A Freshwater Controversy – Repairing the Estabrook Dam is not the best alternative for the Milwaukee River or the Community

Removal of the Milwaukee River Estabrook Dam is the most cost-effective and environmentally sound dam management alternative. That was the conclusion Milwaukee County's consultant AECOM came to in a 2015 draft of a comprehensive assessment of the socio-economic and environmental benefits and costs associated with repairing or removing the dam, and a number of other alternatives that were developed as potential compromises to accommodate the concerns of dam repair and removal proponents. Several public meetings were held over the last few years, and the public weighed in with support for dam removal.

It is unfortunate that Supervisor Theodore Lipscomb, Jr., who was present at early meetings for the County's own expert assessment and had the opportunity to review the assessment, failed to offer it to the full County Board for review and debate after public hearings in 2014 or after the draft assessment was issued in summer 2015. In fact there has never been a standalone up and down vote at the Milwaukee County Board level based on the merits of this issue. This simple act could have avoided the political gamesmanship that followed, where the County's policy was changed from repair, to removal, and then back to repair with fish passage through several budget cycles in 2014-2016.

Some of the information cited by Mr. Holmes from the draft September 2014 Environmental Assessment (EA) is outdated (e.g., dam management costs). Unfortunately, even the most recent EA must go through yet another revision because of the County Board's change in policy to repair the dam and add fish passage, and to comply with the DNR's requirement to establish an Operational Order for operating and maintaining the dam and fishway, and setting water levels. A Public Hearing is tentatively planned in March 2016. I encourage all interested residents to follow and participate in the process and review the most recent October 2015 environmental assessment http://dnr.wi.gov/topic/EIA/Estabrook.html

Milwaukee County's current policy to repair the Milwaukee River's Estabrook Dam and to construct an engineered fish passage facility around it should be **postponed**. The County should appoint an ad hoc committee of scientists and other independent professionals to review the existing information and provide recommendations. Scientists and engineers from local universities and colleges, and water resource management agencies with expertise in surface water resource studies and management should be asked to participate on the committee. Additional alternatives can be explored that mitigate the severe environmental impacts of 1.5 miles of deepening and widening of the river channel and the construction and operation of the Estabrook Dam that, that are sustainable, approach the historic functions and uses of the Milwaukee River, and unlike the existing dam, do not increase potential flood and drainage damages. As in the past, the findings and recommendations should be presented to the public for review and input. Supervisor Lipscomb, proponents and opponents to repairing the dam should accept those recommendations as expertly informed and follow them without any more political maneuvering. What could be more responsible than that? After all is said and done, the ultimate decision on the fate of the Estabrook Dam will affect existing and future generations to come and will extend to the Milwaukee River and Lake Michigan Basins, well beyond the confines of the 103-acre impoundment. It's important the County and its residents make that decision based on the best information available.

While I found the series by David Holmes describing the geology and history of modifications to the Milwaukee River in Lincoln and Estabrook Parks , and his technical arguments in support for dam repair and construction of a fish passage facility (fishway) interesting, I need to respond to many of Mr. Holmes' claims that the technical information offered by proponents for other dam management alternatives

including dam removal are *"…unsubstantiated by either actual data collected from this section of the Milwaukee River or by data collected from comparable rivers and dam removal projects"*.

That said, here is some of my relevant background. I am a former water resources and fisheries biologist with the Wisconsin Department of Natural Resources (DNR) having retired in July 2015 after 38 years with the agency. My experience as it relates to the Estabrook Dam included working with over 15 dam owners and stakeholders to assess dam management alternatives in the Milwaukee River Basin, the pre- and post-monitoring of those projects, as well as assisting with the design of fish passage features including the fishways at the Mequon-Thiensville Dam on the Milwaukee River and several projects along the Menomonee River. I was also the local DNR project manager for the $4.7 million North Avenue Dam removal completed by the City of Milwaukee in 1997, and was also involved with the initial assessment that identified the extent of sediment accumulation and PCB contamination in the Milwaukee River's Estabrook Dam impoundment. I am a long-time, taxpaying resident of Milwaukee County and deeply care for what is best for the long-term uses and values of the Milwaukee River. And now for my disclaimer: my opinions are my own and not those of any government agency or private firm, group, individual, or non-profit, and I have not received any form of compensation for preparing them.

What was the Milwaukee River's historic morphology? Drainage Lake or River?

I disagree with Mr. Holmes argument that keeping the Estabrook Dam restores the *"…unique hydrologic feature – a drainage lake that appears to have existed in the area of **Lincoln Park** since before the end of the Wisconsin glaciation."* Firstly, a drainage lake that may have existed since before the end of the Wisconsin glaciations (over 10,000 years ago) is not relevant to the river that existed at the time of European settlement and present day arguments by dam repair proponents to restore the natural "drainage lake". Secondly, the historic low-gradient, narrow and deep run and pool stream features, and meandered river morphology in Lincoln and Estabrook Parks was not unique to the Milwaukee River watershed. There are numerous examples of similar river reaches in Milwaukee, Ozaukee and Washington Counties, some have been altered and others remain in a relatively natural state. Local examples include the Milwaukee River former North Avenue Dam impoundment between Concordia Avenue extended and North Avenue, and the Milwaukee River between Brown Deer Road and Range Line Road. Lastly, by many abiotic and biotic measures, the Milwaukee River in Lincoln and Estabrook Parks prior to excavating the river and construction of the Estabrook Dam and its impoundment was a free-flowing river and supported river ecological functions and values. The Milwaukee County's GIS-based 1937 aerial photographs that were taken after completing half of the river channel modifications (downstream of Hampton Ave.), prior to excavating the river "center-cut" upstream of Hampton Avenue and construction of the dam; and historic planning documents from that project bear this out (Figure 1). (Readers interested in accessing the Milwaukee County Interactive GIS Mapping website may need to download the supporting Microsoft Silverlight application and then access the website using the Internet Explorer browser).

Figure 1. 1937 aerial photograph showing historic meander of the Milwaukee River in Lincoln Park prior to construction of the Estabrook Dam and 3,000-ft long by 200-ft wide "center-cut" (yellow dashed line). Widening and deepening of the river channel and rock outcrop is completed upstream of future dam site to the temporary cofferdam just upstream of Hampton Ave. bridge. Planning documents stated the rock outcrop backwater effect extended 3 miles upstream which coincides with the "big bend". Source: Milwaukee County Interactive GIS Mapping website.

Prior to the 1930's lowering of the rock outcrop and construction of the 0.4 mile long "center cut" between Hampton Avenue and the upper confluence of the present day "east and west Oxbows", the Milwaukee River was a low-gradient, meandering alluvial river channel dominated by pool and run features. Its immediate corridor and broad floodplain included wetlands that supported habitat for a diverse plant and animal community sustained by seasonal flood waters that deposited nutrient-laden sediment. The top of the bank was reported to be only 2-feet from the normal (base-flow) water surface suggesting the entire river valley was inundated during floods. The flood waters likely extended upstream into additional wetlands along "Mud Creek" (present day Lincoln Creek).

There never was a natural drainage lake in Lincoln and Estabrook Parks. Deepening and widening of the 1.5-mile river reach altered or destroyed those features or buried them in accumulated sediment after constructing the dam and impoundment. Construction of the Estabrook Dam and impoundment did not replace the unique historic features of the Milwaukee River. It did not replace the former narrow and deep meandering river and floodplain wetlands. It did not replace historic fluvial processes that transport water and sediment, build floodplain and maintain historic and sustainable water depths. By all measures, the Estabrook Impoundment is longer by 1-mile, deeper by at least 0.4-feet, larger by 38-acres, and wider between 140-feet and 350-feet than the historic Milwaukee River.

According to planning documents, the backwater effect of the rock outcrop extended 3-miles upstream of the rock outcrop, which based on 1937 aerial photographs extended from the rock outcrop to the 130-degree "big bend". Planning documents for excavating the river channel stated that the rock outcrop was located 0.4-miles upstream of the dam, and the current impoundment extends 0.6-miles upstream of the "big bend" to almost Bender Road, or an increase of 1-mile compared to the historic river channel length (Figure 1). (There is evidence that incising of the river channel between 1 and 2-feet between Bender Road and the "big bend" may have contributed to an increase in pool length).

To my knowledge, detailed survey notes that describe the river's water depth prior to completion of the channel excavations and construction of the dam are not available. However, based on planning notes, the outcrop crest was excavated 6-feet to create a level channel slope upstream and downstream. This would imply that the maximum depth of river run-pool features upstream of the rock was 6-feet. The hydraulic height and maximum depth behind the Estabrook Dam is 8-feet.

The minimum and maximum elevation of the outcrop were reported to be 35.4-feet (616.0-feet above sea level) and 36-feet (616.6-feet above sea level), respectively. The minimum water elevation of the present day impoundment is equal to the fixed crest spillway's stop logs section at 616.4-feet and is 0.4-feet higher than the minimum level reported for the former rock outcrop; or a 0.4-ft increase in water depth compared to that provided by the rock outcrop under static or no flow conditions. The actual depth increase would be greater than 0.4-feet under median flow conditions. This increase likely contributes to extending the impoundment pool closer to Bender Road and beyond the river's historic rock outcrop affect at West Riverview Road and the "big bend".

Based on 2010 aerial photos, the area of the historic river channel inundated by the Estabrook Dam (between the dam and rock outcrop) totaled 15-acres. This is a conservative estimate since some early drawings suggest the channel was also widened in this reach up to 40-feet. While the plans proposed to excavate the center cut to 200-feet wide by 2000-feet long or about 9-acres, the present day center cut median width is considerably wider ranging between 220-feet and 600-feet or 18-acres. Not accounting for the additional impoundment pool length to Bender Road described above**, the dam and impoundment has increased the surface water acreage by at least 33-acres compared to the historic river's footprint, equal to 25 football fields.**

Between Hampton Avenue and the" big bend", the 1937 median width was 160-feet and ranged between 60-feet and 240-feet or 3-times narrower than the median 500-ft width of the impoundment's center cut. (Table 1). There are no complete historic aerial photos or drawings of the historic channel widths between Hampton Avenue downstream to the Estabrook Dam and down to the existing Estabrook Park "falls".

Table 1. Milwaukee River channel widths prior to excavation of the river channel and construction of the Estabrook Dam based on 1937 aerials. 2010 conditions are in parenthesis. (NC) denotes no appreciable change. Comparison of two low-gradient stream reaches along the lower Milwaukee River in Milwaukee County. All values rounded to the nearest ten feet.

	Channel Width (ft)		
River Reach and Data Source	Median	Minimum	Maximum
1937 width of the Milwaukee R. 0.6 mile long reach between Bender Rd. and "big bend". Minimum and maximum widths based on C. of Milwaukee Engineer survey.	80 (NC)	70	130
1937 width of the Milwaukee R. 0.4 mile long reach between "big bend" and Silver Spring Dr.	130 (NC)	60	180
1937 width of the Milwaukee R. 0.55 mile long reach between Silver Spring Dr. and present day "east-west oxbows"	170 (NC)	160	200
1937 width of the Milwaukee R. 1.5 mile long meander between present day "east-west oxbows" and Hampton Ave. and present day center cut.	150 (500)	60 (220)	240 (600)
2010 width of 1.5 mile reach Milwaukee R. former North Ave. Impoundment Concordia Ave. to North Ave.	130	100	180
2010 width of 1.5 mile reach Milwaukee R. Range Line Rd. to Brown Deer Rd.	210	130	270

No river channel deepening or widening occurred upstream of the east and west oxbows and the river widths are generally unchanged. However, a recent canoe trip down the river revealed evidence that the river channel has experienced some deepening of the river channel by erosion (incising) between the abandoned railroad bridge to downstream of Silver Spring, and more so upstream of the "big bend" toward Bender Road between 1-ft and 2-ft.

The 1937 river width between the “big bend” and Bender Road was narrower at 80-feet, which is consistent with historic survey accounts by the City of Milwaukee Engineer that reported channel widths ranging between 70-feet and 130-feet. The 1937 aerial photographs and City of Milwaukee engineer drawings shows alternating lateral sand and gravel bars that are consistent with the morphology of a free-flowing, moderate-gradient alluvial river channel dominated by shallower riffles/runs unaffected by the rock outcrop (Figure 2 and 3).

Figure 2. 1937 aerial photograph of Milwaukee R. between the “big bend” and Bender Rd. showing extent of lateral bar development consistent with free-flowing alluvial river channel. Note the lack of residential development along both left and right banks that pre-dates the construction of the Estabrook Dam in 1940. Currently there are an estimated 72 waterfront residential structures in this reach. Source: Milwaukee County Interactive GIS Mapping website.

The 1937 160-ft median width and 6-foot water depth between Hampton Avenue and the “big bend” is similar to other low-gradient Milwaukee River reaches located in the former North Avenue impoundment at 130-ft and the Milwaukee River near Brown Deer Road at 200-ft.

The historic river's median width of just 160-feet and maximum depth of 6-feet would not have been compatible with today's demands for an impoundment to accommodate deep drafting power boats, high-speed personal watercraft (e.g., jet skis) and activities such as water skiing.

Figure 3. Photo of Milwaukee River between Bender Road and Silver Spring Drive approximately 2.6 miles upstream of the Estabrook Dam showing lateral bars formed by the river during the extended drawdown of the Estabrook Dam since 2008. A good example of sediment transport and river channel adjustment from an impounded condition to a free-flowing river. The large gravel to small cobble sized material is typical of the river's forces to transport sediment as "bed-load", maintain a stable river channel dimension and water depth, and create floodplain along this narrower reach of the river. These lateral bar features can be observed from 1937 aerial photographs prior to excavation of the center cut and construction of the Estabrook Dam. Pre-construction and existing channel widths are relatively unchanged. The daytime flow at the time of the photo was approximately 180 cubic feet per second which is 60 cubic feet per second lower than the 100 year median flow of 240 cubic feet per second. These water depths may be challenging to navigate by larger deep drafting power boats but are sufficient for small water craft such as kayaks and canoes. Photo taken August 4th, 2015 by Michael Horne, UrbanMilwaukee.com

All rivers transport water and sediment. The physical, chemical and biological functions of the river ecosystem depend on this process. Unlike a "drainage lake", a river's flow of water, its sediment and its nutrients is unidirectional and because the water is flowing, the river is undergoing continuous physical change. The retention time of the water, sediment and nutrients at any point along the river during channel forming flow events is on the order of minutes, whereas a drainage lake's retention time is much

longer depending on its in flow and volume. A river's stable channel plan form (e.g., meanders) and other dimensions (e.g., depth, width), and its floodplain is dependent on the channel slope and the balance between the supply of water and sediment that is transported during flood events that typically occur every one to two years. Compared to drainage lakes, rivers have a high degree of plant, animal and habitat diversity. **Modify its morphology by excavating a deeper and wider channel; flatten its slope; and increase the rate of sediment accumulation by constructing a dam and everything changes for the worse.** Increasing the retention of fine sediment by decreasing the channel grade, increasing channel width and constructing a dam buries diverse habitat types such as wetlands and coarser riverbed substrate that fish and other aquatic life such as mussels depend on for reproduction and feeding. As an example, the diversity and abundance of recreationally important game and non-game fish species intolerant of degraded habitat such as smallmouth bass are reduced, while the diversity and abundance of species tolerant of degraded habitat such as common carp are increased. The diverse plants and animals that a river ecosystem sustains are specialized to live in flowing water.

Dam Management Issues - Sediment quality and quantity will decide the future state of the Estabrook Impoundment

Owners of dams faced with evaluating the impacts and benefits of maintaining or removing a dam must understand and weigh a variety of social, economic and environmental issues before making their final decision. Failure to do so may be costly for the dam owner, the resource and users for decades to come. The following list of issues is not necessarily all inclusive:

- Water Quality (e.g., dissolved oxygen, temperature, nutrients, turbidity and potential toxics)
- Sediment Quality and Quantity (e.g., potential toxics, nutrients, oxygen demand, sediment texture, volumes and sedimentation rates, mobility)
- Fish and Aquatic Life, Wildlife and their Habitats (e.g., fish and mussel populations, tolerance, habitat needs and availability, wetlands)
- Hydraulics and Flood Control (e.g., flooding and drainage, pool elevations)
- Land Use, Ownership, Value (e.g., access, property values, floodplain functions)
- Historical, Social, Aesthetic (e.g., archeological, "viewsheds")
- Infrastructure (e.g., dam safety, buried infrastructure, sewer outlets and scour)
- Parks & Recreation (e.g., fishing, swimming, wading, navigation)
- Cost and Implementation (e.g., capital, operation and maintenance cost, who pays, legal and regulatory)

Mr. Holmes identified some of these issues and how they are affected by two of the Estabrook Dam management alternatives, dam repair with a fishway versus dam removal. Management of sediment quality and quantity is the most important issue affecting the near-term (years) and long-term (decades) outcome following a decision to repair and operate a dam or dam removal. Sediment functions as the major storage and recycling compartment for virtually all material that flows into and out from aquatic ecosystems. The quality and quantity of sediment directly or indirectly affect all of the other management issues. Managing sediment quality and quantity is the most technically challenging and

costly to manage for maintaining or removing a dam, especially in developed watersheds and in particular those with a large contributing urban land use.

Sediment Accumulation Concerns: Will sediment accumulate and impact the sustainability of the Estabrook Impoundment?

In his November 24, 2015 article titled *"Why the Estabrook Dam must be saved"* Mr. Holmes stated that *"In terms of sediment accumulation, based on the storage capacity of the impoundment relative to the mean average annual flow volume of the Milwaukee River, the sediment trap efficiency of the impoundment should be nearly zero".* For his most recent January 17, 2016 article, he applied an empirical model for estimating the sediment trapping efficiency of the Estabrook Impoundment based on the ratio of the normal impoundment capacity to the average annual flow of the river. His result and conclusion is that the sediment trapping efficiency of the Estabrook Impoundment is zero (0%). More importantly, he concludes that because the impoundment does not effectively trap sediment from the Milwaukee River, the sediment driven impacts on water quality, fish and aquatic life and wildlife and their habitats, recreation, and other socio-economic and environmental issues will not occur.

The model first developed by Brune (1953) and applied to the Estabrook Impoundment is not an appropriate model for the Estabrook Dam and impoundment.

More accurate models need more data.

For some applications, the Brune model may be an appropriate model for estimating gross suspended sediment trapping efficiency (as a percentage of total suspended sediment loads) for impoundments. The model was calibrated from previous studies and data was skewed toward large dams (>50-feet high) and reservoirs, and by comparison the Estabrook Dam is a small dam and pond. The Brune model is not capable of predicting the temporal (e.g., inches of sedimentation per year) or spatial (e.g., location) processes of sedimentation in small impoundments. Predicting these processes in small impoundments with more diverse sediment and flow inputs and morphology may require a more dynamic model that requires more types of data collected over longer periods of time. Additional data needs may include continuous flow monitoring from all significant sources (e.g., Lincoln Cr.), long-term dam operation records (e.g., the frequency, duration and seasonality of drawdowns), measures of impoundment bathymetry over time, an accounting for the shape of the impoundment that affect differences in sedimentation rates (e.g., floodplain and "oxbows"), suspended sediment particle size and settling rates, sediment sampling from all significant sources over different flow regimes including "suspended sediment" (small particles primarily from upland soil erosion transported via the river in the water column) and "bed load" (larger river bed and bank sediment transported via the river by rolling or bouncing along the bottom). The Brune model did not account for bed load for estimating sediment trapping efficiency.

Are the assumptions correct and the data unbiased?

Mr. Holmes sediment trap efficiency model results for the Estabrook Impoundment was *"Based on the volume of 700 acre feet of water stored in the Estabrook Dam impoundment when filled, and a mean flow of 619 cubic feet per second for the river observed during 2008-2014 for the four month "summer period" when the gates would be closed,…".* A more complex and accurate sediment model would be biased if it was limited to using the seasonal (years and months) data and dam operation assumptions used by Mr. Holmes. There was no explanation as to why he chose the mean flow for the 2008-2014 water years when the dam gates were opened and the impoundment drained or why it was limited to the four month summer period (the "summer" hydrologic/hydraulic record is typically the three month period of June-August). River sediment transport is dynamic and occurs throughout the water year, and in our geographic area, the bulk of the suspended and bed load sediment load occurs during channel forming flow periods on a 1-year to 2-year recurring flow event. In less developed watersheds, these flows typically occur during the spring months March-April. However, in urbanized watersheds the effective channel forming flows, erosion and sediment transport occur more frequently even for smaller storm and runoff events.

