Habitat Enhancement using Water Level Management on the Upper Mississippi River

Water Level Management Task Force

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Habitat Enhancement Using Water level Management on the Upper Mississippi River

A Summary of the Research and Monitoring Results from
Seasonal Water Level Reductions in Navigation Pools 5, 6 and 8

Compiled and Edited by

Ruth Nissen, Wisconsin Department of Natural Resources

River Resources Forum-Water Level Management Task Force
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Contents

Tables

Figures

Executive Summary

The Upper Mississippi River System

The Upper Mississippi River System (UMRS or Upper Mississippi River) as defined by Congress in the Water Resources Development Act of 1986, includes the Upper Mississippi River from Minneapolis, Minnesota to Cairo, Illinois; the Illinois Waterway; and navigable tributaries. In this Act the UMRS was recognized as being a both a nationally significant ecosystem and a nationally significant commercial navigation system.

Water Level Management on the Upper Mississippi River

Water level management on the Upper Mississippi River has been a process based on scientific analysis as well as adaptive management through a series of demonstration projects and experimental water level reductions or draw-downs under the guidance of the Water Level Management Task Force (WLMTF), a technical advisory group to the River Resources Forum. The River Resources Forum (RRF) is an advisory body to the U.S. Army Corps of Engineers-St. Paul District, and was formed to offer recommendations and coordination of river-related issues. The WLMTF members include:

- U.S Army Corps of Engineers- St. Paul District,
- U.S. Fish and Wildlife Service,
- U.S. Geological Survey,
- U. S. Coast Guard,
- Iowa Department of Natural Resources (DNR),
- Minnesota DNR and Department of Transportation (DOT),
- Wisconsin DNR and DOT,
- representatives from the commercial navigation industry,
- non-governmental organizations (NGOs),
- citizen groups.

In 1995 the WLMTF began to evaluate the potential for water level management in the northern reaches of the UMRS with funding and technical support from the U.S. Army Corps of Engineers-St. Paul District. After successfully conducting several small-scale drawdowns, a demonstration large scale drawdown of a navigation pool was planned. Pool 8 was chosen for the first pilot large-scale drawdown following a lengthy selection process. The goals of the pilot pool drawdown as established by the WLMTF were as follows:

1. Improve conditions for the growth of aquatic vegetation with special emphasis on perennial emergent species.
2. Continue to provide safe navigation channel for use by 9- foot draft commercial transportation vessels and barges.
3. Minimize adverse effects on river resources and river users to a level acceptable to the public.
4. Increase the level of knowledge concerning the effects of a pool drawdown to support future decisions concerning the use of this management measure.

Ecological objectives for the drawdown included:

1. Increase the extent of emergent and submersed aquatic vegetation.
2. Consolidate sediment and reduce sediment resuspension following reflooding.

A monitoring effort was planned to evaluate the effects of the drawdown on maintenance of the navigation channel, vegetation, fish and wildlife, water quality, nitrogen, sediment consolidation, contamination, recreation and commercial uses of Pool 8 and cultural resources.

The Pool 8 drawdown was initially scheduled for the summer of 2000; however it was postponed due to projections of summer river discharges not conducive to implementing the drawdown. The drawdown of Pool 8 (1.5 -feet at the lock and dam) was conducted June-September 2001 and repeated in 2002.

A similar drawdown of Pool 5 was conducted in 2005. An attempt was made to repeat the drawdown in 2006 but due to low flow conditions the drawdown was discontinued several days after reaching the target level.

An experimental minor drawdown (a drawdown of 1-foot at the lock and dam) was scheduled for Pool 6 in 2003, 2004, 2008, and 2009, but river conditions were not conducive to a drawdown. A drawdown of Pool 6 was conducted in 2010.

Planning was conducted for a minor drawdown in Pool 9 including the completion of the Definite Project Report (DPR) and a hydraulics and hydrology analysis. A shallow water mussel survey was also completed but a pool wide population estimate was also considered necessary. In 2006 planning efforts were discontinued because vegetation surveys conducted in 2005 indicated the vegetation status was satisfactory especially in the middle and lower portions of the pool.

Summaries of Monitoring and Research Results

A brief summary of the monitoring results for each of the pools by component follows. The pools are listed by the chronology of the drawdowns, i.e. Pool 8, Pool 5 and Pool 6.

