting Club v. Husting is still the definition of the OHWM used today and was recently codified in State of Wisconsin Administrative code as, "…the point on the banks or shore up to which the presence and action of water is so continuous as to leave a distinct mark either by erosion, destruction of terrestrial vegetation or other easily recognizable characteristics." The significance of the OHWM is that it defines the demarcation point between public trust land and private property. Essentially the state claims public interest in all land below the OHWM elevation. In Wisconsin, the state actually owns title to natural lakebeds and asserts a qualified interest in streambeds and those portions of the beds of natural lakes raised above their original levels.

In regulation of dams, the OHWM is important because a change in operation or water levels that affects the OHWM could result in a change in property from public to private or vise versa. In September and October of 2001 the Lake District and the Department surveyed several OHWMs around Lake Koshkonong. The details of that survey can be found in a report by RSV Engineering dated November 18, 2002 and titled ***Ordinary High Water Mark Study Lake Koshkonong Jefferson County, Wisconsin***.

Figure 14 shows the location of those OHWM determination and Table 3 shows the result of that survey. The Montgomery report assumed OHWM based upon Table 3 of 778.11 MSL. The Department's order 3-SD- 82-809 referred to an OHWM of 776.7 MSL, a difference of 1.41 feet. It is difficult to explain this large difference. The most likely explanation is that the lake now reaches higher levels more often than it did in 1979 when the original OHWM work was done. This simple supposition is supported by the fact that the wicket gates have not been in a state of good repair and would have significantly reduced the capacity of the dam to pass flows, resulting in more fluctuation of the Lake. The Montgomery study had to assume a reduced area of the wicket gates in order to achieve calibration of their model. While the actual opening of the turbine area is about 150 square feet. Montgomery used a reduced area of 53.6 feet to achieve calibration. This reduced flow wicket area could in part explain more pool fluctuation and a higher OHWM. A review of past water levels before the 1979 OHWM and the 2001 OHWM seem to indicate that the water levels have increased to a point were the OHWM could have been influenced (Figure 15). Of particular interest is the mode of the distribution for the spring period. The mode of course is the most frequently appearing point in any distribution. The mode of the water level distribution leading up to the 1979 OHWM and again leading up to the 2001 OHWM falls almost exactly on the OWHM. While the overall mean of the spring distribution did not change, the mean of the summer, fall and winter water level distributions have all increased by 0.7 feet, 0.17 and 0.32 feet respectively.

There are several likely explanations for the apparent rise in water levels between the two series discussed above; First, there is simply more runoff flowing into the lake in the last twenty years. A review of Attachment 5 in part supports this explanation since the trend line for water levels has increased 1.5 feet over the course of the monitored water levels at Fort Atkinson; Second, a lack of operation of the spillway gates including lack of maintenance of the trash racks and wicket gates has resulted in higher water levels; Third, implementation of the last water level order (3-SD-82-809) has resulted in raising the water levels; Fourth, a combination of all of the above has resulted in higher water levels and a higher OHWM.

Another possibility is that the 1979 OHWM was simply wrong. In any event the Department concurs with the RSV report and for the purposes of this analysis will use an OHWM of 778.11 MSL.

Figure 14.