The original approval for construction of the Estabrook Dam was to keep the dam gates closed year around and the impoundment full except during flood events. For unknown reasons the County has not adhered to this operating condition. For decades, the County has opened the 10 gates of the dam and drained the impoundment in early-September and closed the gates and filled the impoundment in early-May. By doing so polluted sediment is eroded from the impoundment and transported downstream. This annual event occurs as a spate of water, sediment, and man-made debris when the gates are opened and the impoundment drained, and continues through the fall, winter and especially the spring when the higher flows and river forces erode accumulated sediment.

The lack of an appropriate model that does not account for the decades-long flushing of sediment creates false estimates of the true sedimentation processes and accumulation rates in the Estabrook Impoundment, and most importantly minimizes the impacts that sedimentation has on the short- and long-term impacts on the socio-economic and environmental functions and uses of the impoundment and Milwaukee River.

How well do the modeled predictions and conclusions fit the real world?

Ultimately, the application and results of any sedimentation model, no matter how sophisticated and extensive the supporting data, is only as good as how the estimates compare to what is observed to occur. Verification of the model estimates could include a mass balance approach whereby the flow and sediment entering and exiting the impoundment is monitored over a complete and typical water year when the dam is operated at full pool. Another method is to deploy sediment traps throughout the impoundment and conduct detailed bathymetric mapping throughout the impoundment over an extended period of time (years). While these are not the only methods for verifying and quantifying modeled sedimentation rates and trap efficiency estimates for the Estabrook Impoundment, these and

other methods would be time consuming and expensive. That said, one would not need to expend time and money to conclude that the Estabrook Impoundment is an effective sediment trap and the efficiency is much greater than "zero". Recent planning and construction documents for the Estabrook Impoundment dredging and sediment remediation project should be adequate for reaching this conclusion.

Over the course of the Blatz Pavilion, and Phase I and Phase II sediment remediation projects, hundreds of samples were obtained from the Estabrook Impoundment to document the thickness, volume and mass of accumulated contaminated sediment. Vertical measurements were made from the top of deposited sediment to the point of "refusal", meaning that the amount of deposited sediment did not extend beyond the original river channels bedrock or coarse alluvial material. The survey boundaries included the lower reach of Lincoln Creek, and the impoundment extending from the Estabrook Dam upstream to just beyond the confluence of the river's "east" and "west" oxbows in Lincoln Park. While the depths of the accumulated sediment were variable, large amounts of sediment had accumulated in all areas of the impoundment up to 10-feet.

The exception was the reach in the vicinity of the I-43 Bridge where depths were approximately 0.5-feet. Mr. Holmes states *"The lower portion of the impoundment was largely clear of sediment when surveyed in 2010 as part of planning for the second phase of contaminated sediment removal project, with only 6-inches of sediment present above the bedrock beneath the I-43 Bridge." "All this suggests the flow dynamics within both the natural and man-made impoundment are sufficient to keep significant portions of the impoundment largely free of sediment."* I would agree that the limited amount of sediment accumulation in this river reach is related to *"flow dynamics"*. However, the process is far from being just *"natural"*. The County has routinely contributed to this process by routinely opening the dam gates and flushing accumulated sediment to river reaches downstream of the dam (Figure 4). The accumulation of large volumes of contaminated sediment behind the fixed crest spillway but not behind the adjoining gated spillway where the drawdown occurs provides some evidence to this man-made process. Pre-remediation deposits of contaminated sediment were identified along the I-43 reach but were eroded away prior to mobilizing for removal.

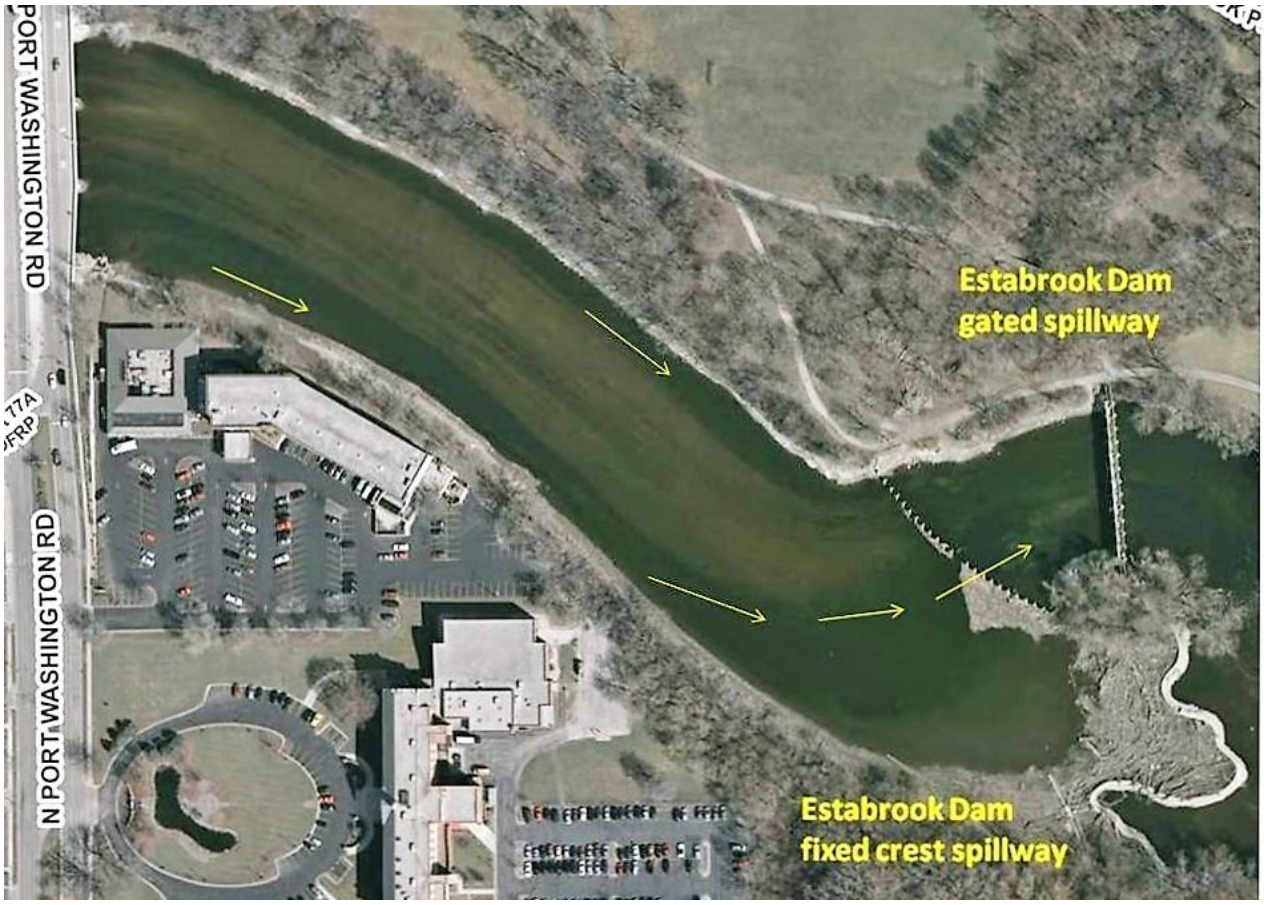


Figure 4. 2010 aerial photo of the Milwaukee R. between Port Washington Rd. and the Estabrook Dam. Scoured sediment plume is visible as light brown hue exiting through the dam's gated spillway. Sediment and comingled debris visible behind the fixed crest spillway was removed along with sediment that extended up the shoreline in 2015. Source: Milwaukee County Interactive GIS Mapping website.

While the final estimated volumes of accumulated sediment and contaminants removed during the three remediation projects are not published, based on my conversations with a DNR engineer the final volume of contaminated sediment removed from the Estabrook Impoundment will be close to 176,200 cubic yards, 7,630 pounds of PCB and 16,718 pounds of PAH at a cost of $49 million (Table 2). **The volume of removed sediment is equivalent to over 12,580 dump trucks.** I'm confident that if sediment surveys were extended throughout the 103-acre impoundment so to provide estimates of all accumulated sediment in the Estabrook Impoundment, and if the County had not been opening the dam gates and eroding a portion of accumulated sediment downstream of the dam on an annual basis, the amount of accumulated sediment since construction of the dam in 1940 would well exceed the 176,200 cubic yards of just the contaminated sediment removed from the impoundment (Figure 5).

Table 2. Summary of Estabrook Impoundment sediment remediation project; by project, surveyed sediment thickness, volume and mass of PCB, PAH and NAPL removed and costs.

Project	Area	Sediment Thickness (feet)	Sediment Removed (cubic yards)	PCB Removed (pounds)	PAH Removed (pounds)**	Cost ($_million)
Blatz	Lagoon	1 to 5	4,705	300	n.a.	$ 1.3
Phase 1	Lincoln Cr. Milwaukee R. confluence	1 to 4	119,039	5,000	4,035	$ 28.0
	"West Oxbow"	1 to 9.5				
Phase 2	Milwaukee R. "center-cut"	1 to 5	52,456	2,330	12,683	$ 20.0
	Hampton Ave. to I-43*	1 to 4				
	Dam spillway	1 to 5				
Total			176,200	7,630	16,718	$ 49.3

* Mean depth of accumulated sediment along reach was 0.5-feet. One isolated lateral bar removed 1 to 4-feet thick

** Approximately 359,000 pounds (180 tons) of non-aqueous phase liquid (NAPL) contaminants were also removed. NAPLs are contaminants that do not readily dissolve in water. Examples include oil, gasoline and solvents.

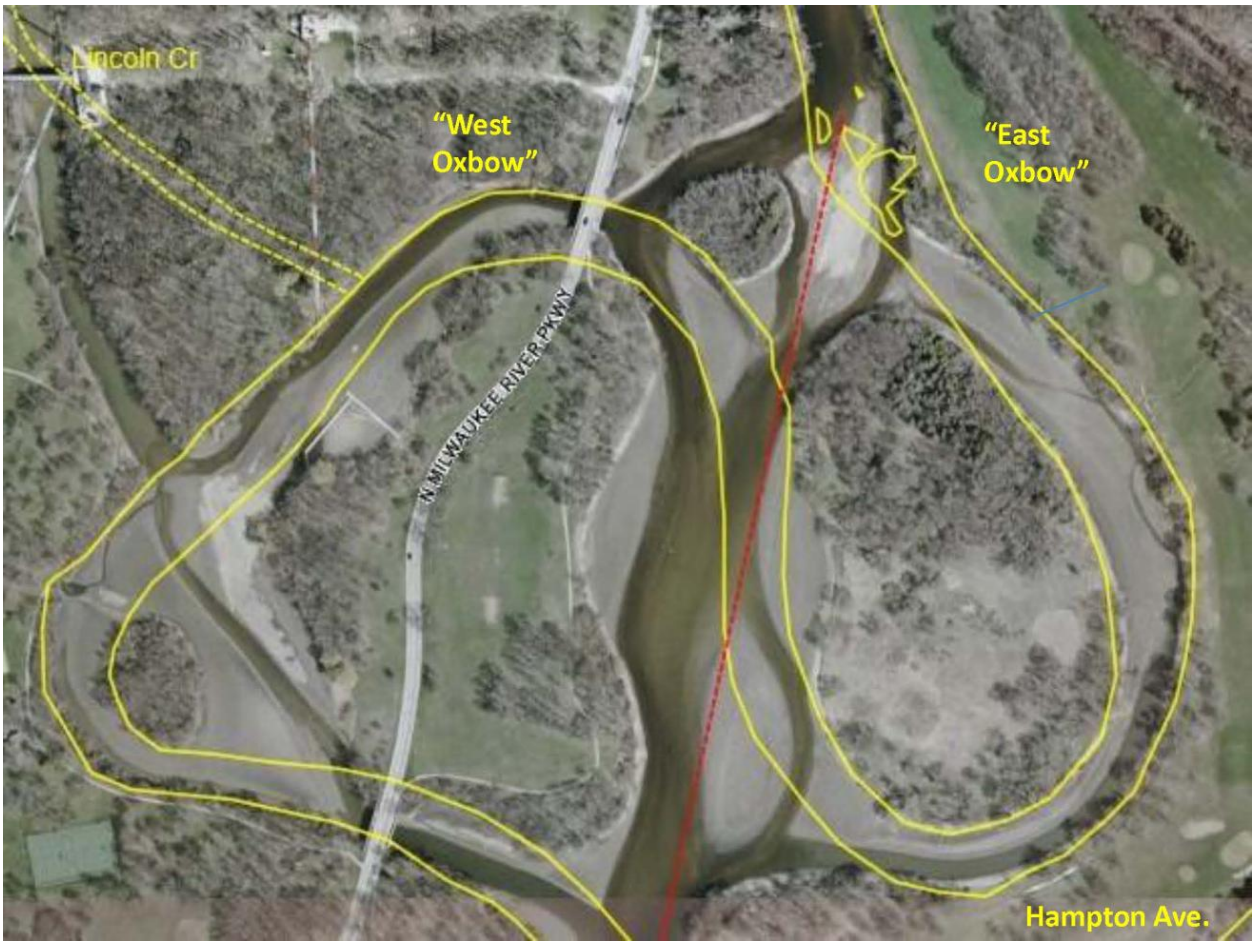


Figure 5. A 2005 aerial photograph of the Milwaukee River in Lincoln Park between Hampton Ave. and the upper confluence of the present day "east and west oxbows". The spring 2005 photograph was made during the annual drawdown of the Estabrook Impoundment and pre-dates the WDNR's 2008 ordered drawdown and removal of contaminated sediment between 2011 and 2015. The yellow lines are the 1937 natural river shorelines and meander that pre-dates excavation of the 0.6-mile long by 200-ft wide center-cut for mitigating the impact of flood flows and ice dams, and construction of the Estabrook Dam in 1940. The dashed red line is the approximate centerline of the excavated center-cut. Exposed and shallow water fine grained sediment deposited in the impoundment is evident as light gray shaded areas. Shoreline vegetation depicts the extent of the impoundment when the dam gates are closed and the impoundment is filled. Source: Milwaukee County Interactive GIS Mapping.

The accumulation of large volumes of sediment is not unique to the Estabrook Dam and impoundment. There are a number of impoundments in the Milwaukee River watershed that have completed sediment management surveys that estimate all or a portion of accumulated sediment volume (Table 3). These examples are actual data collected from this section of the Milwaukee River and by data collected from comparable rivers and dam removal projects. All of these impoundments would be a reasonable analog for predicting the future state of the Estabrook Impoundment as an efficient sediment trap. The former North Avenue Impoundment, located just downstream of the Estabrook Dam, is an especially appropriate analog as they have similar morphology, sediment loads, hydrology and hydraulics, and land uses. Although most are lacking long-term flow monitoring that could be used to complete a more comprehensive sediment trap efficiency model, I'm confident that if flow data were available the results would also predict low sediment trap efficiencies.

Table3. Summary of available accumulated sediment volume and thickness estimates for impoundments in the Milwaukee River Watershed.

Stream and Dam	Dam Removed	Spillway Hydraulic Height (feet)	Pond Surface Area (acre)	Pond Storage Volume (acre/feet)	Drainage Area (square miles)	Sediment Volume (cubic yards)	Sediment Thickness (feet)	Ref.
West Br. Milwaukee R. Campbellsport Dam	Yes	13	22	250	53	26,600	Avg. 2.6, 0.1 - 4.8	1
East Br. Milwaukee R. New Fane Dam	Yes	8	3	25	54	20,000		3
Milwaukee R. Woolen Mills Dam, West Bend	Yes	12	67	630	247	200,000 to 250,000	3 - 10	8, 9
Milwaukee R. Newburg Dam	Yes	5	7	54	264	62,900		3
Milwaukee R. Waubeka Dam	Yes	6	20	120	426	40,000		3
Milwaukee R. Bridge St. Dam (Grafton)	No	12	35	400	469	82,300	<1 - 6	2
Milwaukee R. Chair Factory Dam (Grafton)	Yes	9	6	40	470	5,000	0 - 7	3
Milwaukee R. Lime Kiln Dam (Grafton)	Yes	8	4	15	471	3,900	0 - 4.5	3
Cedar Cr. Schweitzer Dam (Jackson)	Yes	8	8	30	16	48,000	Avg. 3.5, 0 -9	3
Cedar Cr. Ruck Dam (Cedarburg)	No	10	4	27	122	7,700		4
Cedar Cr. Columbia Dam/Ruck Raceway (Cedarburg)	No	9	15	80	123	58,900		5
Cedar Cr. Wire & Nail Dam (Cedarburg)	No	20	2	27	124	12,400		5
Milwaukee R. Estabrook Dam (Glendale)	No	8	103	700	696	174,000	<1 – 9.5	6
Milwaukee R. North Ave. Dam (Milwaukee)	Yes	14	90	1,200	699	710,000	<1 - 12	7

1 Bonestroo, Inc., August 30, 2010. Campbellsport Millpond pre-dam removal sediment depths (ft)). Volume is a partial and conservative estimate based on seven cross-sections and 51 soundings to refusal along lower 1,000-feet of millpond and area of 280,000 square feet or 6.4 acres.

2 Bonestroo, Inc., 2011. Dredging Feasibility Study for the Bridge Street Dam Mill Pond, Village of Grafton. Evaluated costs and benefits for a limited dredging of 82,300 cubic yards of sediment from five areas in the 12-acre impoundment. No estimate for total volume of accumulated sediment.

3 Wisconsin DNR Environmental Assessments http://www.co.ozaukee.wi.us/1634/Lime-Kiln-Dam http://www.co.ozaukee.wi.us/1635/Newburg-Dam
4 Thomas H. Praeger, Stuart D. Messur, Richard P. DiFiore. Remediation of PCB-containing sediments using surface water diversion "dry excavation": a case study. Water Science and Technology 33 (6) 239-24. Partial estimate of accumulated sediment in the mill pond. The reported sediment volume is the volume of remediated sediment and does not include estimates of non-remediated sediment.
5 U.S. Environmental Protection Agency Proposed Plan for Cedar Creek Site, Cedarburg, Wisconsin. November 2015. Sediment volume estimates are for volumes requiring remediation. Total volume estimate of sediment deposited in impoundments not available. http://media.jrn.com/documents/cedarcreekplan.pdf
6 Wisconsin Department of Natural Resources http://dnr.wi.gov/topic/greatlakes/lincolnpark.html Sediment volume estimates for remediated sediment only.
7 Woodward and Clyde, Inc. 1995. North Avenue Dam Feasibility Study
8 Kanehl, P.D., Lyons, J., and Nelson, J.E. 1997. Changes in the Habitat and Fish Community of the Milwaukee River, Wisconsin, Following Removal of the Woolen Mills Dam. North American Journal of Fisheries Management 17:387-400, 1997.
9 City of West Bend, Department of Community Development, 1987.

Estabrook Dam Operational Plan

An environmental assessment is required to establish an Operation Plan for the Estabrook Dam, and includes an Operational Order, and an Inspection, Operation and Maintenance (IOM) plan. The plan is needed to address a number of issues including past deficiencies in responding to structural maintenance, the accumulation of debris along the spillway that may impact spillway flow capacity and structural integrity, potential to cause and prevent flooding and drainage damage, and environmental impacts associated with seasonal drawdowns.

The Operational Order will establish a formal water level for the dam and impounded pool. The order will evaluate maximum, minimum and normal water levels; run-of-the-river and seasonal drawdowns; release rates during normal and flood flow conditions. The order will be based on a review of the various social, economic and environmental impacts and benefits.

The IOM is required for large dams. Elements include a safety manual, protocol and schedules for structural inspections and maintenance including debris removal, and description of how the dam is staffed and operated for a range of flows (normal flows and flood flow conditions).