Navigation Channel Dredging Summary

In both Pool 8 and Pool 5 a large amount of dredging was done to deepen the navigation channel so commercial traffic could continue during the drawdown. In both pools this resulted in reduced dredging for several years following the drawdowns. Subsequent analysis indicated that increasing the amount of sand dredged in a given year will increase sediment trap efficiency and as a result the annual dredging volumes will increase over time.

Channel Hydraulics and Sediment Transport

During the drawdowns in both Pool 5 and Pool 8, discharge measurements indicated that a greater percentage of the total river flow was conveyed in the main channel, and that main channel flow velocity increased. Discharge measurements in secondary channels indicated that flow in the secondary channels closer to the dam was decreased to a greater extent than those further upstream, and that at some point the effect of the drawdown was not measurable. The results of a two dimensional hydraulic model indicate that while velocities in the main channel are increased, velocities in secondary channels are not changed significantly.

The increase in channel velocity caused increased bed material (sand) transport in the main channel. Based on one -dimensional model results in Pool 5, a drawdown increases the sediment transport capacity in the main channel, however because of longitudinal differences in this capacity, dredge cuts fill in at a faster rate than during non-drawdown periods. This is because most dredge cuts are located downstream of secondary channel flow splits where there is an abrupt decrease in the sediment transport capacity in the navigation channel. When water levels are drawn down, the sediment transport capacity is increased because of the higher flow and velocities in the main channel, however there is still differential capacity due to the secondary channel flow splits. While this causes more rapid infilling during the drawdown, drawdowns are usually done during low to moderate flows when sediment transport is not significant. This means that the additional dredging that was done to do the drawdown lasts into the next year, and as explained above, several years more.

Tributary degradation in Pool 8 was not significant. Some degradation occurred on Coon Creek near the mouth of the creek; however it was generally less than 0.5 feet. Changes occurred on the Root River also, however these changes were not consistent with what would be expected from a drawdown and were probably caused by flow events on the Root River.

Vegetation Response

Pool 8

More than 50 species of moist soil, perennial emergent and submersed aquatic plants were identified on the exposed substrate. The plant response to the drawdown was very similar to the results of a seedbank study designed to quantify the availability of seed. Plant density, plant diversity, moist soil seed, and arrowhead tuber production were largely related to the duration of substrate exposure. A shift was observed from a plant community dominated by annuals the first year of the drawdown to one dominated by perennials the second year. Growth of perennial emergent vegetation was robust the second year and arrowhead tuber production increased 16-fold across transects examined. Submersed aquatic plants were not negatively impacted by two summer drawdowns. Following the drawdowns, a substantial expansion of aquatic plant communities in the lower third of the pool was recorded, as well as a comparable reduction in open water habitat. The perennial plants grown on the sand and mudflats during the drawdowns persisted for at least six years post drawdowns (2003-2008) in some areas.

Much of the plant response observed on exposed substrates was directly influenced by the drawdown. Many emergent, moist-soil, and terrestrial species that require exposed substrates or shallow water (i.e., < 5 cm) for germination and development would not have become established under the normal flooding regime

Pool 5

More than 70 plant species were identified on the exposed substrate. Similar to Pool 8, there was a predominance of annual plants the first year, followed by a shift to more perennial species the second year. Submersed vegetation was not negatively impacted and increased in some areas. Changes in vegetation from 2005-2009 were also monitored. A number of desirable plant species that were established on exposed substrates during the 2005 drawdown persisted, and in some cases flourished, through 2009. A general pattern of increase was observed in submersed aquatic plant species and a decrease in moist soil and terrestrial species including willows in 2009 compared to the vegetation composition of the same area in 2005-2007. The pattern in emergent aquatic vegetation varied by species. Much of the emergent vegetation that occurred within the sampling area (substrates exposed in 2005) was likely established with the 2005 drawdown.