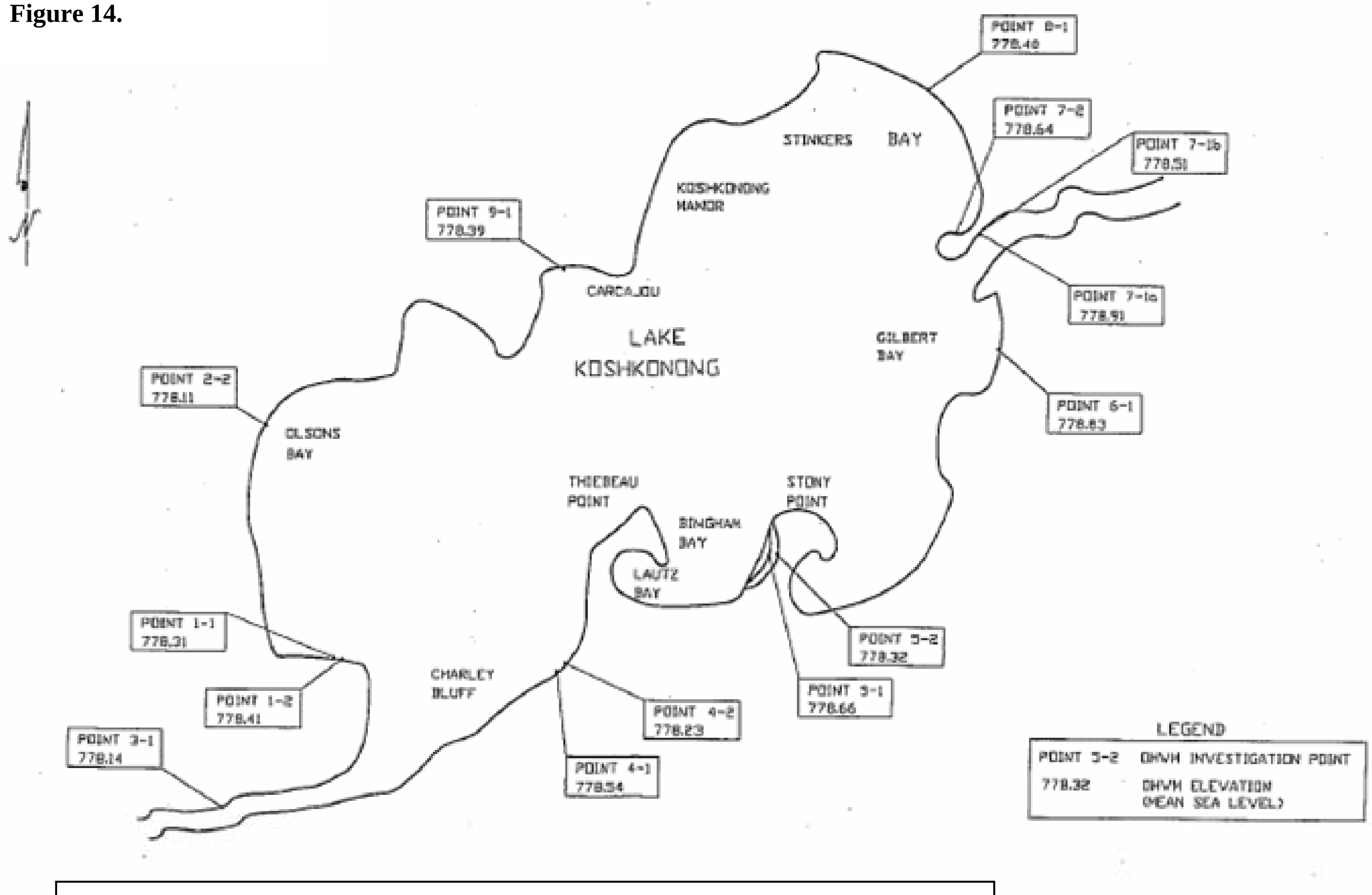
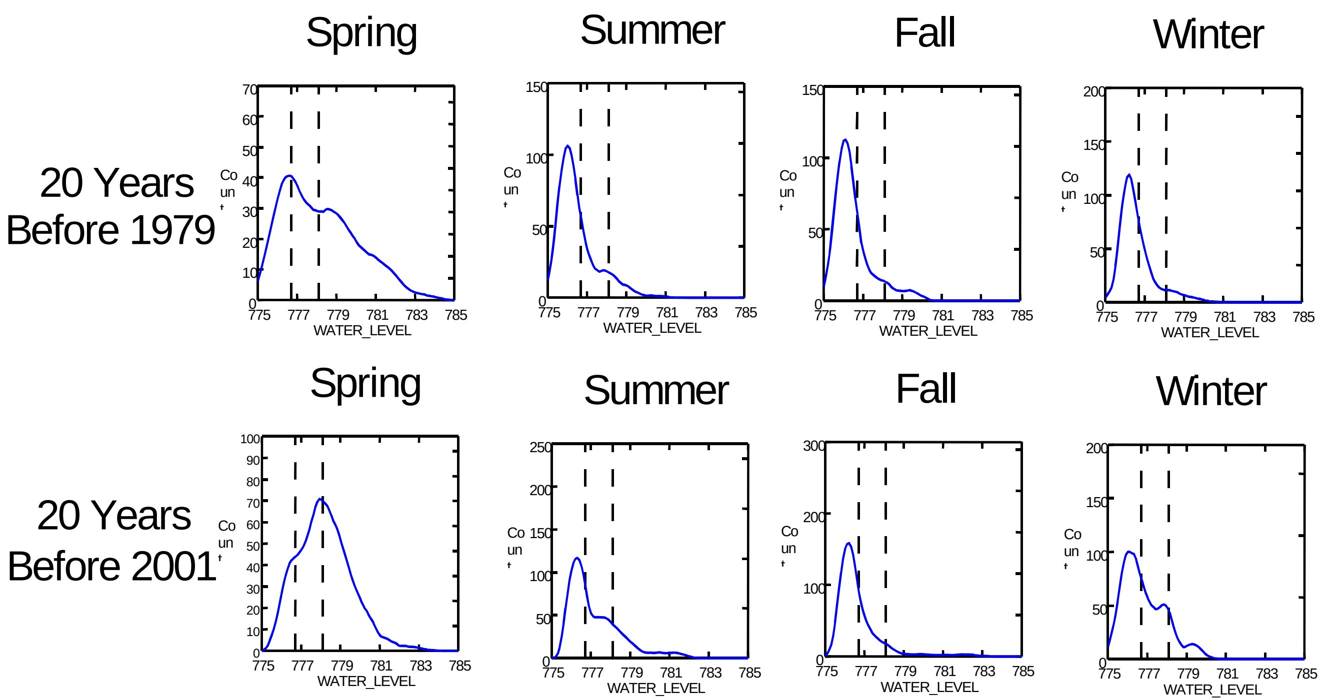