The original PSC approval for constructing the Estabrook Dam was for a full pool and run-of-the-river meaning that the gates would be closed year around and the impoundment filled, except during flood events. Over the last several decades the County has departed from this operating protocol by opening the gates in early-fall and closing the gates in late-spring despite the negative environmental impacts within the impoundment and the Milwaukee River downstream of the dam. Impacts associated with partial or complete seasonal impoundment drawdowns include:

- Scouring of polluted sediment and impacts to local and downstream water quality, fish and aquatic life habitats
- High flows and freeze/thaw cycles that contribute to erosion of river bed and banks
- Desiccation, freeze-out and increased predation of mussel beds

- Desiccation, freeze-out and erosion of aquatic plants and invertebrates
- Desiccation and freeze-out of herptile over wintering habitats
- De-watering of floodplain wetlands
- Loss of fish spawning substrate and juvenile refuge
- Fish stranding and fish kills by asphyxiation and poor fish year class recruitment
- Loss of aesthetics

There is no formal accounting as to why Milwaukee County has departed from the original year around pool full and run-of-the-river flow condition. Some previously stated reasons and my response include:

- *Allow "flushing" of accumulated sediment*. This is not an environmentally sound sediment management option. As an example, the accumulation and erosion of sediment and PCB entering and exiting the Estabrook Impoundment was studied and reported by the USGS in 1999 as part of a Cedar Creek and lower Milwaukee PCB mass balance study. During just a single drawdown event sampled on October 12, 1994 an estimated 206,000 pounds (103 tons) of sediment and 1.1 pounds of PCB was initially scoured from the impoundment when the gates were opened. The amount of sediments and pollutants flushed from the impoundment during the remainder of the drawdown period and higher spring flows was not sampled or quantified by the study.
- *Install and remove private piers*. Thousands of waterfront landowners in Wisconsin on rivers, impoundments, and natural lakes manage to install and remove their piers without manipulating water levels. Granted it would be easier, but given the impacts of the drawdown it is not justified.
- *Inspection and repair of eroded private shorelines*. I completed a review of the DNR Chapter 30 permit database over the last 38-years. Six permits were approved for private shoreline rip rap since 1977, and none since year-2000. All were located between Bender Road and Silver Spring Drive. Engineered and bioengineered shoreline protection practices would not require lowering of the impoundment for inspection, design and installation. While canoeing this reach 3-years ago, I did observe a number of private shorelines with "homemade" and poorly engineered stream bank protected shorelines, and some shorelines were experiencing some degree of bank failure.
- *Avoid the creation of ice dams*. Drawdown of the Estabrook Impoundment is not effective at preventing the formation of ice dams, in particular the river reach upstream of the "center cut" and oxbows. Early planners for the removal of the rock outcrop and excavation of the center cut through Lincoln Park recognized the project would not eliminate ice dams: *"A condition favorable to the formation of ice jams exists between Bender Road and the Silver Spring Road. The situation is shown on Map 2. At Station 180 of the City's Engineer's Survey, about 1,000 feet south of Bender Road, the river is about 130 feet wide. At a point about 500 feet down stream, Station 173, the channel narrows down to a low water width of about 70 feet. This bottleneck continues for about 300 feet, and from this point the width of the low water channel is 100 feet or less for a distance of more than 1,000 feet. Between Station 151 and 143, the river makes a sharp turn to the right ("big bend") through approximately 130 degrees, with a radius around the inner side of the curve of approximately 200 feet. The low water channel at the beginning of the curve is approximately 160 foot in width, but just below the turn, the channel narrows to a width of about 70 feet. A concrete wall has been built on the west side of the river, at the narrowest point, apparently to keep the bank from washing away." "The combination of sharp*

turns, together with the narrow channel, is conducive to the formation of ice jams when weather conditions are favorable. Such jams can easily dam the river, and cause flooding of the low banks even when the river is at a moderate stage", (Wisconsin Planning Board, 1940). Both general types of ice jams, freeze up and break up ice jams, form as a result of extreme cold and accumulate at obstructions to flow including river bends, confluence of large contributing tributaries, changes in channel slope, channel narrowing, bridges and dams. As observed during the last two years of cold weather, river reaches historically prone to ice and debris jams continued to experience them. Potential ice forming reaches include the "big bend", narrow reaches (between Silver Spring and Bender Rd. and between Hampton Ave. and Port Washington Rd.), and reaches that exhibit significant changes in river bed slope (at Silver Spring, the upper confluence of the river and "oxbows", and the fixed crest spillway). Despite the Estabrook Impoundment being drawn down since 2008 a large ice dam formed upstream of Silver Spring Drive during the winter of 2014 and a smaller ice dam as recently as December 2015. Considering the meteorological, morphological and structural features most responsible for the formation of ice dams under run-of-the- river conditions, complete or partial winter drawdowns will not reduce the formation of ice and debris jams.

- *Protect spillway and protect dam gates from ice and debris.* Reconstruction of the "dragon's teeth" is intended to deflect ice and debris. Ice freezing onto the gates can be managed by the addition of aerators, heaters, or both. The original design for the dam was to include heaters for each gate. No one at the County can verify if they were ever installed.
- *Avoid spring flood and drainage liabilit*y. Simply stated, the County must take responsibility for providing long-term funding for technical upgrades, and for hiring and training personnel to manage debris, monitor river flows and operate dam gates in a timely manner to avoid flooding and drainage damage, and environmental impacts.

The County has been delinquent in removing large debris, especially from the fixed crest spillway. Debris stored behind the spillways and dragon's teeth can reduce flood flow capacity, and prevent the operation of the gates. Lack of funding has been a problem. The County has never responded to directives to remove debris from behind the fixed crest spillway, and instead relied on flood events to pass the debris downstream, like the 2010 flood. Removal can be difficult and expensive, and only recently was the County able to obtain an access agreement to the spillway via private property (Figures 6 and 7).

Figure 6. 2005 aerial photograph showing debris field accumulated behind the Estabrook Dam “serpentine” fixed crest spillway (lower) and the “dragons teeth” array installed to protect the gated section of the spillway (upper) from ice and debris. Comingled debris and contaminated sediment up to 5-feet thick is evident as light brown material inside the yellow boundary. Debris continued to accumulate behind the spillway until a 2010 flood eroded the debris and a portion of the comingled contaminated sediment downstream. Source: Milwaukee County Interactive GIS Mapping website.

Figure 7. May 26, 2009 photo looking downstream along debris field deposited behind the Estabrook Dam's fixed crest spillway. The debris can impact the flood flow capacity and structural integrity of the spillways Flashboards and supports bounded by the yellow line were damaged by the debris and had to be replaced. Debris continued to accumulate behind the spillway until a 2010 flood eroded the debris and a portion of the comingled contaminated sediment downstream. Source: Will Wawrzyn

"Stagnant" Water and Water Quality

Mr. Holmes provided estimates of the Estabrook Impoundments residence time and because of its short residence time even during summer base-flow periods; the impoundment would not experience "stagnant" conditions. The use of the word "stagnant" is a vague term. Rather it is more informative from a management perspective to describe the type of "nuisance" conditions that the river may experience in an impounded state. A "stagnant" condition, as a function of the impoundment's water residence time, is not the only determinant for developing nuisance conditions.

In simple terms, the residence time calculations for the Estabrook Impoundment is the time it takes for the impoundment's entire volume of water and substances suspended or in solution to be replaced by the Milwaukee River. There are other significant sources of replacement flow to this area, in particular Lincoln Creek and to lesser extent local storm sewers. Hydraulic residence time is what controls the concentrations of substances (e.g., nutrients) entering the impoundment and is important for predicting

what the water quality response might be. As an example, knowledge about the residence time, nutrient concentration and growth rate for suspended algae may be useful in determining if suspended algae (phytoplankton) have sufficient time to grow and reproduce to create nuisance algae blooms.

The morphology of the Estabrook Impoundment is diverse enough such that not all areas have their water thoroughly mixed and replaced at the same rate, especially during the warm water summer growing months when the Milwaukee River and other contributing flows are lowest and last longer periods of time. These areas may include the "east and west oxbows", the lower reaches of Lincoln Creek and confluence with the Milwaukee River, the Blatz Pavilion Lagoon, the gated section of the dam's spillway, the subtle indentations of the center-cut located between the two islands and oxbows, and the wide monotonous reach between Hampton Avenue and the dam where the flow is concentrated along the right bank (Figures 1 and 4). Longer residence time in these areas during the low-flow and warm water summer months, high nutrient levels in the water column, and sediment will contribute to produce benthic and planktonic algae blooms. The Estabrook Impoundment would be classified as a eutrophic pond such that the conditions would be suitable for the development of nuisance algae. Some algae produce toxins, and when present in large amounts, can be a health concern for humans, pets and wildlife.

Residence time will not be the deciding factor that contributes to nuisance rooted aquatic plant growth. The Estabrook Impoundment will continue to accumulate nutrient and organically rich sediment, and with sufficient sunlight penetrating all water depths throughout the impoundment, conditions will be ideal habitat for benthic algae and rooted aquatic plant production. These conditions were present in the former North Avenue impoundment and other impoundments in the Milwaukee River watershed and were responsible for nuisance biomass of rooted aquatic plants, in particular non-native Eurasian watermilfoil and Curly-leaf pondweed which unlike many native plant species, are tolerant of degraded habitat. The Estabrook Impoundment will not be immune to developing similar nuisance conditions (Figure 8 and 9).

Figure 8.Photo of the Cedar Creek, Schweitzer impoundment in Washington County, WI, September, 2001 showing nuisance growth of non-native Eurasian watermilfoil and blue-green algae (green surface "scum") prior to removing the dam in 2003. Source: Will Wawrzyn

Following the large $49 million investment spent on remediating contaminated sediments, the quality and quantity of remaining sediment may be as good and as small as it will ever be. While historic and future industrial discharges that contributed to the massive contaminated sediment problem have been abated through regulations, PAHs and heavy metals are ubiquitous with urban runoff. Absent the political will to invest heavily in controlling urban nonpoint sources of pollution, one should expect that polluted sediment will accumulate in the Estabrook Impoundment again, albeit at lower amounts than the obscene concentrations that were just removed. The health effects of repeated human exposure to low levels of PAHs may not be known. However, exposure of PAHs at low levels can be toxic to aquatic life and wildlife. PAH toxicity is magnified when exposed to the Sun's ultraviolet light and sunlight can penetrate all the shallow depths of the impoundment. This is problematic for wildlife, especially sensitive reptiles and amphibians, which spend a fair amount of time in water and floodplain habitats. The potential chronic and acute affects to aquatic life and wildlife impact entire life cycles and generations. PAHs are often associated with a toxic "soup" that includes other organic contaminants such as the hydrocarbon-based NAPLs described earlier.

Fish Habitat and Fish Community

In his most recent article dated January 17, 2016, Mr. Holmes stated that, *"Attributing improvements in fish habitat to dam removal (beyond those that would result from repair of the dam in conjunction with construction of a fish passage) also appears to be a general assumption not supported by actual data."* More succinctly, Mr. Holmes is suggesting that the quality and quantity afforded by dam removal is comparable to the quality and quantity of fish habitat in the Estabrook Impoundment by adding fish passage at the dam. The purpose of a fish passage facility is to pass migratory fish past a barrier; to enable fish to access suitable habitat for reproduction and growth; and contribute to a diverse and self-sustaining fishery for the Milwaukee River, Milwaukee Estuary and Lake Michigan. The addition of fish passage will have no bearing on fish habitat in the Estabrook Impoundment. It will not affect habitat aside from the footprint it is constructed on. **A fishway will not affect the most important issue impacting fish habitat and the fishery in the impoundment, that being the quality and quantity of sediment and the rate by which it accumulates. If the dam is repaired and the impoundment is restored to a full pool without the benefit of full or partial seasonal drawdowns, the ecosystem will swing toward a eutrophic and sediment laden pond.** The rate and locations at which abiotic and biotic factors respond will be different, but it will most definitely occur.

The quality and quantity of sediment has a direct and indirect affect on fish and aquatic life habitat. Nutrient and organically rich sediment can produce nuisance biomass of plant material that impact dissolved oxygen levels through plant respiration and their decomposition will contribute to sediment oxygen demand. Eutrophic and turbid water quality conditions benefit tolerant non-native aquatic plants species such as Eurasian watermilfoil at the expense of native species that are better utilized for food and cover by fish, other aquatic life and wildlife. The accumulation of impounded sediment enriched by substances such as heavy metals and PAHs from urban runoff can have acute and chronic impacts on fish and aquatic life at all life stages and the impacts can extend over generations. The accumulation of silty-clay sediment, potentially toxic compounds, nutrients and organic matter from benthic algae and decomposing plant material create very inhospitable habitat for fish and other aquatic life.

Most of the approximate 60 native fish species present in the Milwaukee River and its tributaries evolved and are specialized for all or a portion of their life cycles (spawning/reproduction, development, feeding and growth) in flowing river or stream (lotic), and floodplain wetland habitats. The value of flowing rivers and streams with clean and coarse substrates and connected floodplain wetlands as critical fish habitat cannot be over stated. Among the 60 native species in the Milwaukee River watershed:

- Most require clean and coarse substrate for spawning and successful embryonic development (lithophilic) (e.g., walleye, most minnows and shiners).
- Most are insectivores. Their diets are primarily aquatic insects that require clean and coarse substrate (e.g., sunfish species excluding predator smallmouth and largemouth bass).
- Many are benthivores. They spend all or most of their lives in direct contact with the substrate (e.g., all darter and Redhorse species, channel catfish).
- Many are intolerant of degraded water quality and sediment (e.g., smallmouth bass).

- Many require wetlands and aquatic plant vegetation for spawning (phytophils) and nursery habitats (e.g., northern pike and some shiners).

Some potamodromous species mature as adults in Lake Michigan or estuaries and must return to rivers or wetlands to reproduce. Barriers to river spawning and nursery habitats, such as dams, have contributed to the near-extinction of Lake sturgeon in the Great Lakes. Destruction of wetlands and barriers to wetland spawning habitat has greatly reduced once abundant northern pike populations in the Milwaukee Estuary.

By amendment, Supervisor Lipscomb added $750,000 to the County's 2016 budget to construct fish passage at the Estabrook Dam. While including funds for an engineered fish passage facility at the Estabrook Dam may have been done by the Milwaukee County Board with good intentions, an engineered fish passage would only partially address one of the many negative environmental, and none of the remaining environmental, flooding and drainage impacts, and high costs for repairing and operating the dam. If a fishway can be designed and constructed to not increase flooding, important questions remain regarding its value once fish are passed to the impoundment. The current strategy for fish management is to pass fish from Lake Michigan, the Estuary and lower reaches of the Milwaukee River to where suitable wetland and riverine spawning and nursery habitats exist upstream. As the impoundment fills with fine sediment and inundates floodplain wetlands, habitat suitable for preferred species such as walleye, northern pike, smallmouth bass and lake sturgeon will be poor, which means less fish will successfully reproduce and recruitment to local impoundment populations will be low.

Habitat quality affects the diversity and abundance of the fish community. Inversely, the presence and abundance of a single species can change the dynamics of a river ecosystem, including its habitat. There may be no better demonstration of a fish species's negative impact on aquatic ecosystems than the non-native common carp. As the impoundment fills with fine sediment, habitat suitable for preferred native species will be poor, which means less native fish will successfully reproduce and recruitment to local populations will be low. These preferred native species will likely continue upstream in search of more suitable habitats. Undesirable species such as common carp will do very well in the Estabrook Impoundment. No other species, native or non-native, is so well adapted to degraded habitat, and modifying habitat to their benefit and at the expense of native species. Preferred spawning habitat is slack backwater areas with vegetation and incubating carp eggs can tolerate silty sediment. Carp spawning success is reduced in flowing water with coarse substrates. Carp tolerate high water temperatures and turbidity, and low dissolved oxygen levels. As omnivores, carp consume a wide range of food types and can adapt to changing food supplies caused by environmental degradation. As benthic (bottom) feeders, they have adapted to feeding on small invertebrates tolerant of fine silty substrate and aquatic vegetation. As they feed, they re-suspend nutrient-rich silty sediment and uproot aquatic vegetation and by doing so increase turbidity. Turbid water is not tolerated by most native aquatic plants, and as a result, native plants populations decrease and non-native plants tolerant of turbidity such as Eurasian watermilfoil and benthic algae flourish. Turbid water limits site feeding by top predators (e.g., northern pike and bass) that might otherwise feed on younger carp before they reach spawning age. Absent natural controls, carp populations can proliferate in just a few years. A young (age-4) mature

female carp can produce over 50,000 eggs and a large age-16 female was reported to produce over 2 million eggs. Successful spawning and recruitment of carp will infect more than just the Estabrook Impoundment as offspring will migrate to other reaches of the Milwaukee River and its tributaries, the Milwaukee Estuary and Lake Michigan. Prior to removal of the Milwaukee River's North Avenue Impoundment, the feasibility study correctly predicted a decline in carp populations and an increase in smallmouth bass populations. These predictions were consistent with those observed following the removal of the Milwaukee River Woolen Mill Dam at West Bend.

Native fish in the Milwaukee River and its tributaries evolved and are specialized for all or a portion of their life cycles (spawning/reproduction, development, feeding and growth) in flowing river or stream (lotic) habitats. The Index of Biotic Integrity (IBI), developed by Lyons (1992), is a bioassessment method that uses data from the fish community to assess environmental quality. The Wisconsin IBI for warm water rivers and streams includes 12 metrics that determines how a fish community's function (e.g., spawning behavior and spawning habitat) and trophic attributes (e.g., feeding and diet) respond to environmental degradation. Many of the fish community metrics are directly and indirectly affected by water and sediment quality. The 12 metrics include the numbers of:

- Native species. Excludes non-natives species such as common carp and salmon from Lake Michigan. Number of native species decrease with environmental degradation.
- Darter species. As benthivores they live on the bottom of the stream and are intolerant of polluted and fine textured substrate. Numbers decrease with degradation.
- Catostomid species. Includes suckers and Redhorse species. As benthivores they are dependent on clean, coarse substrate for food and spawning, and use pool and run habitats. Number decrease with degradation.
- Centrarchid species. Members of sunfish family (e.g., bluegill) that prefer pool habitat.
- Species intolerant of degraded habitat. Species intolerant of degraded water and sediment quality. Numbers decrease with degradation.

And the Percentage of:

- Individuals tolerant of degraded habitat. Numbers increase with environmental degradation. (e.g., tolerant of turbidity and sedimentation such as common carp and white sucker). Percentage increase with degradation.
- Omnivores. Opportunistic for limited food sources and diet of plant, detritus and animal. (e.g., common carp). Percentage increase with degradation.
- Insectivores. Diet of terrestrial and aquatic insects found predominately on clean, coarse substrates. Percentage decrease with degradation.
- Top predators. Primarily diet of fish (e.g., smallmouth bass and northern pike). Percentage decrease with degradation.
- Simple lithophilic spawners. Species that spawn over clean, coarse gravel and larger substrate and do not build a nest or provide parental care. Sensitive to sedimentation. Percentage decrease with degradation.
    - The combined catch per unit effort (CPUE) of all individuals except tolerant species. CPUE decrease with degradation.

- The percentage of individuals with deformities or disease. Response to toxic water and sediment quality. Percentage increase with degradation.

Mr. Holmes cites a DNR report for surveys completed along the lower reaches of the Milwaukee River between 1996 and 2001 (Hirethota et al., 2005). He is partly correct when he states that the results are difficult to draw conclusions from due to different sampling frequencies (years), effort and equipment. The difficulty lies with making comparisons beyond gross comparisons (e.g., number of fish species and catch per unit effort) between sample sights (e.g., Estabrook Impoundment versus Milwaukee River at Brown Deer Road). However, the study objectives did allow for reaching conclusions and insights to fish communities with regards to individual sites over time.

Mr. Holmes stated, *"One of the findings of the WDNR study that somewhat surprised me was that index of biotic integrity* (IBI) *(a measure of ecological health) was characterized as excellent for both the section of the Milwaukee River in Kletzsch Park that is immediately upstream from the Estabrook Dam impoundment, and the section near Capitol Dr. that lies approximately one-half mile downstream of the impoundment. Thirty-two species of fish were observed in the Kletzsch Park segment of the River in 1996-2001. While the Estabrook Dam impoundment contained lesser numbers of fish and fish species, on several measures, it appeared to be comparable to the free-flowing segment of the Milwaukee River near Brown Deer Road." (emphasis added)*.