Pool 6

Sixty-six plant species were identified on exposed substrates. Growth of broadfruit bur-reed, barnyard grass, chufa flatsedge, redroot flatsedge, and rice cutgrass was robust in some areas. A comparison of frequency of occurrence of plant species observed during the Pool 6 drawdown to that occurring during the 2005 drawdown on Pool 5 indicate some notable differences. Moist soil species were not as prevalent, common arrowhead and soft-stem bulrush occurred less frequently, and submersed aquatic species were generally more widespread among Pool 6 sample sites compared to Pool 5 sites. This pattern was most likely related to the re-inundation of much of the exposed area of Pool 6 due to the bounce in the elevation (and river discharge) during mid-August.

Fish Response

<u>Pool 8</u>

Overall, there were no negative short-term trends or differences in fish catch rates that could be attributed to the drawdown. An increase was observed in catch rates for the forage fish group and in the catch rate for bluegill in mini fyke nets and largemouth bass in fyke nets, surrounding the drawdown period. No fish kills were observed in the backwaters.

<u>Pool 5</u>

Even though there was a decrease in the bluegill young of the year abundance in Pool 5 the year of the drawdown, there was no detectable effect from the drawdown on the 2005 year class by 2006. This data suggests that any negative impact on spawning success the year of the drawdown is outweighed by improved survival of the young of the year. The large increase in bluegill abundance which occurred in both Pool 5 and 8 two years post drawdown suggests the drawdown may have had a positive effect on nursery habitat.

Freshwater Mussels

<u>Pool 8</u>

A pre-drawdown survey conducted in 1999 indicated that limited numbers of mussels were in the drawdown zone, therefore no large scale monitoring effort was planned for 2001. An informal survey conducted during a volunteer mussel rescue effort in July 2001 indicated more mussels than expected on exposed sites, possibly due in part to the effects of the extended flood in spring 2001.

<u>Pool 5</u>

Monitoring the effects of the drawdown on freshwater mussels in shallow water indicated mussel survival differed by species and was related to the initial water depth and the slope of the site. Mussels impacted the most included those located in one foot of water on flat sites. Mussel mortality on the exposed areas was greater than was anticipated. Therefore to better estimate the significance of mussel mortality, a comprehensive survey of mussel populations was completed in Pool 5 in 2006 to determine a statistically accurate estimate of the pool-wide mussel population.

The population study estimated 189 million mussels in Pool 5 (95% CI range = 152-221million), with a relative error of less than 20%. Of this total, 2.3 million mussels were estimated in the shallow dewatered zone (95% CI range = 1.0-3.6 million). The estimate in the shallow zone had a relative error much greater than 20%. No mussels were collected in 2006 at depths less than 10 inches (0.25-meter) possibly due to a combination of increased aquatic vegetation in the shallow dewatered zone and mortality of mussels during the 2005 drawdown.

<u>Pool 6</u>

The survey objective was to estimate total live mussels within Pool 6 to estimate the proportion of the total population that could be impacted by dewatering. The study estimated 60,530,422 mussels in Pool 6 (95% CI range = 45,551,530 -75,509,313). The systematic design did not produce acceptable estimates in the dewatered area during the Pool 5 survey therefore a different design was tested in Pool 6. A one-stage cluster double sampling design was selected for surveying mussel populations in shallow areas. Using the total population estimates in dewatered area from the quantitative sampling (total = 333,278; 95% upper confidence limit = 535,839), the percent of mussels that were in the predicted dewatered area was about 0.55% (95% upper confidence limit of 1.19%).

Mortality, movement and behavior of two species of mussels in response to lowering of the water levels were studied. Across both species, estimated mortality was 5% during the non drawdown year (2009) and 11% during the drawdown (2010). Mortality estimates in *Lampsilis cardium* were ~2 times higher than those in *Amblema plicata.* All mussels generally moved perpendicular to shore into deeper water regardless of the year, treatment or slope. Overall mussel movement was ~ 1.5 times higher at the treatment sites than the reference sites in 2010.

Burrowing into the substrate and being in the shade increased survival of *Amblema plicata,* but did not increase survival of Lampsiline species in another experiment despite similar burrowing behavior. Without the ability to move to deeper water these animals perished. Aestivation by sealing in moisture and avoiding temperature extremes brought on by exposure to direct sunlight is probably impossible for many Lampsilines due to shell morphology but was still only a marginally effective survival strategy for *Amblema plicata*.