Table 3

OHWM Identifier	Elevation of OHWM	Benchmark Used	Location
1-1	778.31	Chiseled Square , SW corner of Slab, Pump House	Maple Beach
1-2	778.41	Chiseled Square , SW corner of Slab, Pump House	Maple Beach
2-1	778.11	N. Rim San MH, E-1.3, Lot 41	Glen Oaks Point
2-2			Glen Oaks Point
3-1	778.14	B53-146-90	Highway 59 Bridge
4-1	778.54	BM CB 79	Charlie Bluff Point
4-2	778.23	BM CB 79	Charlie Bluff Point
5-1	778.66	BM 299	Binghams Bay
5-2	778.32	BM 299	Binghams Bay
6-1	778.83	BM 297	Vinnie Ha Ha
7-1a	778.91	BM 295	Blackhawk Island
7-1b	778.51	BM 295	Blackhawk Island
7-2	778.64	BM 295	Blackhawk Island
8-1	778.4	BM 298	North Shore
9-1	778.39	PK in Cul-de-Sac	Carcajou Point

Figure 15. A comparison of water level density distribution curves between the two ordinary high water mark (OHWM) determinations reported in 1979 and 2001. Lines shown are nonparametric kernel density estimators, thus make no assumption regarding normal distributions. Kernel density functions are like continuous histograms and show areas where the data are most concentrated in the sample. Water levels at the Fort Atkinson Water Plant are shown on the x-axis and frequency of data points are shown on the y-axis. Spring (Mar, Apr, May), Summer (June, July, Aug), Fall (Sept, Oct, Nov), and Winter (Dec, Jan, Feb) are arranged in columns. Density distributions are comprised of all data for a period 20-years prior to the OHWM determination year. For example, the top row of plots includes all data from the years 1960 through 1979. Lower and upper x-axis range lines show the Oct. 1979 OHWM (776.7) and the Sept. 2001 OHWM (778.1).



OHWM & Hydraulic Modeling

The Rock Koshkonong Lake District (RKLD) supports their request to raised water levels with a report, "Hydraulic Analysis of Indianford Dam and Lake Koshkonong" by Montgomery Associates: Resource Solutions, LLC dated January 2003. The Montgomery report uses mathematical hydraulic models to simulate the operation of the Indianford Dam and the resulting water levels on Lake Koshkonong and concludes that the proposed increase in lake levels will not change the ordinary high water mark (OHWM). The report uses a hydraulic model to determine the still water level and adds a calculated wave height to predict the lake effects on the OHWM. The calculation doesn't take into effect the human impacts that affect the OHWM like boat-generated wakes or waves.