Mr. Holmes was surprised at the "good" to "excellent" IBI results for the Milwaukee River reaches at Kletzsch Park and Capitol Drive stations. To be sure, I was not surprised since these sample reaches are beyond the direct influence of the Estabrook Impoundment. The IBI is a measure of river (free-flowing) environmental quality. Both sample reaches provide good river habitat and the fish community has responded to those features. While the Estabrook Impoundment did not have a direct affect on the two free-flowing river sample reaches, the operation of the dam's discharge or lack of it has caused negative impacts to the fish community. I personally observed hundreds of stranded Redhorse spp. immediately downstream of the Estabrook Dam as a result of a sudden closure of the dam gates. No mortalities were observed but the fish were clearly stressed for oxygen as they were observed to be "piping" at the surface for atmospheric oxygen. In the DNR report cited by Mr. Holmes, the authors stated, *"Operation of the Estabrook Dam, upstream of the Capitol Drive station, appears to have significant impacts on the year-class strength of smallmouth bass and obstructs the movement of fish further upstream. In this study, both sharp increase and decrease in water flow attributable to current Estabrook Dam operations, appears to have caused negative impacts to several year-classes of smallmouth bass. In order to maximize the benefits of the dam removal and habitat enhancements in the lower Milwaukee River, the Estabrook dam and its operation will need to be addressed."*

Mr. Holmes comparison of Estabrook Impoundment's number of fish species and total numbers of fish to that of the Milwaukee River at Brown Deer Road may not be relevant. Fish populations from year to year can be highly variable as a result of natural environmental variability, in particular annual variations in flows and water temperature. The Estabrook Impoundment was sampled 2-years and 4-years after the Brown Deer sample station.

More significant was the reported catch per unit effort (total catch/sample length) at the free-flowing Kletzsch station and Capitol Drive sample station (former North Avenue Impoundment), compared to the Estabrook Impoundment station during the same sample years of 2000 and 2001. The catch per unit effort for the Kletzsch and Capitol Drive stations were 12 times greater in year-2000 and 66 times greater in year-2001 than the Estabrook Impoundment station. The Estabrook Impoundment station had 11 and 8 fewer species, respectively compared to the Capitol Drive and Kletzsch stations, which is appreciable.

The Estabrook Impoundment fish community is responding to the impacts of sedimentation and the operation of the dam and water levels, as a quasi-free flowing river ecosystem for seven months of the year (October-May) when the gates are opened and the impoundment is drained and partially scoured of sediment; and an impounded ecosystem for the remainder of the year (June-September) when the gates are closed and the pond is accumulating sediment. The decade's long seasonal drawdowns affects the impoundment's resident fish other aquatic life and wildlife communities in a number of ways. The drawdowns provide an insight into the benefits of sediment transport and the evolution towards a free-flowing river channel plan form of riffle, run and pool habitats, and coarse spawning substrate along the 0.6-mile headwater reach located between the "big bend" and Bender Road. Consistent with these features, most of the Estabrook Impoundment catches of smallmouth bass, white sucker and four species of Redhorse spp. that dominated the catch were from this upstream reach, and this is not necessarily reflective of the fish community and poor habitat that dominates the 103-acre impoundment.

Many of the native fish species found in the Milwaukee River evolved and are specialized for all or a portion of their life cycles (spawning/reproduction, development, feeding and growth) in flowing river or stream (lotic) habitats. Spawning habitat necessary for self-sustaining populations in the Estabrook Impoundment is limited to the furthest upstream reaches. Recruitment by many adult native fish species to the Estabrook Impoundment is primarily as adults or immature juveniles from Milwaukee River populations migrating upstream through the opened dam gates and from populations emigrating from the river upstream of the dam and impoundment.

Mr. Holmes stated that, *"Improvements in fish habitat and recreational fishing are one of the most important benefits cited in the EA and by Riverkeeper as a benefit from removing the dam, but the previous survey data as well as the anecdotal reports suggest these improvements may be limited, and almost certainly not analogous to improvements that occurred following removal of the North Avenue Dam" (emphasis added)*. Mr. Holmes did not provide any reasons as to why fish habitat and fish population improvements observed following removal of the North Avenue Dam and impoundment (or other dams and impoundments in the watershed) are not appropriate analogs for predicting similar responses to removal of the Estabrook Dam and its impoundment. In my opinion, the improvements in Milwaukee River habitat and the fish community following removal of the North Avenue Dam in 1997, and other dam removals in the Milwaukee River watershed, do provide reasonable analogs for the Estabrook Impoundment should the dam be removed. The most common and important impact is that all of these impoundments, including the Estabrook Impoundment, were effective at accumulating large volumes of silty sediment. Given the County's change in policy for repairing the Estabrook Dam and

restoring it's impoundment, a more urgent and relevant argument is that the degraded quality of the Milwaukee River prior to removal of the North Avenue Dam and impoundment is a reasonable analog for predicting the degraded future state of the Estabrook Impoundment if the dam is repaired. This is especially true if the County will no longer have the benefit of managing accumulated sediment by continuing to open the dam gates every year and flush sediments and debris downstream.

Both the Estabrook and former North Avenue impoundments have similar morphology and respond to the same sources and quality sediment, and flow regimes. Both experienced the legacy of polluted sediment from point and non-point sources of pollution, and while the sources of PCBs no longer exist, the Estabrook Impoundment will continue to accumulate polluted sediment from stormwater runoff including nutrients (nitrogen and phosphorus) from rural and urban sources, and potentially toxic heavy metals and polynuclear aromatic hydrocarbons (PAHs) from urban runoff. Sediment accumulation in the 150-year old North Avenue impoundment was estimated at 710,000 cubic yards with a maximum sediment thickness of 12-feet. Without accounting for the compaction of cohesive clay and fine silt particles, that amounts to a sedimentation rate of 1-inch per year over the 150-year life of the North Avenue Dam and impoundment. This rate and thickness of accumulated sediment may not impact some uses in the short term (e.g., navigation), but the rate and thickness of accumulated sediment will begin to impact water quality, fish and aquatic life habitat and their populations in just a few years. I am not aware of any records that account for drawdowns but personally observed partial drawdowns in 1971 and 1985. Water depths varied from less than 1-foot over half of the 90-acre impoundment, to a maximum of 9-feet along a narrow thalweg that meandered through the impoundment. Shallow areas were overgrown with nuisance amounts of submerged aquatic plants and filamentous algae. An investigation of a massive fish kill on August 1990 found 1,000's of dead fish. Eight species were identified, six of which are classified as tolerant to environmental degradation. Greater than 90% of the fish and biomass were non-native common carp and tolerant native white sucker. Common carp, white sucker and goldfish were represented by a wide range of year classes indicating ideal conditions for reproduction and survival, and top predators were absent (e.g., northern pike). Dissolved oxygen levels in the shallow and extensive respiring Eurasian watermilfoil plant beds were less than 0.5 part per million, well below the state water quality standard of 5 parts per million for protection of fish and aquatic life. Sediment was described as "effervescent" from methane gas released from the sediment, which also contributes to oxygen depletion. Physical habitat, sediment and water quality was very degraded. Over the years leading up to the removal of the North Avenue Dam in 1997, recreational fishing was non-existent. Similarly, recreational boating was almost non-existent except for the Milwaukee Rowing Club which had operated out of the Village of Shorewood's Hubbard Park for years until they relocated to the Milwaukee River in downtown Milwaukee just prior to removing the dam (Figure 9).

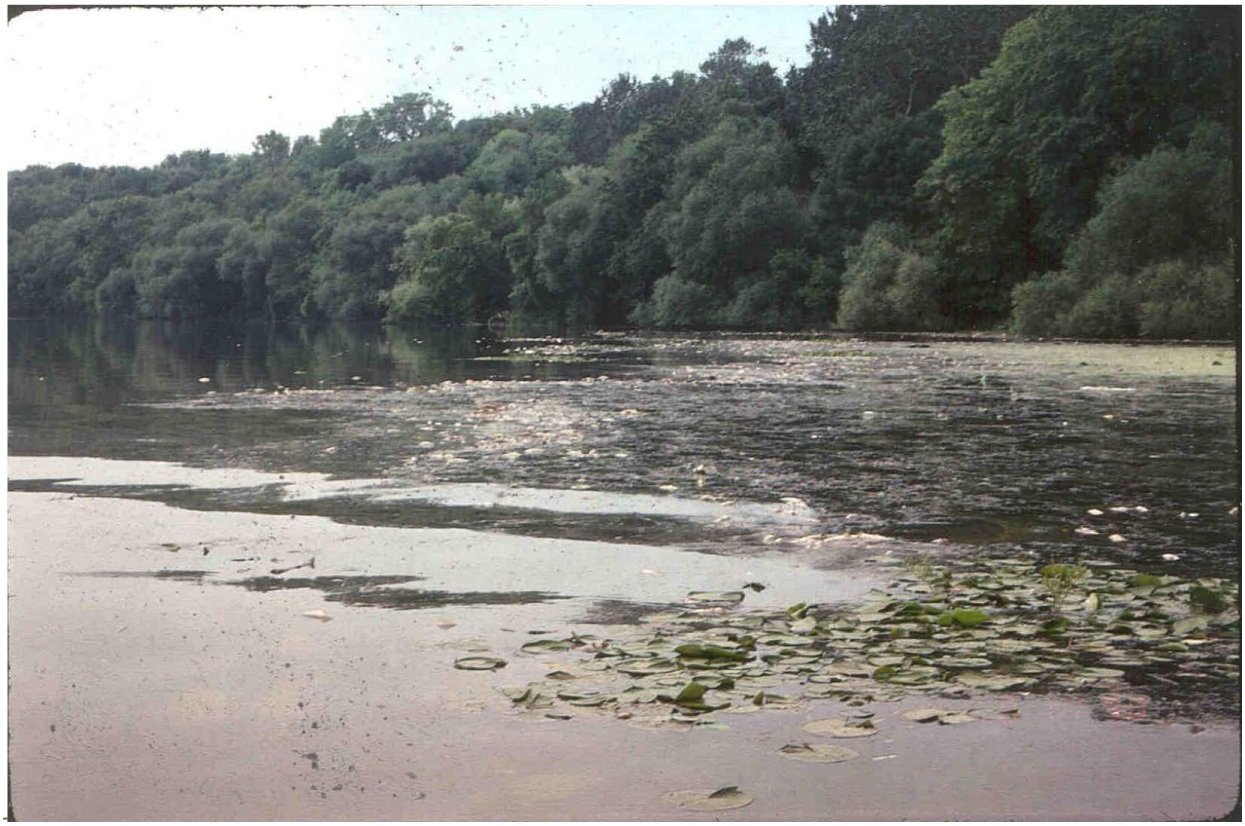


Figure 9. Photo from August 1990 fish kill investigation on the Milwaukee River North Avenue impoundment near Locust Street. Source: Will Wawrzyn

Following removal of the North Avenue Dam, improvements in the riverine habitat increased native fish species diversity several fold in the formerly impounded area from six native species in 1990 to 35 native species in 2012. Smallmouth bass became and remain the most abundant game species with frequent strong year-classes. Additional native game fish included walleye, northern pike, channel catfish, largemouth bass and rock bass. The overall environmental quality measured by the Index of Biotic Integrity (IBI) increased from 20 ("poor") in 1996 to 80 ("excellent") in 2000-2001, and ranges from "good" to "excellent" through 2012. Concurrent with the improved diversity and relative abundance of native fishes, there has been a dramatic decrease in common carp populations which once comprised over 90% of the numbers of fish and total biomass. Removal of the North Avenue Dam has created a popular recreational fishery that includes native fishes, as well as Lake Michigan fall and spring runs rainbow trout, and fall runs of brown trout, coho and Chinook salmon. These Lake Michigan run of trout and salmon provide a recreational fishery that extends along the Milwaukee River and principal tributaries 32-miles upstream of Lake Michigan to the Village of Grafton in Ozaukee County.

Similar improvements in fish habitat and fish communities Index of Biotic Integrity (IBI), recreational sport fishery, and decrease in non-native common carp populations have been noted at dam removal projects in the Milwaukee River watershed. There are no reasons not to expect comparable improvements in the Milwaukee River habitat and the fish community should the Estabrook Dam be removed.

Recreational Uses: Will alternatives to dam repair eliminate unique recreational use opportunities for the impoundment?

Mr. Holmes and proponents for repairing the dam argue that removal of the dam would result in significant impacts on unique recreational values within the impoundment, and specifically mentions lost opportunities for recreational power boating, kayaking and other paddle sports, ice skating and swimming. In my opinion, repairing the dam to create a "natural lake" will not provide any unique or additional recreational opportunities that all County residents would be able to participate in.

There are no adequate public boat launch and trailer parking facilities along the impoundment that would allow all County residents an opportunity to participate in power boat or powered personal watercraft (e.g., jet skis) recreation. Those opportunities are generally available to river property owners that typically launch and retrieve their deep drafting power boats once during the boating season. Unbeknownst to most boaters, there is a public launch located at the end of Apple Blossom Lane in the City of Glendale. However, the launch is in fair condition at best and is not always maintained. Vehicle and trailer parking is very limited along the residential street.

If the County chose to adopt a safe boating ordinance that is consistent with the state boating safety laws, power boat speeds would be limited to slow no wake within 100-feet of a shoreline, and within 200-feet of a shoreline for powered personal watercraft (PWC). These rules also have the benefit of reducing waves breaking on the shoreline that cause erosion, most of it along publically owned shoreline. By my estimates, power boats would be limited to wake speeds for a 1-mile and just 34-acres between the dam and the upper confluence of the east and west “oxbows”, and PWC would be limited to just 0.2-miles and 9-acres. Given these limited areas, encouraging more *public* power boat access and operation would only cause congestion and compromise safety. This bolsters the public perception that the dam is being repaired to create an impoundment for a small number of private landowners with power boats.

The Milwaukee River will continue to be boatable should the dam be removed; just not by deep drafting power boats. Recreational boating by paddle boats such as kayak and canoe would always be possible. **So the question remains, given the cost difference of $4.5 million between repairs to the dam with fish passage ($6.2 million) versus dam removal ($1.7 million), should Milwaukee County taxpayers subsidize the few riparian landowners who wish to operate deep drafting power boats on a limited portion of the impoundment for less than six months out of the year?** Even though all 156 riparian properties with residence along the impoundment may not operate and maintain power boats or support repairing the dam, but assuming they did, the $4.3 million dollar cost difference for repairing the dam to support power boating amounts to a $27,564 Milwaukee County subsidy to each riparian owner for that unique use.

Dam repair proponents are correct in stating that the dam and resulting impoundment was constructed, in part, to re-create swimming opportunities lost following removal of the rock outcrop and that the swimming beaches were eventually abandoned because of poor water quality. All of the historic beaches

along the Milwaukee River at Lincoln and Estabrook Parks were present when the river was free-flowing and prior to construction of the Estabrook Dam and impoundment (Figure 10).

Figure 10. Looking northwest along the free-flowing Milwaukee River meander prior to excavating the center cut and construction of the Estabrook Dam. 1930's beach is located along lower right corner of frame and was eventually abandoned due to degraded water quality. As a result of the center cut, the beach would have been located in the present day "east oxbow" which has filled in with sediment. Photo and text modified from UrbanMilwaukee.com, February 16, 2016.

Public beaches and private swimming schools were operated along the former North Avenue Dam and its impoundment and eventually abandoned because of poor water quality and, I might add, filling in by deep "mucky" sediment (Figure 11).

Figure 11.Looking downstream along the Milwaukee River from the Locust Street Bridge following drawdown of the former North Avenue impoundment in December 1990. Lower right area of exposed sediment and emergent vegetation was the site of the former swimming beach and school at Gordon Park in Milwaukee's Riverwest neighborhood that featured water depths of 5-ft prior to filling in with sediment (see Figure 6). Over 700,000 cubic yards of sediment up to 12-feet deep were deposited in the 90-acre impoundment over its 150-year existence. Partial impoundment drawdowns occurred in 1970 and 1985. Source: Will Wawrzyn

He is also correct in saying that billions of dollars have been spent abating water pollution and making waters "fishable and swimmable". Those investments and accomplishments to date are impressive, but unfortunately absent a similar financial and political investment to abate stormwater and leaking sanitary sewers, we are decades away from meeting water quality standards protective for full body contact.

As a group, fecal coliform bacteria are present in the intestinal tract of warm-blooded animals. Although fecal coliform bacteria are not harmful, their presence indicates that other pathogenic organisms may be present in the water. Fecal coliform are a relatively quick and inexpensive test and are used as an indicator of water quality.

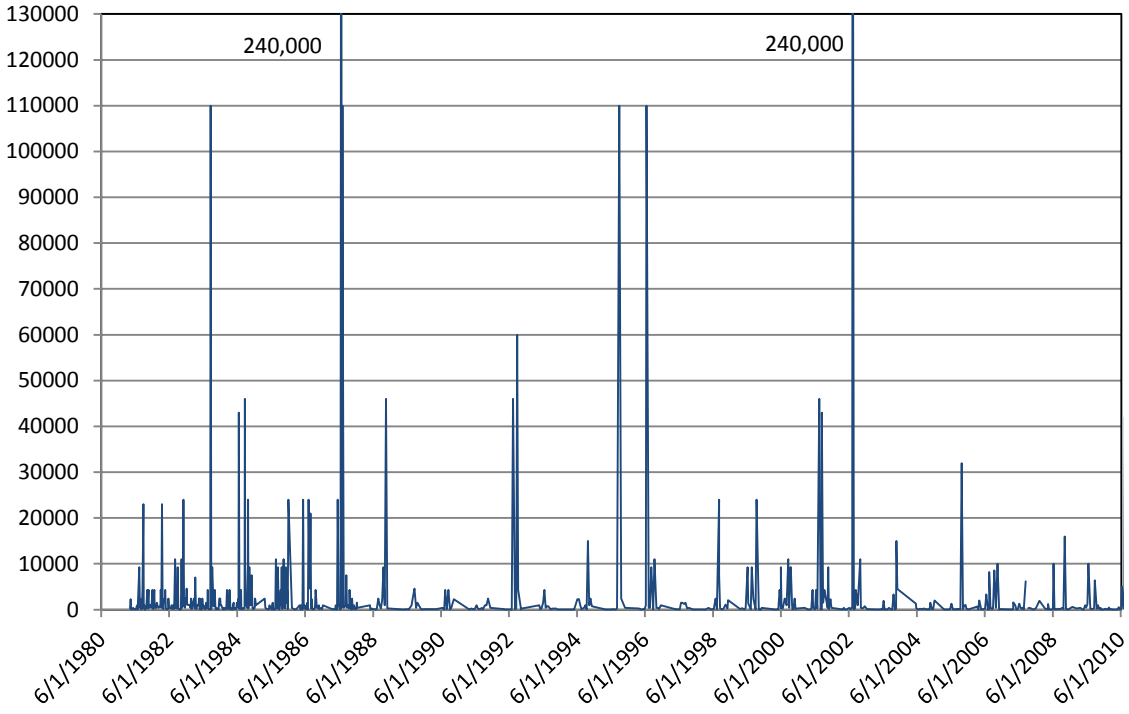
The state established a full body contact criteria using fecal coliform criteria and may be considering adopting a recreational use standard and test that is more indicative of human sourced bacteria. Fecal coliform bacteria levels can be very elevated in the Milwaukee River Estabrook Impoundment, especially following precipitation and runoff events (Figure 12).

The US EPA is recommending a beach action value of 235 cfu (colony forming units) per100 ml for swimming beaches using the bacteria *Escherichia coli*, or *E. coli*. Like fecal coliform bacteria, *E. coli*

bacteria are also present in the intestinal tract of warm-blooded animals. While most strains of *E. coli* are harmless, several rare but virulent strains of *E. coli* bacteria can cause serious illness. *E. coli* were present in moderate to high levels in Underwood Creek, Honey Creek, the Kinnickinnic River and Lincoln Creek near its confluence with the Milwaukee River's Estabrook Impoundment (MMSD, 2014) (Figure 13). The recreational use standard for most rivers is 200 mpn (most probable number) per 100 ml of fecal coliform (does not distinguish between source of coliform—from humans or wildlife), and MMSD data also show that most of our local rivers greatly exceed that number currently (Figure 12 shows data for the Milwaukee River at Port Washington Rd).