Shorebird Response

Pool 8

The water level reduction in Pool 8 created important foraging habitat for migrating shorebirds as indicated by the number of shorebirds and the different species observed. In 2002, the number of shorebirds observed during weekly monitoring surveys nearly doubled from the 2001 season. The increase in 2002 was primarily due to observations during three surveys in late August and early September, a time period when the drawdown had ended in 2001 due to low flow conditions in the river. The survey results indicate the importance of maintaining a drawdown to mid- September if feasible to provide habitat for peak shorebird migration during late August and September.

Pool 5

Temporary feeding areas created by the drawdown were quickly found by locally breeding shorebirds. Although the surveys did not detect a significant increase in migrating shorebirds this is probably due to both the lack of a weekly survey and an inability to get close enough to the exposed substrates using the Go-Devil in 2005 and the premature end of the 2006 drawdown in July.

Waterfowl Response

Pool 8

There was a positive response by waterfowl, including dabbling ducks, and Tundra Swans to the improved habitat which resulted from the drawdowns. Dabbling ducks responded to the food resources offered by flooded moist soil annual plants in September which grew during the first year of the drawdown on the exposed substrates. The restoration of emergent vegetation in lower Pool 8 that resulted from the drawdown changed dabbling duck and swan distribution within Pool 8. Swan use was maintained from 2002 –2007 in some areas, which suggests the drawdown effect on the expansion and development of arrowhead beds and other emergent aquatic plants has been sustainable for at least six years post-drawdown. Swan use was maintained after 2007 but the construction of Phase III Islands in 2008-2009 also affected swan distribution.

The positive effect on habitat in Pool 8 influenced swan distribution on Pools 4-13. In 2006 Pool 8 provided 53.4 % of the total Refuge use days. The restored emergent vegetation and improved habitat conditions in 2006 in Pool 8 appear to have also influenced the Eastern Population of Tundra Swans (EP) distribution during fall migration. The average peak fall count in Pool 8 (which represents a minimum count) increased from representing 9.8% of the Eastern Population of Tundra Swans (EP) for the years 1997-2000 to 12.5% for 2001 and 2002 and 29.8 % for 2006. The difference is primarily due to the increase in use days in Wisconsin Islands Closed Area (WICA), a 6,461 acre closed area, located in lower Pool 8, which produced 93.7% of the Pool 8 Tundra Swan use days in 2006 and more swan use days than any other pool. The WICA peak count represented 27.6% of the EP.

Diving duck use days also increased steadily after the drawdowns but the increase was most likely due a combination of natural causes.

Pool 5

The response by waterfowl including dabbling ducks, diving ducks and tundra swans to the Pool 5 drawdown was evident. Use days for puddle ducks, divers, and swans were the highest recorded in 10 years. And although adjacent pools also saw an increase, the increases in Pool 5 were much more dramatic particularly for dabblers and diving ducks.

Water Quality

Pool 8

In general total suspended solids and turbidity were not significantly greater during the summer of 2001 when the pool was drawn down 1.5 feet as compared to 1999 when accounting for changes in river flow between the monitoring periods. Wind induced effects on sediment resuspension explained less of the variation in total suspended solids, turbidity or light penetration than river flow. As a result, it cannot be concluded that wind-induced effects on sediment resuspension were greater during the drawdown based on these data. There were no obvious changes in water quality parameters that could be directly attributed to the drawdowns. Most parameters were within the normal range of variability and followed the same patterns or trends as previous years.

Pool 5

There was no response in Pool 5 water quality that could be directly attributed to the drawdown in the two years following at either backwater or main channel sites. Although summer turbidity levels at the Pool 5 backwater site were at record lows following the drawdown, similar results were observed in lower Pool 4 over the same time period. The low turbidity in 2006 and 2007 is likely the result of increased aquatic vegetation in these backwaters and the low discharge that occurred during this period.

Contaminants

Pool 8

The bioavailability of contaminants in the exposed sediments did not appear to increase as a result of the drawdown.

Sediment Consolidation

Pool 8

Limited consolidation of sediments was expected because most of the drawdown zone was silty-sand with low organic content. Data collected in Lawrence Lake (mid pool) showed increases in available nitrogen, which coupled with consolidation of loose organic sediments suggested that desiccation of sediment in Lawrence Lake or other areas with high organic content would likely result in improved conditions for submersed aquatic plant growth including: reduction in sediment resuspension potential, and improvement of rooting medium (i.e. nutrients and sediment texture) for submersed aquatic plant growth.