Montgomery 's hydraulic study indicates that the Indianford Dam affects water levels during low flows to small, more frequent flood flows. The model predicts that the dam controls small floods up to about 1000 cfs. The hydraulic study also indicates that the dam submerges during larger floods, meaning that the channel downstream of the Indianford Dam controls the outflow of Lake Koshkonong, not the dam structure. During large floods, observers viewing the dam would see that the water level downstream of the dam is approximately the same as the water level upstream of the dam, which means the dam is submerged.

Though the Montgomery hydraulic model has merit, it has some limitations when predicting lake levels, flow at submergence and lake impacts primarily due to uncertainties in the dam's flow capacity through the powerhouse. Other factors contributing to the model's limits include the lack of accurate inflow data, debris blockage of the wicket gate trashracks, poor outflow data at the Indianford Dam, lack of calibration data for a fully-operating dam and the HEC-RAS hydraulic model restrictions.

The basis for most of the Montgomery report's hydraulic conclusions is the comparison of computer simulations of alternative dam operations compared to a simulation of the Indianford Dam operated in accordance with the current water level orders. Figure I5 of the Resource Solutions' report shows a stage-duration comparison between the Lake Koshkonong gage and current water level order model simulation. The current order simulation is about 0.4 feet lower than the actual lake stages measured at the US Geological Survey gage more than 50% of the time. It might be expected that actual lake levels were higher than necessary over portions of the 1987–2001 period of record that was used for this study due to flow capacity problems at the dam, including trashrack debris blockage and inoperable wicket gates. Additionally, the models' stage results are too high due to inaccurate flow capacity for functional wicket gates. It's impossible to determine the actual amount of water level difference that these problems caused based on available records. The basic assumption that the current water level simulation is accurate cannot be concluded. Since the current water level simulation can't be shown to be accurate then the conclusions drawn from the comparisons aren't accurate enough to conclude that the OHWM will not be affected by raising water levels.

The Indianford Dam passes flow over a 277-foot, concrete, fixed-crest spillway, through six lift gate sections on the east side of the dam and through two wicket gate sections in the powerhouse on the west side. Trash racks are located on the upstream side of the powerhouse at the entrance of the turbine bay and are considered necessary appurtenances to hydro electric dams to protect wicket gates and turbines from damage from large debris. Roughly, the capacity of the six open gates and the capacity of the fixed-crest spillway to pass water are equal to the flow that can pass through the fully-opened wicket gates in the powerhouse. For example at the target lake level of 776.2, the fixed-crest spillway and the 6-lift gates fully open can pass about 1050 cfs, and the wicket gates can pass 1090 cfs.

Flow through the wicket gates is calculated with an orifice equation. The variables in the equation are the orifice coefficient, the head (the difference between the upstream and downstream water levels), and the area of the opening through the wicket gates or discharge tube. The head is determined by the flow in the river and the operation of the dam as long as the dam isn't submerged.

The orifice coefficient represents the energy loss due to the physical configuration of the opening. Coefficients are most accurately determined when the flow, head and area are measured at the site and the resulting coefficient is calculation. These measurements have not been complete at the powerhouse to determine the wicket gates' coefficients. In the absence of actual measurements, literature references of actual measurements taken at other sites can be reviewed and a coefficient selected to best fit the Indianford Dam wicket gates. Orifice coefficients can range from 0.5 to 0.99. The larger the coefficient the more flow that can pass through the opening.

Several literature sources were reviewed to select orifice coefficient to compare to the coefficient used in the Montgomery calculation. *Handbook of Hydraulics* by Brater and King, sixth edition states that the orifice for a converging bell-mouth opening can range from 0.959 to 0.994. *Hydroelectric Handbook* by Creager and Justin, second edition states that the orifice for a bell-mouth is 0.97. Based on the dam plans and that hydro dams attempt to create an efficient system to generate power and profit, it is reasonable to assume that an orifice coefficient of 0.97 is appropriate.

There are two wicket gates in the dam controlling openings with a total cross sectional opening area of 127 square feet. The Montgomery model uses 60-square feet or only 47% of the available gate area in an attempt to best match the dam's actual outflow. There are not good records of wicket gate flow conditions or a time relationship of clean, partially obstructed, or fully blocked trash racks to adequately calibrate the Montgomery model. The Montgomery model underestimates the outflow of the dam when the wicket gates are open and the trash racks are clean. It also overestimates the outflow when the wicket gates are significantly obstructed.