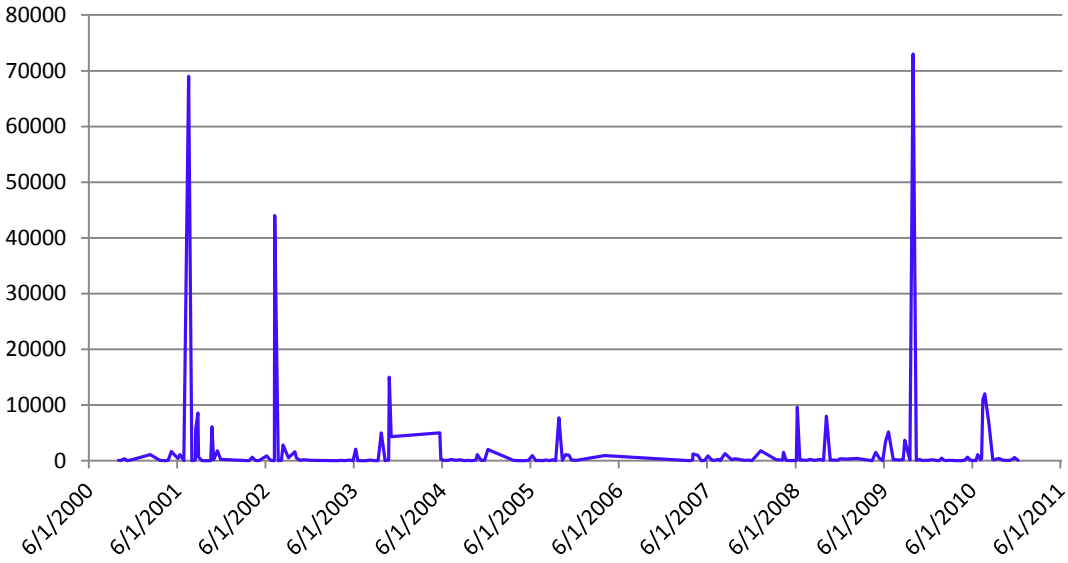
While safe swimming opportunities are a laudable goal, promoting a return of publically operated swimming beaches along the impoundment without abating high levels of bacteria and sedimentation in the impoundment may not be economically or technically feasible, nor is it good public health policy for the foreseeable future.

Figure 12. Fecal coliform bacteria (MPN/100ml) for the Milwaukee R. at Port Washington Rd. 1981-2010 Source: Milwaukee Metropolitan Sewerage District http://www.waterbase.glwi.uwm.edu/mmsd/



STATE CRITERIA FOR RECREATIONAL USE. As bacteriological guidelines, the membrane filter fecal coliform count may not exceed 200 MPN/100 ml as a geometric mean and may not exceed 400 MPN/100 ml in more than 10% of all samples during any month. Samples shall be required at least 5 times per month. Direct comparison to recreational "pass or fail" criteria could not always be made because the sample frequency criteria of 5 samples per month. However, in relative terms the bacteria levels are extreme enough to indicate potentially unsafe immersion of head or ingestion.

Figure 13. Escherichia coli bacteria (cfu/100ml) for the Milwaukee R. at Port Washington Rd. 2000-2010 Source: Milwaukee Metropolitan Sewerage District http://www.waterbase.glwi.uwm.edu/mmsd/



While ice skating is more feasible on an impoundment than a free-flowing river, neither is an ideal site from a safety perspective. Even on impounded water, river currents, flow and freeze/thaw cycles, and water inputs from Lincoln Creek and storm sewers affect the quality and safety of ice. While the County would have difficulty controlling all park access points along the impoundment, they would likely restrict formal ice skating to backwater areas that are easy to monitor. This would be an added cost to the Parks already limited budget and would not eliminate potential safety and liability issues. The County has approximately 33 park ponds well distributed throughout the County of at least 1-acre that provide safer conditions. According to the Parks web site, the County operates nine formal ice skating facilities, of which four are on ponds with the remainder being artificially flooded land-based sites. Staffing and budget constraints, lack of interest or other factors may account for the limited number of ice skating facilities offered by the County.

Recreational fishing opportunities for game fish would be expected to improve in the absence of the dam and impoundment. Overall fish diversity and abundance would increase for native game and non-game fish species less tolerant of degraded habitat, while numbers and relative abundance of fish species tolerant of degraded habitat would be lower, especially common carp. Similar results were observed along the Milwaukee River after removal of the 90-acre North Avenue Dam and following the removal of the Milwaukee River Woolen Mills Dam and 67-acre impoundment at West Bend in 1988, and removal of the Chair Factory Dam and Lime Kiln Dam in Grafton. Who wouldn't prefer a smallmouth bass or walleye over a carp as table fare?

Based on DNR creel surveys, recreational fishers in Milwaukee County can have direct access and successful fishing outings along the Milwaukee River, its tributaries, and the Milwaukee Estuary and Lake Michigan by shoreline fishing, wading and by small canoe and kayak. Residents with limited resources do not need to invest time and money in expensive powered boats for a unique and successful fishing experience.

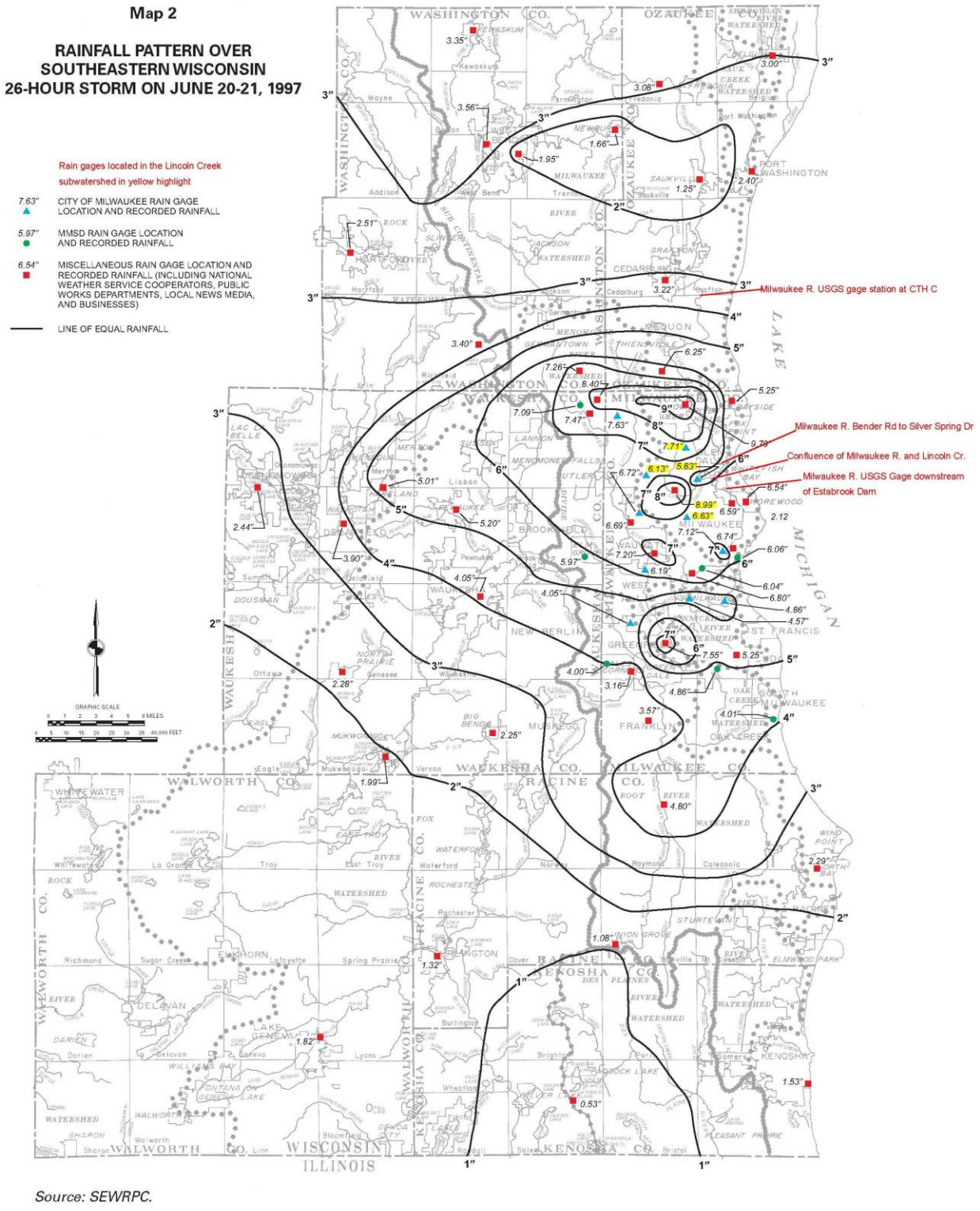
As of 2008, the deferred maintenance on County Park facilities was estimated at $250 million based on an independent study by the Public Policy Forum. Those deferred costs are now approaching $275 million and does not include other County-owned failing infrastructure. Additional park improvement budget amendments were proposed by other County Supervisors for improvements to their district's park facilities, not all were successful. **Shouldn't our representatives be looking for taxpayer savings and potential funding for needier, more cost effective and sustainable water-based projects that will benefit more County residents closer to their neighborhoods?** For example, park ponds are readily accessible facilities. The County has over 30 park ponds totaling 144-acres throughout the County, many of which are located in neighborhoods with limited resources. Many are degraded by failing banks, sedimentation and nuisance vegetation. Some experience winter fish kills, and most could benefit from the County following through with existing management plan recommendations for improving their condition.

Flood Control: Does the dam lessen or worsen flooding and potential property damage?

In his December 30, 2015 article Mr. Holmes *stated "But my own review of the modeling data used to predict water levels after removal of the dam suggests as few as 10 homes might as a result see reduced flooding levels (292 with reduced flooding). Moreover, the modeling data might be wrong: an actual 200-year-flood in 1997 did not result in flooding at levels as high as those predicted by the model."*

Mr. Holmes is correct to conclude that the June 1997 Milwaukee River flows observed at the USGS gage downstream of the Estabrook Dam did exceed the 100-year flood event. However, fortunately for the 292 or more residential structures located in the floodplain between Bender Road and Silver Spring Drive in the City of Glendale (hereafter referred to as the Sunny Point neighborhood) the river did not exceed the 10-year flood event.

The model used for the FEMA federal flood insurance program and local zoning purposes is based on watershed-wide hydrological contributions (e.g., precipitation and runoff) and hydraulic responses (e.g., river flows and surface water elevations). The 26-hour June 20-21, 1997 precipitation event affected a broad area of southeastern Wisconsin, and was especially intensive over north central Milwaukee County and in particular the highly urbanized and impervious 21 square mile Lincoln Creek watershed, where the 26-hour rainfall totals ranged between 5.8 and 9-inches and averaged 7.1-inches (Map 2).



Source: SEWRPC.

It's important to note that the USGS Milwaukee River flow gage station that recorded the June 1997 peak flood flow of 16,650 cubic feet per second (cfs) is located downstream of the Estabrook Dam and 1-mile

downstream of the confluence of Lincoln Creek with the Estabrook Impoundment. Furthermore, the flood prone Sunny Point neighborhood is located 1-mile upstream of the Lincoln Creek – Estabrook Impoundment confluence (Figures 14 and 15).

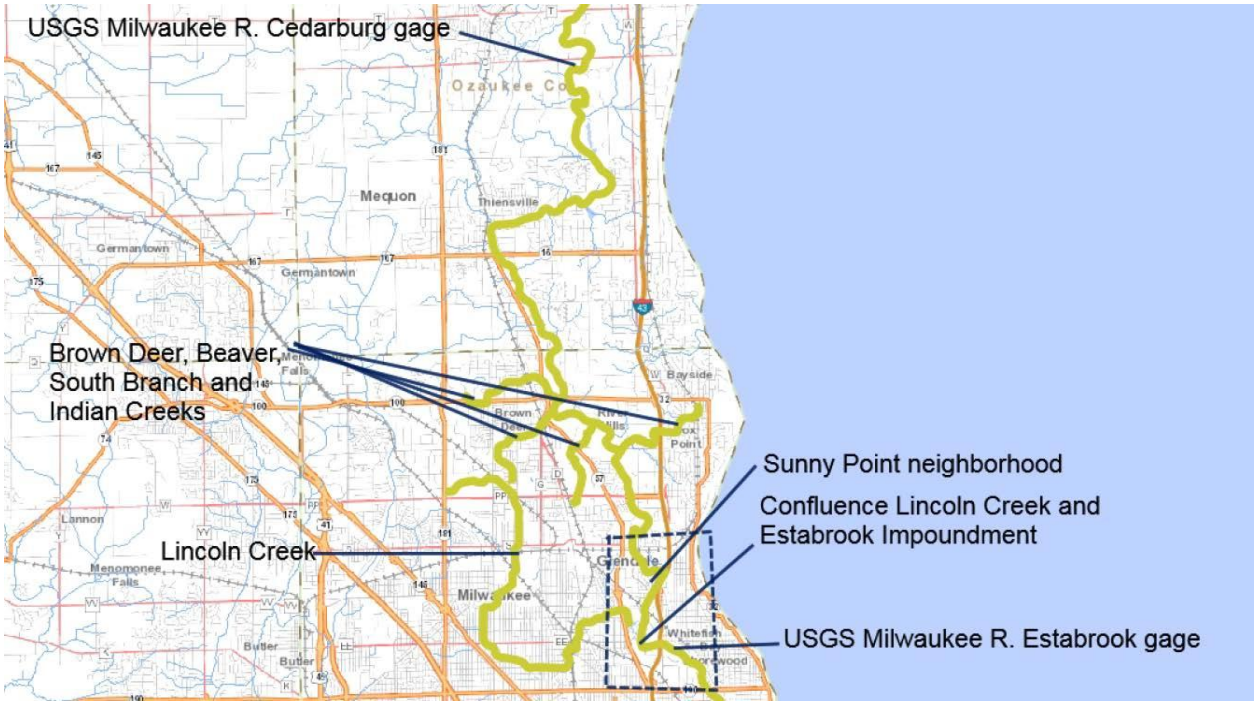


Figure 14. Location of USGS Milwaukee R. flow gages at Cedarburg and Estabrook Park; four northern Milwaukee County tributaries Brown Deer, Beaver, South Branch and Indian Creeks; Lincoln Creek and confluence with Estabrook Impoundment and V. of Glendale Sunny Point neighborhood. See figure 14 for inset figure. Source: DNR Surface Water Data Viewer

Figure 15. Inset from figure 13. Location of the Milwaukee River USGS flow gage at Estabrook Park in relation to the Lincoln Creek confluence with the Milwaukee River in Lincoln Park, and the City of Glendale Sunny Point neighborhood's 100-year floodplain boundary. The floodplain is the land along the river that is inundated by the "100-year" flood that has a 1 percent chance of occurring in any given year. The floodway (white cross-hatch) is that portion of the floodplain that is a conduit for moving flood waters. When the floodway is obstructed by buildings, ice or other debris the flood waters will cause damming and increase flooding elsewhere. The flood fringe (blue cross-hatch) is the balance of the floodplain lying outside of the floodway and is flooded by stagnant or slower moving flood waters. Source: DNR Surface Water Data Viewer.

According to SEWRPC Technical Report 40, the 24-hour 100-year rainfall event for southeastern Wisconsin is 5.88-inches and that a rainfall event of this duration and intensity over the Lincoln Creek watershed would have resulted in a peak discharge of 8,000 cfs for Lincoln Creek at its confluence with the Milwaukee River Estabrook Impoundment, which is 1-mile downstream of the Sunny Point neighborhood. Lincoln Creek would have contributed more than 50% of the record peak discharge of 16,650 cfs observed at the USGS Estabrook Park gage station, but not at the Milwaukee River upstream of Silver Spring Drive and the flood prone Sunny Point neighborhood.

Heavy rains were recorded in the range of 5-inches to 9-inches elsewhere in north central Milwaukee County upstream of the Sunny Point neighborhood. The contributing tributary watersheds are smaller and less impervious than the Lincoln Creek watershed. According to SEWRPC Community Assistance Planning Report No. 152, the four most significant contributing watersheds and their peak 100-year flow for the 24-hour 5.88-inch rainfall event include Brown Deer Creek (1,060 cfs), Beaver Creek (1,180 cfs), Southbranch Creek (1,690 cfs), and Indian Creek (2,040 cfs) with a combined discharge of 5,970 cfs upstream of the Sunny Point neighborhood. Because these tributaries have different discharge locations

to the Milwaukee River, their time of flows and other hydraulic factors would not likely result in their combined peak flows arriving at the Sunny Point area at the same time. But for a worst case scenario, we can assume the combined discharges arrived at the Sunny Point neighborhood at the same time. More importantly, the Milwaukee River's watershed-wide contribution at the Sunny Point neighborhood was appreciably less than the four tributaries combined flow of 5,970 cfs. The peak discharge observed at the Milwaukee River Cedarburg USGS flow gage was 2,060 cfs the following day, or 3,910 cfs less than the estimated combined discharges of the four tributaries. The Milwaukee River's estimated peak discharge for the June 1997 event upstream of the flood prone Sunny Point neighborhood would have been approximated 7,370 cfs which is less than the 8,790 cfs 10-year flood event for the USGS Milwaukee River Estabrook Park gage. This flow mass balance for the Milwaukee River is a conservative estimate since the 10-year flood flow event for the Milwaukee River at the Sunny Point neighborhood would be somewhat lower without the contribution from Lincoln Creek (Figure 16).

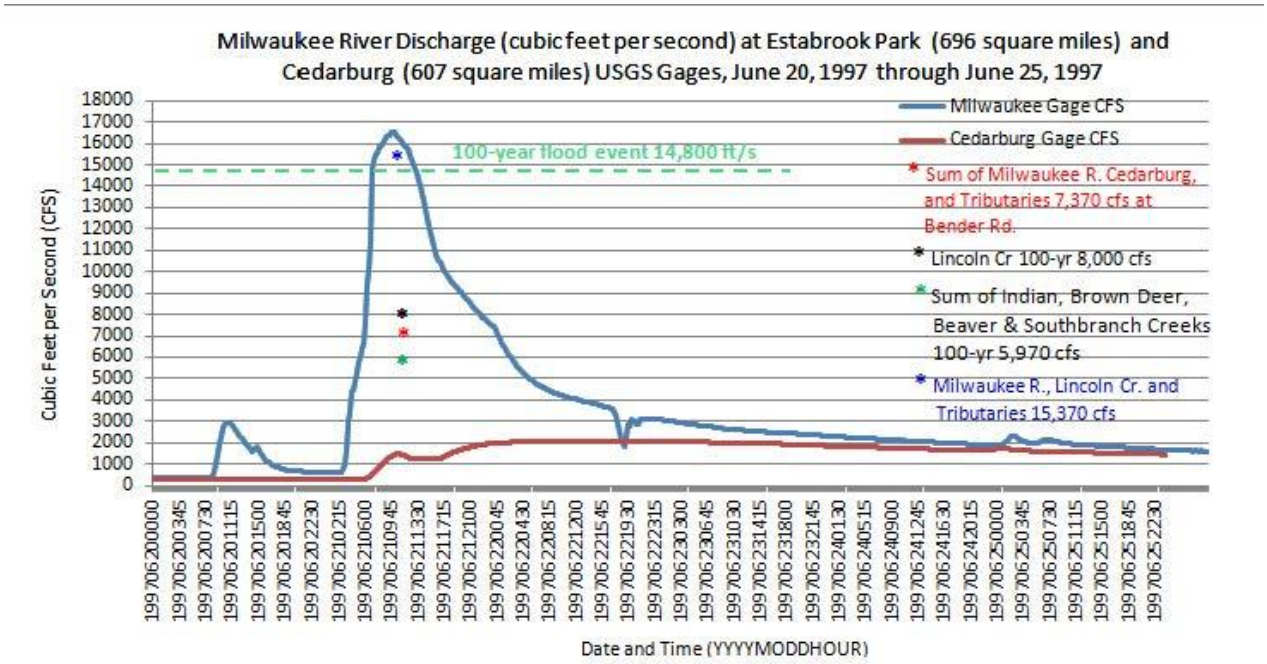


Figure 16. Flow mass balance for the USGS Milwaukee R. Estabrook Park gage for the peak discharge of 16,650 cfs on June 21, 1997. The combined observed peak discharges of the Milwaukee R. at Cedarburg (2,060 cfs); estimated peak 100-year discharge of four north central Milwaukee County tributaries (5,970 cfs); and estimated peak 100-year discharge of Lincoln Cr. was 15,370 cfs or 1,280 cfs less than the observed peak discharge of 16,650 cfs observed at the USGS Milwaukee R. Estabrook gage.