Nitrogen Cycling

Results indicate that water level drawdowns are probably not an effective means of removing nitrogen from the Upper Mississippi River.

Commercial Navigation

All three pools were described in the tow boat pilot survey as being tougher to navigate during the drawdown.

Recreation

Pool 8

Provisions were made for dredging to provide adequate access at some recreational boat landings and access channels through the federal Continuing Authority Program-Section 1135. The Minnesota-Wisconsin Boundary Area Commission served as the non-Federal sponsor for the project. The commission did not provide funds, but collected funds from local entities to support the dredging in various locations. Nine sites were dredged as part of this project. Monitoring results from the Recreation Boating Study indicated there was no reduction in recreational boating activity as a result of the drawdowns.

Pool 5

An extensive effort was made to minimize recreational boating impacts resulting from the Pool 5 drawdown, including formation of a Citizens' Advisory Committee to help identify sites to be dredged to provide "reasonable" recreational access. All sites identified and the three sites later dredged were channels used to access the main channel from a public boat ramp. Results from the recreation boating study indicate no major fluctuation in boating activity in the immediate or adjacent pools as a result of the drawdown. There were no significant trends or changes in recreational boat lockages through Lock and Dam 3, 4, 5, and 5A for the years 1989-2005. Public use access levels for Pools 4, 5 and 5A in 2003, 2005, and 2006 were examined and both 2005 and 2006 had more boating use than 2003 during the summer period. In summary, the drawdown had little effect on public use of Pool 5.

Pool 6

The WLMTF provided assistance to marina owners including: signage, maps, buoys, dredging permit assistance, etc. Recreational access dredging was provided for one site.

Cultural Resources

Cultural resources monitoring focused on known archeological sites located on the shoreline portion of Pool 8 and later Pool 5. Known sites were monitored during the drawdowns for impacts from shoreline erosion or looting. Previously unrecorded sites exposed during the drawdown were identified. Fifteen of 33 sites on Pool 8 had a high probability of impact from shoreline erosion or looting. Two of five sites on Pool 5 had a high probability of impact from erosion and looting.

Chapter 1. Water Level Management on the Upper Mississippi River

1.1 Historical Conditions and Background

The Upper Mississippi River System (UMRS) has been modified for navigation, floodplain agriculture, and flood protection for urban areas for over 100 years. Channel modification for navigation began in 1824, with the authorization of the 4-ft channel. A 4.5-ft channel was authorized in 1878, followed by a 6-ft in 1907. Modifications included removing snags, dredging, constructing wing dams and closing dams to create the necessary depth. Congress authorized the 9-ft channel project in 1930 which resulted in the construction of 26 locks and dams between St. Paul, Minnesota and St. Louis, Missouri. The dams created a series of shallow impoundments or navigation pools which provide higher and relatively stable water levels during non-flood periods to maintain the Nine-Foot Navigation Channel.

The amount of allowable fluctuation at the locks and dams was periodically reduced primarily to reduce navigation channel dredging requirements. For example: the allowable fluctuation at Lock and Dam 8 in 1937 was 3.5 feet. It was reduced to 2 feet in 1945, to 1.5 feet in 1964, and the current 1 foot in 1972. The minimum water surface elevation at the primary control point in La Crosse has always remained at 631.0 (4.7 on the La Crosse gage).

Impounding the Upper Mississippi River (UMR) had numerous effects. Over time, alteration of the hydrologic regime, island loss due to erosion, and increased sedimentation of the UMR affected the distribution and abundance of aquatic vegetation. Consequently, habitat quality of the pools degraded and large expanses of open water with little aquatic vegetation developed that were of less benefit to fish and wildlife resources.

The Upper Mississippi River System-Environmental Management Program, established through the Water Resources Development Act in 1986 funded habitat improvements including rebuilding and construction of new islands, restoring channels, and deep-water habitat to restore habitat. These projects produced conditions beneficial to submersed aquatic vegetation, but emergent aquatic plants were slow to respond.