The combination of a low orifice coefficient and lower opening area results in significantly lower discharges from the wicket gates. Using standard orifice flow equations, the table below demonstrates the difference between the flow though the wicket gates for the Montogomery analysis and the values supported in literature and the dam plans.

Table 4. Estimated Discharge of the dam at lake level of 776.2 msl – slide gates closed

Information Source	**Orifice Coefficient**	**Wicket Gates Total Area**	**Discharge (cfs)**
Montgomery Report	0.6	60 sq. feet	970
Dam Plans	0.6	127 sq. feet	1540
Literature* and Dam Plans	0.76	127 sq. feet	1650
Literature* and Dam Plans	0.97	127 sq. feet	1930

*see *Hydro Electric Handbook by Creager and Justin*

Table 4 shows that the Montgomery hydraulic analysis underestimates the discharge of the dam resulting in higher modeled lake levels than actual would occur if the trash racks are kept clean. This means that the Montgomery model underestimates the discharge at which the dam submerges and therefore underestimating the elevation at which the lake is no longer controlled by the dam. Montgomery concludes that the purposed higher water levels plus the affect of wind driven waves not impact the OHWM. However such a conclusion cannot be supported without a better understanding of flow through the power house.

Debris, such as leaves, branches, floating lake vegetation and dead fish, collect on the trash racks at the entrance of the wicket gates. The debris decreases and can eliminate flow through this portion of the dam, which may mean reducing the dam's total flow capacity by as much as half. When the dam was used to generate power, the racks would be cleaned very often to make sure that water could flow to the turbines. Debris in the trash racks would mean a loss of power generation and income. Since the dam is not used to generate power, trash rack cleaning is irregular. It is difficult to determine the amount of trash rack blockage and records of the amount of daily debris blockage are not kept. Therefore trash rack blockage couldn't be accurately considered in the Montgomery hydraulic model.

The affects of trash rack cleaning can be shown with the flow records and the wicket gate cleaning records. The dam's operational logs indicate when the trash racks are cleaned. The Montgomery report figure E2 and the flow gage at the Indianford Dam shows that the flow increased about 300 cfs after the trash rack were cleaned on March 14 & 16, 2000. In figure E3, the trash rack cleaning on October 24, 2000, and one lift gate opened increased flow through the dam by about 700 cfs. About 230 cfs of the flow increase would have been due to the gate opening.

Montgomery calibrated their hydraulic model using the estimated inflow and the 'poor' outflow from the Lake measured at the Indianford Dam. To make the model best match this inflow and outflow data, Montgomery drastically reduced the flow capacity of the wicket gates. Two factors in the equation representing the wicket gate flow capacity appear to be underestimated. The orifice coefficient and the gate opening area appear to be too low in the Montgomery report compared to the actual physical dimensions of the dam and literature research. Actual stream gaging during debris free condition would be necessary to definitively establish an appropriate flow relationship and an appropriate coefficient for orifice flow.

Because the amount of blockage effects on the wicket gates'capacity cannot be reliably determined and is not documented, USGS rates the gage measuring the flow at the dam to be 'poor' as of October 2000. A 'poor' rating means that the gage data cannot meet the standard of 95% of the daily discharges are within 15% of actual flow. Though the gage's rating changed in 2000, the reasons for the change have existed for many years. USGS is confident of the historical flows when the wicket gates are not open. Going back to at least 1979, the USGS gaging notes state, "During the period from July 5 to Aug. 18 and Sept. 17-30, the wicker(t) gate of the powerhouse was open. Current ratings do not account for this flow." In November 1980, USGS's gaging notes state essentially the same with the following addition, "A turbine rating was studied but was found unfeasible due apparently to trash collecting on the trash barriers upstream of the wickets in the powerhouse." In December 1981, the USGS gaging notes were similar to the 1980 notes with the following addition, "Since the powerhouse is not yet generating, a regular maintenance of the trash barriers is not performed". The 1982 notes state, "During the fall and winter of the

1982 water year, 1 turbine was open but measurements showed negligible flow through the wicket gates and this was attributed to trash buildup on the upstream trash barriers of the power house."