It was very fortunate that the Sunny Point neighborhood and the 292 residential properties did not experience the regional 200-year event much less the 10-year event estimated by Mr. Holmes. The City of Glendale's reported damage of 128 structures and public infrastructure totaled $400,000 from direct flooding by the Milwaukee River and from local streets recognizing that most streets and storm sewers are designed to convey a 5-year rain event. The 128 structures that experienced flood damages are comparable to the 71 structures in the Sunny Point neighborhood located in the 10-year floodplain. An Important question remains with regards to other factors that may have contributed to flooding and

drainage damages. Was the County able to respond in a timely manner to open all of the 10 dam gates, and were all 10 gates in operable condition?

For many years leading up to the recent changes made to the County's decision to repair the dam, supporters for repairing the dam argued that the dam was constructed for flood control. Evidence to that affect offered up by the Milwaukee River Preservation Association (MRPA) was anecdotal at best. Despite earlier flood and drainage studies dating back to the 1980's that noted the dam and operation of the dam could contribute to drainage and flood problems, campaigns by supporters to repair the dam because of its flood control benefits continued.

The Estabrook Dam was not constructed to prevent all over bank and local nuisance flooding. Early planning documents recognized that only the removal of the rock outcrop and construction of the center cut through the Lincoln Park river meander would offer some flood relief. Flooding associated with high river flows and ice jams would continue to be a problem, in particular along the flood prone Sunny Point neighborhood located between Bender Road and Silver Spring Drive in the City of Glendale, *"We believe that the work now being done will quite adequately take care of the situation north of Silver Spring. However, we make no predictions with respect to the actual effect north of Silver Spring Road, inasmuch as the channel has not been cleaned out, widened, or deepened north of Lincoln Park, and the other, and possibly more important factor of ice jams occurring during the winter months. During the winter of 1937-38 difficulty was experienced north of Silver Spring Road by reason of water and ice at a time when the river gauges showed a flow of 4,000 to 5,000 c.f.s., (cubic feet per second) which during time when there was no ice in the river would not be considered a severe flood."*

Removal of the Estabrook Dam is the only dam management alternative that reduces potential flood damages from the Milwaukee River or from submerged storm sewers. Compared to the dam removal alternative, the dam repair alternative:

- With all 10 flood gates open, the 100-year flood event elevations increase between 0.5 and 1.5-feet between the dam and Bender Road
- If the County is unable to raise all 10 gates of the dam during the 100-year flood event because of obstacles such as unsafe access to the dam, staff availability, the loss of power during the storm, mechanical gate failure, or the accumulation of ice and debris at the gates, the flood water elevations would be as much as an additional 1.5 feet higher than the 100-year flood elevation near the dam with the gates open, and continue to exceed the 100-year flood elevation at Bender Road. This would result in flood damages to more than the current 292 residences in the current 100-year floodplain.
- If the County is unable to raise all 10 gates during more frequent and less extreme flood events beginning at the 15-year flood event**, the flood levels and resulting damages would be similar to those experienced during the 100-year flood with all 10 gates raised.**
- These gate operation scenarios have occurred in the past and are real world possibilities for the future. If all the dam gates cannot be opened in a timely manner and flood damages occur, it could increase the County's exposure to flood damage liability.
- The dam would be responsible for more nuisance flooding of local streets and yards due to storm sewer backups in the City of Milwaukee and City of Glendale for all modeled flood events. While

nuisance drainage related events have occurred in the past, the full extent of potential nuisance street and yard flooding in neighborhoods has not been quantified.

These are the conclusions of the hydrologic and hydraulic flood models completed by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) and the County's own consultant AECOM. These findings were made available in public documents and at public meetings over a year ago, well in advance of the County's recent policy change to repair the Estabrook Dam in early 2015 at a cost of $6.2 million. The County Board chose not to heed the advice of their own Director of the Office of Emergency Management, the City of Glendale's Certified Floodplain Manager, or an independent risk management and flood insurance provider, that given the flood risks and damages and potential liability to the County the dam should be removed.

The FEMA model and resulting regulations considers a structure or home in the floodplain whether the flood water is in the home on the property at the lowest adjacent grade or elevation. The difference of whether a half-foot or less change in flood water elevation is on a front lawn versus entering the basement can be significant. The significance of the flood elevations for the various alternatives results in increased flood risks and associated damages or in the case of dam removal, a decrease in flood risks and damages.

My attempt to account for the number of residences added or removed from the 100-year regulatory floodplain or less extreme but more frequent modeled floodplain events (50-year and 10-year flood events) for the dam repair versus dam removal alternatives, and dam repair operation scenarios with the gates open or closed was not possible for this article. While the available topographic floodplain maps were prepared at an adequate scale, the elevations were at 2-foot contours. Elevation differences between the dam management alternatives and gate operation scenarios were <1-ft making accurate extrapolations between the 2-ft contours and a determination of whether a structure was in or out of the floodplain not possible.

Until such time more detailed surveys are completed that identifies the lowest flood water entry point for each structure, the argument should not be limited to the number of residences taken out of or that remain in the 100-year regulatory floodplain for the dam repair or dam removal alternatives. An analysis should be completed that:

- Identifies which additional properties might experience flooding for the 100-year and more frequent flood events if the dam's gates could not be raised in a timely manner, and
- Identifies which properties would experience a reduction in potential flooding as a result of less extreme and more frequent flood events should the dam be removed.

The following data shows that with the dam gates closed, the 100-year floodplain increases up 10-inches with most of the properties affected by increasing flood elevations of about 5-inches. This is not an insignificant amount when considering how flat the topography is in the Sunny Point neighborhood and the potential for additional flood water damages, or the consequences of flood water entering floor drains that contribute to sanitary sewer backups and overflows. Alternatively, under the dam removal

option, the 100-year floodplain decreases by up to 6-inches with most properties decreasing by 3-inches. If you own a flood prone residence, every inch decrease in flooding is valued (Table 4).

Table 4.Number of residential properties by river reach and river mile change for the 100-year floodplain elevations (feet) based on Estabrook Dam gates closed and Estabrook Dam removal conditions.

River Reach Description and River Mile (RM)	Residential Properties in Existing 100-year Floodplain	Change in 100-year Floodplain Elevation with Dam Gates Closed (feet)	Change in 100-year Floodplain Elevation with Dam Removal Alternative (feet)
Abandoned Railroad Bridge (RM 8.36) to Silver Spring Dr. (RM 8.74)	4[a]	+0.8 to +0.5	-0.5 to -0.3
Silver Spring Dr. (RM 8.74) to E. Riverview Dr. extended (RM 9.125)	84	+0.5 to +0.4	-0.3 to -0.2
E. Riverview Dr. (RM 9.125) extended to N. Wittee Ln. extended (RM 9.669)	117	+0.4 to +0.2	-0.2 to -0.1
N. Wittee Ln. extended (RM 9.669) to Bender Rd. (RM 10.04)	87	+0.2 to 0.0	-0.1 to 0.0

[a] City of Milwaukee. All others located in City of Glendale
All values rounded to nearest 0.1-ft

Residents with mortgages located in the 100-year floodplain already carry flood insurance, and future flood insurance premiums will be increasing. There are 292 residences in the 100-year floodplain; all but four are located between Silver Spring Drive and Bender Road in the City of Glendale's Sunny Point neighborhood. Approximately 163 or 56% of the 292 floodplain parcels have waterfront property (seven parcels may not have structures). The remaining 129 residences are located inland from the river and do not have direct river access, and the use and added property value associated with owning water frontage. While these inland property owners do not have the added property value that waterfront property owners have, they may have the most to gain from being removed from the floodplain boundary by eliminating payment for flood insurance, and absent that stigma, receive a higher selling price. Should a flood event occur that is more extreme than the 100-year flood, or if flood events occur when the County is unable to raise all 10 dam gates, the 163 riparian homeowners experiencing damage will be the same. However, the number of homeowners who live inland from the river and experience flood damage may increase substantially.

Costs: What are the costs of the various dam management alternatives to taxpayers?

As of 2008, the deferred maintenance on Milwaukee County Park facilities was estimated at over $250 million based on an independent study by the Public Policy Forum. This means the County cannot pay to repair, maintain, and operate its current facilities in good working order, and throwing millions at the Estabrook Dam and impoundment without considering other cost effective and sustainable river management alternatives, means those other important projects will not be funded.

When the final accounting is completed, the cost to taxpayers to remove just the accumulated contaminated sediment will approach $49 million dollars, dwarfing the $6 million cost of repairing, operating and maintaining the dam and proposed fishway over the 20-year lifetime left for the structure.

Repairing the Estabrook Dam will lead to more sedimentation over time and negatively impact the environment and recreational uses. The recent reports documenting the need to repair the Mitchell Park Domes at a cost of $75 million and replace the County Safety Building at a cost of $184 million should speak volumes that the County Board should choose the expenditures that are sustainable and benefit all County taxpayers. If the dam is repaired, will the next generation of residents along the impoundment and their County supervisor ask the rest of the County taxpaying residents to repeat this financially burdensome dredging process?

In his articles, Mr. Holmes provided extensive comments of the dam repair and dam removal management alternatives costs identified in, or omitted from, the draft environmental assessment (EA) prepared by Milwaukee County's own consultant. It is important to note that the EA is being revised to reflect the County's changed policy to repair the dam and add fish passage, and to address the required Operational Order and Operation, Inspection and Maintenance plan for the dam and fishway. Seasonal water levels and fishway design (as an "active" or "passive" designed fishway) will affect the final Operation Plan, and vice versa. As such, estimates for each of the alternatives are fluid.

The most recent estimated 20-year cost for repairing, operating, and maintaining the Estabrook Dam with an engineered fish passage is at $6 million. Other potential capital and operation and maintenance costs not identified or quantified in the EA, or considered to be excessive by Mr. Holmes include:

- Potential County and taxpayer exposure and liability for river overbank flooding and local flooding caused by submerged storm sewers due to failure to open all 10 dam gates during floods beginning at the 15-year event and larger floods.
- *"It's also worth noting (and hasn't been reported) that the county has established a maintenance trust fund for the dam that receives $51,000 in rental income per year from television towers located in Lincoln Park, and which will have a balance of over $300,000 by 2017 when dam operations could resume."* To date, the County has appropriated only $51,000 per year of the estimated $160,000 annual operation and maintenance cost required for the dam and proposed fishway. Mr. Holmes stated that the balance for the dam's operation and maintenance will be $300,000 by 2017. That balance may not add up. County staff has said that there is not a designated account collecting these rental fees, and they could have already been spent on other projects. Even assuming there is such a fund, the annual $51,000 allocation from the television tower rental fund for dam operation and maintenance only started in 2014 or 2015 and the account would have been used for no less than three debris removals in 2015, and debris removal must still be completed for 2016. Past debris removals have cost as much as $40,000 per year and 300 cubic yards of debris are still awaiting removal from the Estabrook Park floodplain next to the dam's gated section. Any additional shortfalls in funding for the dam and fishway O&M will have to be funded through the annual budget process. Since there is no designated fund for the balance of dam and fishway O&M, the County must allocate the balance by way of the same annual budgeting process that competes for all County projects.
- Long-term costs for managing accumulated sediment and other sediment related nuisance conditions that will develop (e.g., man-made debris and nuisance aquatic vegetation).

- Capital, operation and maintenance costs for heaters, aerators or other practices to keep 10 gates free of ice and debris if the County. The original dam plans called for heaters for each of the 10 gates. No one knows for certain if they were ever installed.
- Year around run-of-the-river pool full levels, except during flood events, would allow for the design, construction and operation of a much less costly and effective "passive" fishway. Any deviation from year around run-of-the-river pool full water level operation would involve an "active" fishway design whereby changes in pool elevation would require controllable weirs/gates at the inlet to the fishway and an increase in construction and operating costs.
- Mr. Holmes stated, "*The need for a full-time employee warrants a greater level of critical analysis. So does the $50,000 estimated annual cost for debris removal, which arguably is a cost that would be shifted to other local governments if large floating debris that is now captured in part behind the spillway was instead carried downstream into the navigation channels heavily used by recreational boaters in the downtown and Milwaukee Harbor."* For planning level purposes, personnel costs are based on the number of man-hours per year; and costs include but are not limited to wages and benefits committed to a particular job or task. The assigning of one person exclusively to managing all aspects related to the operation, maintenance, etc., is not what the estimates should be based on. There are many tasks that require multiple staff to accomplish. As an example, for safety reasons one should never expect one person to be responsible for accessing the dam for purposes of raising the gates during severe storm and flood conditions, or any work for that matter where flowing water is encountered such as debris removal and fishway operations. County staff has intimated that a full-time employee would likely be involved in operations at all 3 of the County's dams that are currently subject to repair or abandon orders from WDNR.
- Debris removal cost*s* could include a greater level of review, but not because the current estimate of $50,000 per year is too high. I believe the estimate could be underestimated once the County is required to remove debris on a regular basis at the fixed crest spillway (Figure 17 and 18). When the County contracted for debris removal, it was done so only for the gated section of the spillway and "dragon's teeth". Typical costs for debris *re*moval at the gated spillway and dragon's teeth were up to $40,000. There are no records of the County ever conducting debris removal at the fixed crest spillway despite orders to do so. Compared to the gated section of the spillway, the fixed crest spillway accumulates much larger volumes and mass of debris and comingled sediment. This section of the spillway is longer and irregular and may require a boom to remove instead of an excavator. Access is private, narrow and confined, and will require protection and cleanup from heavy equipment.
- *"The O&M costs are a source of significant contention with members of the Milwaukee River Preservation Association, which cites $10,000 as the high end for annual costs based on an informal survey they conducted of other dam operators in Wisconsin."* The article does not identify the results of the survey as to which dams were surveyed and details on how the dams and operating conditions were similar or dissimilar to those facing the Estabrook Dam in regards to potential impacts of gate operation on drainage and flooding damage potential; debris accumulation and impacts on spillway structural integrity and hydraulic capacity; seasonal drawdown impacts; spillway gate configuration and operability, to name a few.

Figure 17. 2005 aerial photograph showing debris field accumulated behind the Estabrook Dam “serpentine” fixed crest spillway (lower) and the “dragons teeth” array installed to protect the gated section of the spillway (upper) from ice and debris. Comingled debris and contaminated sediment up to 5-feet thick is evident as light brown material inside the yellow boundary. Debris continued to accumulate behind the spillway until a 2010 flood eroded the debris and a portion of the comingled contaminated sediment downstream. Source: Milwaukee County Interactive GIS Mapping website.

Figure 18. May 26, 2009 photo looking downstream along debris field deposited behind the Estabrook Dam's fixed crest spillway. The debris can impact the flood flow capacity and structural integrity of the spillways Flashboards and supports bounded by the yellow line were damaged by the debris and had to be replaced. Debris continued to accumulate behind the spillway until a 2010 flood eroded the debris and a portion of the comingled contaminated sediment downstream. Source: Will Wawrzyn

- If not included, interest paid on bonds for capital costs and also reflected in the total 20-year present worth cost estimate.
- If Mr. Holmes is advocating for the return of the historic or new public uses described in his articles (e.g., ice skating, swimming and boat launch and parking), then those costs should be included as part of the dam repair alternative. Consistent with current beach bacteria monitoring programs at South Shore, Bradford and McKinley beaches, cost for monitoring Estabrook Impoundment swimming beaches should be included.
- Additional costs for automating the remaining 6 manual gates, and repairing/updating the four existing automated gates.
- Update the antiquated mechanical float sensor system for automated gates.
- Ecological costs for restoring a highly urbanized impoundment, and if allowed through the Operational Order, ecological costs of partial or full impoundment drawdowns.

Mr. Holmes identified some examples of costs excluded from the current $1.7 million dam removal estimate. My review of those costs follow:

- *"Costs for Glendale to modify at least 30 stormwater outfalls that discharge to the Milwaukee River that are designed for the higher water level associated with the impoundment*." Storm sewers would drain better and not cause surcharging onto streets, etc., if their outlets were not submerged by the river or impoundment during flood-flow events. If that is the concern, then the potential drainage and local street flooding from storm sewer surcharging will always be less under the dam removal alternative, and there is no need for modifying the sewer outlets. If on the other hand the concern is that elevated storm sewers that outlet onto or across the river bank are causing erosion, then rip rap or some other remedy may be needed. These 30 storm sewer outlets and river banks have been exposed to potential erosion for decades when the impoundment was drawn down for 7-months out of the year when erosion potential is greatest due to the greater volume of stormwater runoff and soils undergoing frequent freeze and thaw cycles. I find it curious and a little self serving that concern over eroding storm sewer outlets has only been raised during the recent dam repair or removal debate.
- *"Costs for private landowners to repair dock walls."* Failing dock walls (and presumably any failing private shoreline structure) has not been shown to be uniquely caused by any particular dam management alternative (dam repair or removal) or dam operation scenario (full or partial seasonal drawdowns, or full pool operation). Dock walls and shorelines are routinely replaced along rivers, lakes and even commercial harbors without the need to de-water the working area.
- *"Costs for private landowners to remove (*and presumably re-install*) docks and other boat infrastructure."* I doubt the docks are permanent structures since high spring river flows and/or ice would have certainly damaged or removed them already. As far as removing and reinstalling docks on an annual basis, 1,000's of waterfront owners throughout the state remove their infrastructure before winter to avoid damage by ice. Should the dam be removed, removing pier and dock structures should not be any more difficult than it was in previous years when the impoundment was drained.
- *"Costs for environmental restoration of land formerly covered by impoundment waters but now exposed*." Depending on the need and interest to enhance the river and its floodplain wetlands following dam removal, there would be costs for planning and implementation. Since the 2008 drawdown, newly created floodplain wetland soils have experienced growth by volunteer pioneer vegetation, initially by annual forbs and later by annual and/or perennial forbs, grasses and woody shrubs. These plant, fish and wildlife habitat communities would continue to evolve as natural recurring (1-yeat to 2-year frequency) flood flows transport sediment, build a stable channel and floodplain. Most importantly, the dominant costs attendant to sediment quality and quantity management following dam removal has been completed as part of the contaminated sediment remediation project in 2015. If the dam removal alternative is pursued following repair of the dam and restoration of the impoundment in the future, then the rate of sediment management costs for dam removal would increase over time depending on the quality and quantity of sediment that had accumulated. (I will discuss a compromise dam management alternative that is technically and environmentally feasible later in my article). Riparian's would still own to the centerline of the river channel including any lands exposed or accreted, and depending on the need and interest to enhance those lands, there would be costs. For decades, these lands were previously exposed for 7-months of the year.

- Mr. Holmes cites the former Woolen Mills Dam on the Milwaukee River in West Bend as a bellwether of unaccounted costs that Milwaukee County could potentially face should the Estabrook Dam be removed. I was very much involved with the entire process leading up to and following the removal of the Woolen Mill Dam. Briefly, the city evaluated four dam management alternatives, including their original preferred alternative that included the replacement of the existing dam with a combination dam and bridge (River Road) at a cost of $3.3 million (1986 dollars). Dam removal was estimated at between $2.2 and $2.5 million. The estimated cost for just the bridge was estimated at between $1.0 and $1.5 million.

  The impoundment had accumulated between 200,000 and 250,000 cubic yards of moderately polluted sediment at a thickness that ranged between 3-feet and 10-feet. Two abandoned landfills were leaking leachate to the impoundment. Dissolved oxygen levels were below the state water quality standards and very turbid. The impoundment fishery was dominated by common carp and the recreational fishery was poor. Few people used the impoundment for recreational fishing or boating. The City understood the cost and benefits of the alternatives. They chose to remove the dam and "recycle" the former impoundment and two abandoned landfills for public use, and acquire additional lands to be incorporated into an expanded Riverside Park.

  Mr. Homes stated, "The former Woolen Mills Dam on the Milwaukee River in West Bend (removed in 1988), is actually presented in one of the reference documents cited in the EA as an example of a dam where the removal cost was estimated at $82,000, but where an additional $2.3 million was eventually spent on restoration costs (including "engineering design, grading, seeding, channel work, fisheries improvements, construction of a new bridge, and development of a park over 61 acres of the former impoundment")." The costs associated with *"restoration"* of the former impoundment were completed in Phase I and II of the project. Tasks included:
  - Dam removal ($86,000)
  - Sediment and bank erosion protection
  - Temporary seeding with cover crop and final seeding with native wetland, prairie plants, and tree samplings
  - Instream habitat cover for fish (e.g., smallmouth bass)
  - Leachate control
  - Sanitary sewer and storm sewer protection
  - Cost approximately $500,000

  The remaining costs were associated with expanding recreational amenities at the existing the Riverside Park. The accreted lands formed by the removal of the dam and impoundment were not viewed as a liability but as an opportunity and public asset. State grants contributed $500,000 to the overall project. Some of the larger park improvements included:
  - 100-acres native plant restoration
  - 22-acres of land acquisition
  - 2-miles of improved trails
  - 4 clear span steel pedestrian bridges

- Baseball, soccer fields
- Park pavilion
- 2 parking lots and canoe/kayak launches

(Figures 19 and 20)

Figure 19. Milwaukee River former Woolen Mills Impoundment at Riverside Park, City of West Bend. Source: by Brucev, June 2012, Google Earth.

Figure 20. Milwaukee River former Woolen Mills Impoundment at Riverside Park, City of West Bend. Source: Will Wawrzyn

Property Values

Supporters for repairing the dam argue two points with respect to lost property values should the County owned dam be removed:

- Removing the dam and "natural lake" would impact their property values estimated at $74,000 for each of the 163 waterfront properties. They have threatened to sue the County over these lost property values, and
- The City of Glendale's lost property tax revenue, which according to Mr. Holmes could be $288,400 per year.

There is no evidence to suggest that this would be the case. To the contrary, there are Wisconsin-based peer-reviewed studies (Born et al., 1998; Provencher et al., 2008) and an independent appraisal completed for the former Milwaukee River North Avenue Dam removal project that looked at the effects of small dam removal on water front property values that concluded property values generally stay the same or slightly increase following dam removal. Admittedly, I have zero experience in matters related to how assessors value land in the same community along a segment of free-flowing river versus its impoundment, however I am not aware of any property devaluations that have occurred as a result of

the 14 dams removed in the Milwaukee River Basin during my career (e.g., North Avenue Dam in Milwaukee, Lime Kiln Dam and Chair Factory Dam removals in Grafton, Woolen Mills Dam removal in West Bend, Newburg Dam, Campbellsport Dam, etc.).

The property's current value is assessed at having water access by way of owning water frontage. There is no distinction between a free-flowing river or impoundment. A more definitive accounting of what the difference in assessed land value and property tax revenue would be is to ask the City of Glendale's assessor, which is Accurate Appraisal, LLC located in Menasha, Wisconsin.

Riparian's along the Estabrook Impoundment would still have the same amount of water frontage with or without the dam. They would still own access to the river and have title to the thread of the river channel with or without the dam. The types of navigation use of the river may change but the river would remain navigable in fact. As an example, a property owner may no longer have year around water depths sufficient to navigate the river with a larger, deep drafting powered boat but would still be able to navigate with smaller craft such as by canoe and kayak.

All property owners are concerned about the future return and salability of their properties. There many tangible and intangible factors that could affect a buyers interest in a riverfront property including the quality of the water, sediment and its fishery, shoreline stability, navigation preferences, and their personal aesthetic preferences of a free-flowing river versus an impoundment. Years ago, prospective river front landowners would not always ask about a river property's location relative to its floodplain. Potential liability and added cost issues would not arise until mortgage providers informed them of flood insurance requirements. Given all the recent reports of the flood events and severe damage to people's health and properties, those questions are now front and center by potential riverfront home buyers. The additional cost for flood insurance over a 15-year or 30-year mortgage is significant, flood insurance premiums will be increasing, and the cost of that insurance is not necessarily recovered at the time a property is sold.

Threats of law suits by property against the County may be a straw dog. Based on my understanding of relevant Wisconsin state law, absent a specific covenant between the County and riparian landowners, landowners that live on an impoundments do not have any rights to water levels that would require the owner of a dam (in this case, the County) to maintain the dam and the resulting impoundment in perpetuity.

Using an equivalency land value model based on impoundment versus free-flowing river property along the Milwaukee River in Mequon, Mr. Holmes estimated the annual loss of tax revenue to the City of Glendale at $66,000 for each of the 163 riparian properties, or $288,000 per year. Based on a review of 50 properties from the 2010 property tax assessments by the City of Glendale, Estabrook Impoundment waterfront property land values were $35,000 higher than non-riparian property values across the street. Differences were quite variable ranging from a minimum of $16,000 to a maximum of $54,000 suggesting there are other valuation factors at work besides owning waterfront. Based on these values, my calculation of the potential annual property tax revenue loss to the City of Glendale using the

maximum difference between riparian and non-riparian property values from 2010 multiplied by tax rate and number of properties ($54,000 x 2.7% tax rate x 163 properties), comes up with a loss in revenue of $154,000 per year and not $288,000 per year estimated by Mr. Holmes. All these assumptions and math aside, there is no way of quantifying the land value differences, if any, between the free-flowing river versus impounded condition until the assessor weighs in, or a fair market valuation is completed. Other studies cited above have shown no difference if the property remains a riparian property.

To lessen or eliminate the costs to County taxpayers, riparian landowners could form a lake association or district and levy fees for the operation and maintenance of the dam, or accept a special County assessment for maintaining their unique privileges afforded by the dam and impoundment.

Alternatives to Repairing the Dam with a Fishway and Dam Removal

As part of the draft October 2015 environmental assessment, AECOM identified a number of alternatives for the Estabrook Dam. The short list of alternatives included:

Alternative 1 – Repair the Dam and No Fish Passage

Alternative 1A – Repair the Dam and Add Fish Passage (County's most recent preferred alternative based on policy change)

Alternative 2 – Abandon and Remove the Dam

Alternative 4 – Gated Spillway Removed, Serpentine Overflow Spillway Lowered, and a 6.3-Foot High Rock Ramp Fishway

Alternative 4 may be considered a hybrid between the dam repair with a fishway Alternative 1A, and the dam removal Alternative 2. Alternative 4 includes the removal of the 222-ft long 10-gated spillway section of the dam and lowering the 562-ft long serpentine fixed crest spillway by 6-inches. The gated spillway would be replaced with a "rock ramp" fishway that mimics a natural stream's riffle run features (Figure 21). It is a "passive" fishway design in that it operates using "run-of-the-river" flows and does not require managing structures to adjust fishway flows. Because large volumes of river flow can pass through the fishway, it is very effective and efficient at attracting fish to the fishway entrance and passing all native fish species regardless of river flow conditions and a fishes swimming behavior. This alternative would not cause any increase in the 100-year flood elevation, and under median river flow conditions, water levels along the impoundment would decrease between 0.4 and 1.2-feet. Water depths would range from 1.9 and 7.9-feet and would be adequate for power boats except near Bender Rd. The "rock ramp" crest elevation would be 615.4-feet or 6-inches lower than the historic rock outcrop's minimum reported elevation. The "rock ramp" alternative has a 20-year present worth cost of $3.3 million or $2.9 million less than the County Board's policy of dam repair with a fishway, but was never seriously considered despite the $2.9 million savings. Dam repair proponents presumably were unwilling to compromise and accept any reduction in impoundment depth. This alternative would not prevent the accumulation of sediment in the impoundment without an approved operational order that allows for an extended seasonal drawdown and flushing of sediment. As a result, sediment would accumulate in the impoundment over time and environmental degradation would follow similar to those described for the dam repair alternative.

Figure 21. 2015 drone photograph of the Estabrook Dam including 562-ft fixed crest spillway and 222-ft 10-gated spillway sections. When the gates are closed, river flow is over the fixed crest spillway. Gates have remained open and the impoundment drained since the 2008 drawdown order by the DNR. Under dam management Alternative 4 developed by AECOM and described in the environmental assessment, the fixed crest spillway would be lowered and the gated spillway would be removed and replaced with a "rock ramp" to enable fish passage while maintaining most of the impoundment depths. Source: Bruce Jorgensen

Repair of the dam and an operational order that allows for partial or complete seasonal drawdowns of the impoundment would compromise an effective "passive" fishway design. Seasonal lowering of the impoundment water level would require an "active" fishway design. "Active" fishway designs are more expensive to design, construct and operate. Depending on peak fish migration periods (mid-March through mid-June and mid-September through early November), river flow conditions and desired impoundment pool levels, active fishways require daily to seasonal adjustments to flow control structures (e.g., gates or weirs) and removal of debris especially. Operating an "active" fishway requires frequent observations for fish presence, debris removal, frequent adjustment to flow control structures. These tasks are very difficult to complete using automated systems. The amount of water they are capable of passing is less than a "passive" design during higher spring flow and the peak fish migrating period. As a result they are less effective at attracting migrating fish to the entrance and therefore less fish are passed upstream. This can be problematic for the Estabrook Dam since an "active" designed fishway would need to be constructed along the gated section of the dam where the County owns property so their personnel are able to access, operate and maintain the facility. The fishway would be

far removed from the fixed crest spillway where the dominant fish attracting flows are located. Priorities would have to be established through the dam operational order between river flow needs for attracting and passing fish versus desired water levels by power boating enthusiasts. As was discussed earlier, the County has an $110,000 annual shortfall of funds to operate and maintain the dam much less the added expense and responsibility of operating and maintaining an "active" fishway.

A "Better Mouse Trap"

Removing the dam will not completely "restore" the historic Milwaukee River's morphology and as a result, its historic uses and values. That train has left the station following widespread land use changes and additional development in the river's floodplain. However, removal of the dam would be the first step toward mitigating 1.5-mile of destructive river channelization and the loss of over 100-acres of floodplain wetlands that extended from the present day Estabrook Park "falls" to the upper limits of the "center cut" and present day confluence of the "east and west oxbows" in Lincoln Park. The 0.8-mile reach between the dam and Hampton Avenue is an especially harsh habitat. Widening and deepening of the bedrock has left this reach morphologically featureless not to unlike concrete pavement. The entire 1.3-mile long modified channel slope is flat.

Should the dam be removed the goal should be to re-create some of the historic river channel and floodplain wetland features, functions and uses. There are at least two guiding principles central to planning efforts:

- An understanding of sediment transport characteristics and flow regimes of the river is critical. An enhanced and sustainable river channel and floodplain must be in balance with the hydrologic and sediment influences. The enhanced river channel should not accumulate sediment (aggrading) nor erode vertically or horizontally (degrading). Transported sediment and debris should be encouraged to be deposited naturally for building functional floodplain and wetlands. For projects as large and as altered as the Milwaukee River in Estabrook and Lincoln Parks, final planning and design efforts should be completed with a full understanding of fluvial geomorphology processes.
- Establishment of project objectives that are sustainable, technically feasible, cost effective and fundable, and accepted by the majority of County and river stakeholders. The following objectives are offered as examples:
  1. Enhancement features must not cause an increase in potential damages from river flooding or surcharging of local storm sewers compared to the dam repair alternative.
  2. Increase effective water levels and depths that benefit passive forms of recreational navigation, fish, other aquatic life, and wildlife.
  3. Maintain minimum base flows, in particular along the Milwaukee River and the east oxbow.
  4. Increase the extent (acreage) of hydrologically connected floodplain wetlands.
  5. Add cover to the river and floodplain that benefits fish, other aquatic life and wildlife, and passive forms of recreational navigation consistent with features found along low-gradient rivers (e.g., coarse wood such as recycled trees).

What might some of the river and floodplain enhancements include?

Historically, the river was located along a single meandered channel. It flowed south through the present day “east oxbow”. From the east oxbow outlet, it flowed north to the present day confluence of the river and east-west oxbows. It then flowed west and then south through the present day “west oxbow”, past the confluence with Lincoln Creek, and then flowed through the bridge at Hampton Avenue (Figure 22).

Figure 22. A 2005 aerial photograph of the Milwaukee River in Lincoln Park between Hampton Ave. and the upper confluence of the present day “east and west oxbows”. The yellow lines are the 1937 natural river shorelines and meander that pre-dates excavation of the 0.6-mile long by 200-ft wide center-cut for reducing but not eliminating the impact of flood flows and ice dams, and construction of the Estabrook Dam in 1940. The dashed red line is the approximate centerline of the excavated center-cut. Source: Milwaukee County Interactive GIS Mapping website.

A design would approximate the narrow and deep low-gradient river channel dominated by run and pool features that existed historically prior to the channel modifications and construction of the Estabrook Dam. The “center cut” could be modified to be more environmentally friendly, but its function to convey flood flows and debris would have to remain because of the upstream floodplain development that occurred prior to and especially after the channelization and construction of the dam. A “two-stage” channel could be designed and constructed along the Milwaukee River between the abandoned Estabrook Dam site and extended upstream to the upper limits of the “center” cut and confluence with the east and west oxbows, a distance of 1.5-miles.

Upstream of Hampton Avenue and between the inlet and outlet of the oxbows (Lincoln Park), the "center cut" reach could be narrowed by one-third to one-half its current width using sediment excavated from the desired river channel's slightly meandered alignment. Excavated sediment would be placed behind new river banks to create a "floodplain terrace" wetland. The new river banks would use common engineered and/or bioengineered practices depending on the predicted shear forces of the river during flood events. The top elevation of the floodplain terrace would be set at an elevation that would allow flood waters to flow over and inundate the terrace and deposit sediment, nutrients and organic matter; while not increasing flood elevations upstream. Base flow water elevations would be maintained using a series of submerged rock weirs. The rock weirs would not be continuous between the opposing river banks in order to allow transport of sediment and create localized scour for creating added depth and cover for fish, and improved navigational depths. The sediment bar located at the inlet of the east oxbow and adjoining the east-side of the constructed island would be removed or modified as a submerged weir to direct some of the rivers flow through the east oxbow, while the majority of flow would still be through the river center cut. Mussels should be removed and relocated to avoid construction impacts. To the extent that it does not increase backwater flooding upstream, flow and especially sediment wash load and bed load should not be encouraged to enter the west oxbow. The west oxbow volume was expanded considerably following the removal of almost 120,000 cubic yards (equivalent to 8,500 dump trucks) of contaminated sediment, and as a result, will be more efficient at accumulating sediment. This reach is entirely located in publicly owned lands in Lincoln Park.

Upstream of the abandoned dam to Hampton Avenue (Estabrook Park), the design concept is similar to that described above. The dominant flow line of the river is the right or west bank along private properties. The "floodplain terrace" would be constructed along the County-owned property on the opposite bank. Material for backfilling of the floodplain terrace wetland would need to be imported since the existing channel is bedrock. Design for the enhanced channel plan form and dimensions would be different than the Lincoln Park reach upstream to account for the dynamic flow regime contribution from the highly urbanized Lincoln Creek watershed.

Admittedly, it would remain to be determined if effective water depths could be created that would accommodate deep drafting power boats at the expense of increasing sedimentation, flooding and drainage problems, and optimizing habitat enhancements. That said, the river's historic uses did not likely include deep drafting power boats.

Summary

<u>Historic Morphology – "Drainage Lake" or River</u>

Dam repair proponent's arguments that the historic morphology was a "drainage lake" is technically flawed and not based on historic river modification records. There never was a natural drainage lake in Lincoln and Estabrook Parks. Deepening and widening of the 1.5-mile river reach altered or destroyed those features or buried them in accumulated sediment after constructing the dam and impoundment. Construction of the Estabrook Dam and impoundment did not replace the unique historic features of the Milwaukee River. It did not replace the former narrow and deep meandering river and floodplain

wetlands. It did not replace historic fluvial processes that transport water and sediment, build floodplain and maintain historic and sustainable water depths. By all measures, the Estabrook Impoundment is longer by 1-mile, deeper by at least 0.4-feet, larger by 38-acres, and wider between 140-feet and 350-feet than the historic Milwaukee River.

An argument that a drainage lake may have existed since before the end of the Wisconsin glaciations (over 10,000 years ago) is not relevant to the river that existed at the time of European settlement and present day arguments by dam repair proponents to restore the natural "drainage lake". Secondly, the historic low-gradient, narrow and deep run and pool stream features, and meandered river morphology in Lincoln and Estabrook Parks is not unique to the Milwaukee River watershed. There are numerous examples of similar river reaches in Milwaukee, Ozaukee and Washington Counties, some have been altered and others remain in a relatively natural state. Lastly, by many abiotic and biotic measures, the Milwaukee River in Lincoln and Estabrook Parks prior to excavating the river and construction of the Estabrook Dam and its impoundment was a free-flowing river and supported river ecological functions and values. All rivers transport water and sediment. The physical, chemical and biological functions of the river ecosystem depend on this process. Unlike a "drainage lake", a river's flow of water, its sediment and its nutrients is unidirectional and because the water is flowing, the river is undergoing continuous physical change. A river's channel plan form (e.g., meanders) and other dimensions (e.g., depth, width), as well as its floodplain, is dependent on the channel slope and the balance between the supply of water and sediment that is transported during flood events that typically occur every one to two years. Compared to drainage lakes, rivers have a high degree of habitat diversity.

Sediment Management

Management of sediment quality and quantity is the most important issue affecting the near-term (years) and long-term (decades) outcome following a decision to repair and operate a dam or dam removal. Sediment functions as the major storage and recycling compartment for virtually all material that flows into and out from aquatic ecosystems. The quality and quantity of sediment directly or indirectly affect all of the other management issues. Managing sediment quality and quantity is the most technically challenging and costly to manage for maintaining or removing a dam, especially in developed watersheds and in particular those with a large contributing urban land use.

Dam repair proponent's empirical model estimates that the Estabrook Dam and impoundment sediment trap efficiency approaches zero are not an appropriate model for the Estabrook Impoundment, and more importantly, do not reflect the volume and thickness of sediment measured from the Estabrook Impoundment or other impoundments located in the Milwaukee River watershed. Based on recently completed sediment remediation surveys completed for the Estabrook Impoundment, sediment thickness was found up to 9.5-feet, and over 176,000 cubic yards of contaminated sediment were removed, equivalent to over 12,580 dump trucks. If the County had not been opening the dam gates and eroding a portion of accumulated sediment downstream of the dam on an annual basis, and if surveys and removal of non-contaminated sediment would have been extended throughout the 103-acre impoundment, the volume of accumulated sediment since construction of the dam in 1940 would have greatly exceeded the 176,000 cubic yards of contaminated sediment removed from the impoundment.

The sediment trap efficiency is much greater than 0%. There are numerous other impoundments in the Milwaukee River watershed that one could apply the empirical sediment trap efficiency model to and the results would also estimate trap efficiencies as near zero. In the real world, as with the Estabrook Impoundment, these impoundments accumulate large volumes of sediment. The former 90-acre North Avenue Impoundment located just downstream of the Estabrook Dam, had a sediment volume of 710,000 cubic yards and up to 12-feet thickness that equates to a sedimentation rate of 1-inch per year.

Without the ability to annually raise the Estabrook Dam gates and "flush" a portion of accumulated sediment from the impoundment, sediment will accumulate at a faster rate than historic sedimentation rates, and environmental degradation will follow. The rate of degradation and nuisance conditions will not be the same for all the various physical, chemical and biological metrics, nor will all areas of the impoundment experience the same rate of declining quality. Following the seven-year long drawdown and the $49 million removal of 174,000 cubic yards of contaminated sediment, the quality of Estabrook Impoundment today is as good as it will ever be. Now is the time to remove the dam.

Dam Operation

The original approval for constructing the Estabrook Dam was for a full pool and run-of-the-river, meaning that the gates would be closed year around and the impoundment filled, except during flood events. Over the last several decades, the County has departed from this operating protocol by opening the gates in early-fall and closing the gates in late-spring, over a 7-month period. Impacts associated with partial or complete seasonal impoundment drawdowns include scouring of polluted sediment and debris downstream; high flows and freeze/thaw cycles that contribute to erosion of river bed and banks; desiccation, freeze-out and increased predation of mussel beds; desiccation, freeze-out and erosion of aquatic plants, invertebrates, and herptiles; de-watering of floodplain wetlands; loss of fish spawning substrate and juvenile refuge; fish stranding and fish kills by asphyxiation, and poor fish year class recruitment; and degraded aesthetics to describe a few.