The calibration data was further compromised by the wicket gates being inoperable during the periods used for calibration and for the lake level analysis. The wicket gates were found to be inoperable in October 1998. It is unknown how long the gates were inoperable prior to the discovery. The east wicket gate wasn't fully operational until late 1999 and west wicket gate was fully operational in November 2002. The Montgomery analysis of data ends in August 2002. At no time was the hydraulic model calibrated with data when both wicket gates were known to be operable, fully-opened and fully-cleaned of debris.

Due to the limitations and lack of data, the Montgomery analysis is not a sufficient prediction tool to assure that the OHWM will not change do to the increase in water levels.

Influence of Wind and Wave Events on the OHWM

There is no known relationship between recurrence interval (the presence and action of water) and the OHWM. While we do not know how often water has to be present to influence the OHWM we do know the presence of water on the shoreline is a function of three elements: 1) still water level, 2) wave action generated from wind or boats, and 3) shoreline configuration. The river hydraulics, including the presences of a dam, controls the still water levels. Wind-induced (wind-driven) water level rises along the shore consist of two elements: 1) wind set up (a temporary rise in the water level at the downwind edges of the lake), and 2) wave runup (the vertical elevation of water rising on the shore as a wave breaks and "runs up the shore). Ultimately, still water plus, wind set-up plus wave run-up result in an elevation at which the water reaches on the shore land.

Assuming the Montgomery report is an accurate predictor of lake levels, we can make a prediction of the water level when different operating regimes no longer have an impact on still water levels, roughly 777.3 msl.

The Montgomery report used the Automated Coastal Engineering System (ACES) to develop the resulting wave run-up which is appropriate. However, the report did not consider wind set-up component. According to Phillip Keillor, Coastal Engineer, "ACES does not contain a program suitable for estimating wind set-up (storm surge)."

The Montgomery report used a 20-mph wind to determine the wave run-up. Wind speed varies significantly and the actual speed and wave action that forms the OHWM is unknown. To assure that the OHWM is not changed as a result of the proposed water level orders, a conservative approach must be used to determine the wind-induced water levels.

The most appropriate shoreline to assess wave generated water levels is a beach shore line (Keillor). "Wave runup on beach slopes is more straightforward and useful in considering whether or not to change planned lake level elevations."

The Montgomery report used a beach slope of 20H:1V and described it as conservative assumption. A review of the x-sections (Figures 54-60) taken by the Department in March of 2004 indicate that for most areas of the lake 20H:1V is conservative but there are areas where slopes do approach 20H:1V.

The Montgomery report concluded that the still water level of 777.0 added to the wave run up on 1-foot for a 20-mph wind was less than the OHWM elevation of 778.1 so the OHWM would not change. Keillor's calculation of wind set-up for a 20-mph wind was 0.3 feet. Adding set up to the Montgomery water level yields an elevation of 778.3 – higher than the 778.1 OHWM elevation. If you assume a 20 mile an hour storm at the still water elevation of 777.3, the point at which the proposed regime would no longer have an impact, the ultimate water level would become 778.6, 0.5 feet above the OHWM.

Clearly, over decades there will be higher wind speeds than 20 miles that could affect wave action. Keillor suggest wind speeds of 38 miles per hour are more appropriate to assess structural design. Keillor's calculations for wave run-up and wind set-up for a wind speed of 38 mph was 2.6 to 3.1 feet. Using the Lake Koshkonong's summer target still water level of 776.2, the resulting could be as high as 779.3.

Table 5. Estimated temporary water level rises on Lake Koshkonong. (feet) including setup calculated by Phillip Keillor.

Parameter	Montgomery Report (20 mph wind) estimate	Keillor (20 mph wind)	Keillor (24 mph wind)	Keillor 38 mph wind)
1. Wave runup on beaches (20:1)	1.0	1.0	1.1	1.6–1.9 @ 777.0 MSL 1.5–1.7 @ 776.2 MSL
2. Wind set up @ 777.0 MSL	0	0.3	0.3-0.5	1.1-1.2
3. Wind setup @ 776.2 MSL	0	0.4	0.4-0.6	1.1-1.4
4. Sum of wave runup and wind set up	1.0 @ 777.0	1.3 @ 777.0 MSL 1.4 @ 776.2 MSL	1.4-1.6 @ 777.0 MSL 1.5-1.7 @776.2 MSL	2.7-3.1 @777.0 MSL 2.6-3.1 @776.2 MSL