There is no formal accounting as to why Milwaukee County has departed from the original year around full pool and run-of-the-river flow condition. Some previously stated reasons included allowing annual "flushing" of accumulated sediment; enabling private riparian homeowners to install and remove private piers, and allow inspection and repair of eroded private shorelines; prevent creation of river ice dams; protect the dam gates from ice and debris buildup; and avoid spring flood and drainage damages to upstream homeowners. Based on the impacts described above, none of the reasons and benefits for continuing the impoundment drawdowns can be justified.

All impoundments accumulate sediment. Depending on the quality and quantity of sediment that accumulates, the desired function and uses of the impoundment may not be sustainable. With respect to the Estabrook Impoundment, the owners of a dam and users of the impoundment must recognize that the environmental impacts of annual drawdowns exceed the benefits of flushing accumulation of polluted sediment from the impoundment to decrease maintenance and dredging. If owners of the dam and a limited number of users of the impoundment are unwilling to accept the consequences of sediment accumulation, they should consider other dam management alternatives and uses of the river

that are sustainable, benefit the environment, provide more diverse uses for a larger segment of the population, and at a lower cost.

Riparian landowners can remove and install piers, and inspect and install bank erosion practices without the need to lower water levels. Waterfront homeowners all over the state are able to accomplish these tasks without the manipulation of water levels, regardless of their properties being located on impoundments, lakes or rivers.

Partial or complete drawdowns of the Estabrook Impoundment will not be effective at preventing the formation of ice dams, in particular in the river reach upstream of Silver Spring Drive. Early planners for deepening and widening of the river channel observed that the narrow river channel, the "big bend" in the river and weather conditions were factors that would continue to contribute to the formation of ice dams along this reach of the river. Factors that can contribute to formation of ice dams in this reach include extreme and prolonged cold temperatures, accumulation of ice at obstructions to flow including river bends, confluence of large contributing tributaries, changes in channel slope, channel narrowing, bridges and dams. Extended drawdowns have not been shown to be an effective practice for preventing ice dam formation upstream of Silver Spring Drive. The Estabrook Impoundment has been drawn down since 2008 and significant ice dams developed during 2014, and a smaller but no less threatening ice dam formed and failed in December 2015.

The County must be responsible for providing long-term funding for technical upgrades including the addition of heaters and aerators to prevent icing of the dam gates, and for hiring and training personnel to manage debris, monitor river flows and operate dam gates in a timely manner to avoid flooding and drainage damage, and environmental impacts.

Development of Nuisance Conditions

The morphology of the Estabrook Impoundment is diverse enough such that not all areas have their water thoroughly mixed and replaced at the same rate, especially during the warm water summer growing months when Milwaukee River and other contributing flows are lowest and over longer periods of time. These areas may include the "east and west oxbows", the lower reaches of Lincoln Creek and confluence with the Milwaukee River, the Blatz Pavilion Lagoon, the gated section of the dam's spillway, the subtle indentations of the center-cut located between the two islands and oxbows, and the wide monotonous reach between Hampton Avenue and the dam where the flow is concentrated along the right bank. Based on high nutrient levels, the Estabrook Impoundment would be classified as a eutrophic pond such that the condition would be suitable for the development of nuisance amounts of planktonic and benthic algae. Some species of blue-green algae can produce toxin.

The Estabrook Impoundment will continue to accumulate nutrient and organically rich sediment, and with sufficient sunlight penetrating all water depths throughout the impoundment, conditions will be ideal habitat for benthic algae and rooted aquatic plant production. As was observed for the former North Avenue impoundment and other impoundments in the Milwaukee River watershed, similar conditions produced nuisance biomass of rooted aquatic plants, in particular non-native Eurasian

watermilfoil and Curly-leaf pondweed which unlike many native plant species, are tolerant of degraded habitat. The Estabrook Impoundment will not be immune to developing similar nuisance conditions.

Polynuclear aromatic hydrocarbons (PAHs) and heavy metals are ubiquitous with urban runoff. One should expect that polluted sediment will accumulate in the Estabrook Impoundment, albeit at less than the extreme concentrations that were recently removed. The health effects of repeated human exposure to low levels of PAHs may not be known. However, exposure of PAHs at low levels can be toxic to aquatic life and wildlife. PAH toxicity is magnified when exposed to the Sun's ultraviolet light and sunlight can penetrate all the shallow depths of the impoundment. This is problematic for wildlife especially sensitive reptiles and amphibians that spend a fair amount of time in water and floodplain habitats. The potential chronic and acute affects to aquatic life and wildlife impact entire life cycles and generations.

Fish and Aquatic Life and Habitat

The addition of fish passage will have no bearing on fish habitat in the Estabrook Impoundment. It will not affect habitat aside from the footprint it is constructed on. A fishway will not affect the most important issue impacting fish habitat and the fishery in the impoundment, that being the quality and quantity of sediment and the rate by which it accumulates.

The quality and quantity of sediment has a direct and indirect affect on fish and aquatic life habitat. Nutrient and organically rich sediment can produce nuisance biomass of plant material that impact dissolved oxygen levels through plant respiration and their decomposition will contribute to sediment oxygen demand. Eutrophic and turbid water quality conditions benefit tolerant non-native aquatic plants species such as Eurasian watermilfoil at the expense of native species that are better utilized for food and cover by fish, other aquatic life and wildlife. The accumulation of impounded sediment enriched by substances such as heavy metals and PAHs from urban runoff can have acute and chronic impacts on fish and aquatic life at all life stages and the impacts can extend over generations. The accumulation of silty-clay sediment, potentially toxic compounds, nutrients and organic matter from benthic algae and decomposing plant material create very inhospitable habitat for fish and other aquatic life.

Most of the approximately 60 native fish species present in the Milwaukee River and its tributaries evolved and are specialized for all or a portion of their life cycles (spawning/reproduction, development, feeding and growth) in flowing rivers or streams, and floodplain wetland habitats. The value of flowing rivers and streams with clean and coarse substrates and connected floodplain wetlands as critical fish habitat cannot be over stated. They require clean and coarse substrate for spawning and successful embryonic development; their diets are primarily aquatic insects that also require clean and coarse substrate; they spend most of their lives in direct contact with the substrate; many are intolerant of degraded water quality and sediment; and some require wetlands and aquatic plant vegetation for spawning and nursery habitats. These critical features are generally absent from the Estabrook Impoundment. As the impoundment continues to accumulate silty sediment, habitat suitable for preferred native species will be poor, which means less native fish will successfully reproduce and recruitment to local populations will be low.

Habitat quality affects the diversity and abundance of the fish community. Inversely, the presence and abundance of a single species can change the dynamics of a river ecosystem, including its habitat. There may be no better demonstration of fish specie's negative impact on aquatic ecosystems than the non-native common carp. Carp will do very well in the Estabrook Impoundment. No other species, native or non-native, is so well adapted to degraded habitat, and modifying habitat to their benefit and at the expense of native species as the carp. Carp spawning success is reduced in flowing water with coarse substrates. Optimum spawning habitat is slack backwater areas with vegetation. Carp tolerate high water temperatures and turbidity, and low dissolved oxygen levels, and incubating carp eggs can tolerate silty sediment. As omnivores, carp consume a wide range of food types and can adapt to changing food supplies caused by environmental degradation. As bottom feeders, they have adapted to feeding on small invertebrates also tolerant of fine silty substrate and poor water quality. As carp feed, they re-suspend nutrient-rich silty sediment and uproot aquatic vegetation and by doing so increase turbidity. Turbid water is not tolerated by native aquatic plants, and as a result, native plants populations decrease and non-native plants tolerant of turbidity such as Eurasian watermilfoil and benthic algae flourish. Turbid water limits site feeding by top predators such as northern pike and bass that might otherwise feed on younger carp before they reach spawning age. Absent natural controls, carp populations can proliferate in just a few years. Successful spawning and recruitment of carp will infect more than just the Estabrook Impoundment as offspring will migrate to other reaches of the Milwaukee River and its tributaries, the Milwaukee Estuary and Lake Michigan. Prior to removal of the Milwaukee River's North Avenue Impoundment, the feasibility study correctly predicted a decline in carp populations and an increase in smallmouth bass populations. These predictions were consistent with those observed following the removal of the Milwaukee River Woolen Mill Dam at West Bend.

Following removal of the North Avenue Dam, improvements in the riverine habitat increased native fish species diversity several fold in the formerly impounded area from six native species in 1990 to 35 native species in 2012. Smallmouth bass became and remain the most abundant game species. Additional native game fish included walleye, northern pike, channel catfish, largemouth bass and rock bass. Concurrent with the improved diversity and relative abundance of native fishes, there has been a dramatic decrease in common carp populations which once comprised over 90% of the numbers of fish and total biomass. Overall environmental quality as measured by the fish-based Index of Biotic Integrity (IBI) bioassessment model increased from "poor" prior to removal of the North Avenue Dam in 1996 to "good" to "excellent" following dam removal in 1997 and through 2012. Similar improvements in fish habitat and fish communities have been observed at dam removal projects elsewhere in the Milwaukee River watershed. There are no reasons not to expect comparable improvements in the Milwaukee River habitat and the fish community should the Estabrook Dam be removed. Inversely, as the Estabrook Impoundment continues to accumulate polluted silty substrate, there is no reason not to expect degraded fish habitat and fish community dominated by a few tolerant species and an abundant carp population.

Recreational Use

The Estabrook Dam and impoundment does not provide any unique recreational use opportunities for County residents. Proponents have previously argued that navigation by deep drafting power boats, small

personal watercraft such as canoes and kayaks, swimming and ice skating opportunities would be reduced or eliminated without the Estabrook Dam and impoundment.

There are no adequate public boat launch and trailer parking facilities along the impoundment that would allow all County residents an opportunity to participate in power boat or powered personal watercraft (e.g., jet skis) recreation. Those opportunities are generally available to river property owners that typically launch and retrieve their power boats once during the boating season, and otherwise dock along the dockside at their waterfront properties. There is a "public" launch located at the end of Apple Blossom Lane in the City of Glendale. However, the launch is in fair condition at best and is not always maintained, and vehicle and trailer parking is very limited along the residential street. For congestion and safety reasons, the size and width of the Estabrook Impoundment is not conducive to a large number of high speed powered boat users. If the County chose to adopt a safe boating ordinance that is consistent with the state boating safety laws, power boat speeds would be limited to slow no wake within 100-feet of a shoreline, and within 200-feet of a shoreline for powered personal watercraft (PWC). By my estimates, power boats would be limited to wake speeds for only 1-mile of the 3-mile long impoundment and just 34-acres between the dam and the upper confluence of the east and west "oxbows". PWC would be limited to just over 1,000-ft and 9-acres of river. The historic river's narrow median width of just 160-feet and maximum depth of 6-feet would not have been compatible with today's demands for an impoundment to accommodate deep drafting power boats, high-speed personal watercraft (e.g., jet skis) and activities such as water skiing.

Proponents for repairing the dam suggest that the impoundment could once again support a public swimming beach. Prior to construction of the Estabrook Dam, there were two public beaches on the free-flowing Milwaukee River. One located in the historic river meander and present day "east" oxbow. The other beach was located downstream of the dam and Estabrook Park "falls". Neither facility is in operation today having been abandoned presumably because of poor water quality. Accumulation of sediment may not have been an issue at the beach located below the dam and falls, but following the construction of the river's "center cut" the historic meander was abandoned to form the "east oxbow" which like its current condition, would have accumulated significant volumes of silty sediment. Based on long-term and recent bacteriological monitoring results from the impoundment and Lincoln Creek, full body contact uses of the impoundment may not be a healthy practice worthy of re-creating a public beach. Urban runoff and leaking sanitary sewers are likely contributors to high levels of Fecal coliform and Escherichia coli bacteria.

Proponents for repairing the dam have also proposed re-creating ice skating opportunities on the impoundment. The County operates just nine formal ice skating facilities, of which four are on ponds with the remainder being artificially flooded land-based sites. Staffing and budget constraints, lack of interest or other factors may account for the limited number of ice skating facilities offered by the County. River ice, even impounded river ice, is not safe relative to land based or a small, quiescent pond. River currents, flow and freeze/thaw cycles, snow melt and storm water runoff, warmer water from Lincoln Creek affect the quality and safety of ice. While the County would have difficulty controlling all park access points

along the impoundment, they would likely restrict formal ice skating to backwater areas that are easy to monitor. This would be an added cost to the Parks already limited budget.

Flood and Drainage Damages

The environmental impacts following modification of the river by lowering the original rock outcrop, deepening and widening the channel over a distance of 1.5-miles, and constructions of the dam have been severe. These modifications may have reduced some of the flooding caused by the river channels limited conveyance of flood flows and ice dams, but they did not eliminate them.

Removal of the Estabrook Dam is the only dam management alternative that reduces potential flood damages from the Milwaukee River or from submerged storm sewers. Compared to the dam removal alternative, the dam repair alternative:

- With all 10 flood gates open, the 100-year flood event elevations increase between 0.5 and 1.5-feet between the dam and Bender Road
- If the County is unable to raise all 10 gates of the dam during the 100-year flood event because of obstacles such as unsafe access to the dam, staff availability, the loss of power during the storm, mechanical gate failure, or the accumulation of ice and debris at the gates, the flood water elevations would be as much as 1.5 feet higher than the 100-year flood elevation near the dam with the gates open, and continue to exceed the 100-year flood elevation at Bender Road. This would result in flood damages to more than the current 292 residences in the current 100-year floodplain.
- If the County is unable to raise all 10 gates during more frequent and less extreme flood events slightly greater than the 10-year flood (15-year flood event), the flood levels and resulting damages would be similar to those experienced during the 100-year flood with all 10 gates raised.

There are approximately 292 residential properties in the 100-year floodplain, 163 properties have water frontage and 129 are located inland from the river and do not have waterfront property and access to the river. In the event that the County is unable to raise all of the dam gates in a timely manner, even for floods much less extreme than the 100-year event, the number of waterfront properties experiencing flood damage will remain the same, however the number of properties experiencing flood damage would increase. If all the dam gates cannot be opened in a timely manner and flood damages occur, it would increase the County's exposure to flood damage liability.

Proponents for repairing the dam suggest that the SEWRPC flood model data, predicted flood water elevations and flood damage estimates for the Milwaukee River are not accurate. They cite the June 1997 flood that approximated the 200-year flood event and limited flood damages in the flood prone Sunny Point neighborhood located between Silver Spring Drive and Bender Road as evidence. While the observed record flows (16,650 cubic feet per second) at the Estabrook Park USGS flow gage located downstream of the dam and Lincoln Creek did occur, Lincoln Creek contributed more than 50% of the peak flow at the USGS gage. Lincoln Creek is located 1-mile downstream of the Sunny Point neighborhood. By way of a flow mass balance, the Milwaukee River at Bender Road did not exceed the 10-year flood event.

Costs

Dam repair and construction of a fishway costs are estimated at $6.2 million or $4.5 million more than dam removal at $1.7 million. Proponents for repairing the dam cite potential law suits against the County for lost property land values should the dam be removed. They suggest that the liability to the County would be $12 million, and as such, this liability to the County should be included in the costs for dam removal. Riparian's along the Estabrook Impoundment would still have the same amount of water frontage, would own access to the river, and have title to the thread of the lands flowed by the river to the centerline of the channel with or without the dam. While the type of navigational use may no longer support recreational navigation by deep drafting power boats, the river would be navigable nonetheless if only by smaller personal watercraft such as canoe and kayak. Presumably, not all waterfront residents operate deep drafting power boats. If all 163 waterfront landowners owned and operated deep drafting power boats, the $4.5 million dollar difference between the estimated costs for repair of the dam versus dam removal would amount to a taxpayer subsidy of over $27,000 per landowner for the unique boating privilege.

Based on my understanding of relevant Wisconsin state law, absent a specific covenant between the County and riparian landowners, landowners that live on an impoundment do not have any rights to water levels that would require the owner of a dam (in this case, the County) to maintain the dam and the resulting impoundment in perpetuity.

To lessen or eliminate the costs to County taxpayers, riparian landowners could form a lake association or district and levy fees for the operation and maintenance of the dam, or accept a special County assessment for maintaining their unique privileges afforded by the dam and impoundment.

Alternatives

Removing the dam will not completely "restore" the historic Milwaukee River's morphology and as a result, its historic uses and values. That train has left the station following widespread land use changes and additional development in the river's floodplain. However, removal of the dam would be the first step toward mitigating 1.5-mile of destructive river channelization and the loss of over 100-acres of floodplain wetlands excavated or inundated by the impoundment. Should the dam be removed and there is a desire to enhance the historic functions and uses of the river, technically viable alternatives are available. Enhancement alternatives should include at least two guiding principles:

- An understanding of sediment transport characteristics and flow regimes of the river is critical, and for projects as large and as altered as the Milwaukee River in Estabrook and Lincoln Parks, efforts should be completed with a full understanding of sustainable, fluvial geomorphology processes, and
- Establishment of project objectives that are sustainable, technically feasible, cost effective and fundable, and accepted by the majority of County and river stakeholders.

One such design would approximate the narrow and deep low-gradient river channel dominated by run and pool features that existed historically prior to the channel modifications and construction of the Estabrook Dam. The "center cut" could be modified to be more environmentally friendly, but its function to convey flood flows and debris would have to remain because of the upstream floodplain development

that occurred prior to and especially after the channelization and construction of the dam. A “two-stage” channel could be designed and constructed along the Milwaukee River between the abandoned Estabrook Dam site and extended upstream to the upper limits of the “center” cut and confluence with the east and west oxbows, a distance of 1.5-miles.

Upstream of Hampton Avenue and between the inlet and outlet of the oxbows (Lincoln Park), the “center cut” reach could be narrowed by one-third to one-half its current width using sediment excavated from the desired river channel’s slightly meandered alignment. Excavated sediment would be placed behind new river banks to create a “floodplain terrace” wetland. The new river banks would use common engineered and/or bioengineered practices depending on the predicted shear forces of the river during flood events. The top elevation of the floodplain terrace would be set at an elevation that would allow flood waters to flow over and inundate the terrace and deposit sediment, nutrients and organic matter; while not increasing flood elevations upstream. Base flow water elevations would be maintained using a series of submerged rock weirs. The rock weirs would not be continuous between the opposing river banks in order to allow transport of sediment and create localized scour for creating added depth and cover for fish, and improved navigational depths. The sediment bar located at the inlet of the east oxbow and adjoining the east-side of the constructed island would be removed or modified as a submerged weir to direct some of the rivers flow through the east oxbow, while the majority of flow would still be through the river center cut. To the extent that it does not increase backwater flooding upstream, flow and especially sediment wash load and bed load should not be encouraged to enter the west oxbow. The west oxbow volume was expanded considerably following the removal of almost 120,000 cubic yards of contaminated sediment, and as a result, will be more efficient at accumulating sediment. This reach is entirely located in publicly owned lands in Lincoln Park.

Upstream of the abandoned dam to Hampton Avenue (Estabrook Park), the design concept is similar to that described above. The dominant flow line of the river is the right or west bank along private properties. The “floodplain terrace” would be constructed along the County-owned property on the opposite bank. Material for backfilling of the floodplain terrace wetland would need to be imported since the existing channel is bedrock. Design for the enhanced channel plan form and dimensions would be different than the Lincoln Park reach upstream to account for the dynamic flow regime contribution from the highly urbanized Lincoln Creek watershed. A significant source of funding could be provided by a variety of state and federal habitat restoration grants.

Billions of dollars have been invested by private entities and public tax dollars over the last several decades to enhance the beneficial uses of the area’s water resources. In general, dollars are decreasingly available for these types of projects. For Milwaukee County residents and political leaders, we have ever increasing and competing fiscal needs and realities for our County-run public facilities. Absent an agreement among all stakeholders to identify and evaluate additional dam management alternatives that “enhances” as many of the river’s historic environmental, social and economic functions and values for the greatest number of users, the weight of evidence among the existing short list of alternatives described in the EA supports the removal of the Estabrook Dam and a return to a free-flowing river and functional floodplain wetlands.

A decision to maintain an 80 year old structure that offers limited benefits at great cost without considering other viable alternatives is not responsible. If we knew then what we know now about the costs, impacts, and sustainability of the resource; perhaps the dam would never have been built. In the words of David Rosgen, a practitioner of river restoration, *"We all tend to learn directly from past experience of trial and error, but if we do not understand – if we do not take a closer, quantitative look at our rivers over time – we have a tendency to unknowingly repeat the errors of the past."*

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