Figure 1.1 Land cover and vegetation changes in lower Pool 8 as a result of impoundment. USGS

Water level reductions (drawdowns) were evaluated by the WLMTF beginning in 1995 for the primary purpose of enhancing aquatic plant production. Several small-scale drawdowns, including Lizzy Paul Pond (Pool 5), Peck Lake (Pool 9), and Small Bay West (Pool 5) were successfully conducted, followed by the demonstration large scale drawdowns of Navigation Pool 8 in 2001 and 2002.

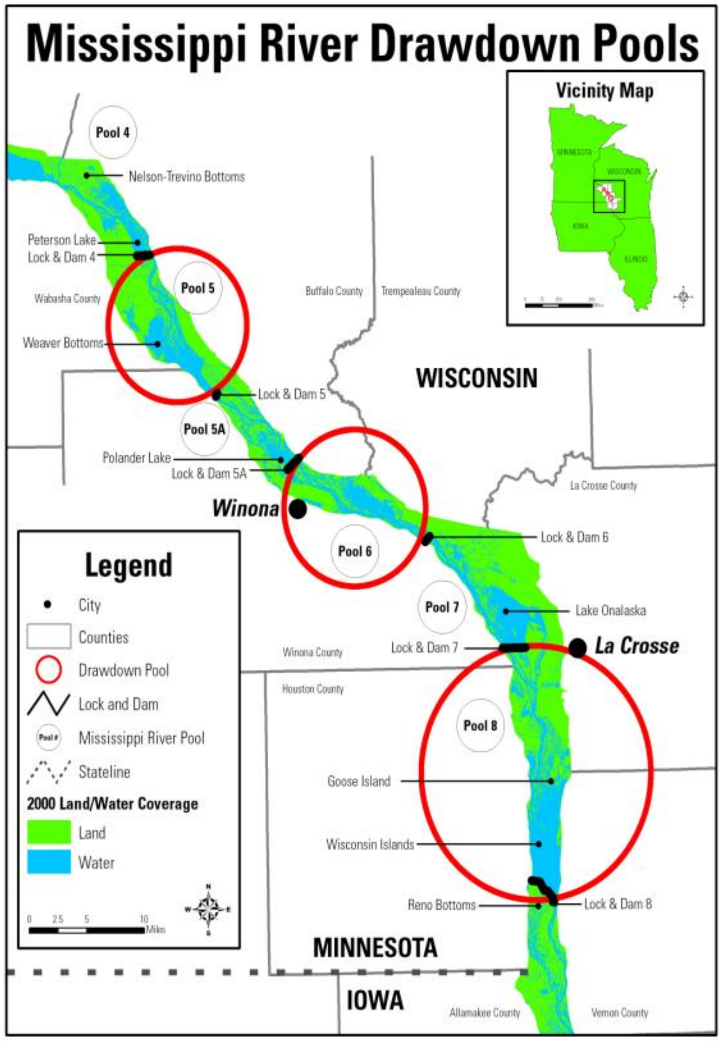


Figure 1.2. Location of Navigation Pools 5, 6 and 8 of the Upper Mississippi River. All three pools are located within the Upper Mississippi River National Wildlife and Fish Refuge. USFWS

1.2 Navigation Pool Drawdown Summaries

The Corps implemented water level reductions on Pool 8, 5 and 6 (chronological order) during the summer growing season under deviations from approved pool regulation plans.

Experimental drawdowns of 1.5-foot at the dam were conducted on Pool 8 in 2001 and 2002, and on Pool 5 in 2005 and 2006. An experimental minor drawdown of 1-foot was conducted in Pool 6 in 2010 (Figure 1.2). The drawdown depth is measured from the low control point elevation at the dam. Drawdowns were initiated in mid-June, and water levels were lowered approximately 2 inches per day until the desired elevation was reached. If flows were suitable to maintain the drawdown, the drawdown continued until mid-September when the level was gradually increased to full pool level by 30 September. The inability to maintain reduced water levels in the lower end of the pool under low discharge conditions is a function of regulations used to maintain depth suitable for commercial navigation (Kenow et al 2007).

The estimated extent of exposed substrates was based on geographical information system (GIS) coverage generated from true color aerial photography collected after the full drawdown was achieved. The extent and location of exposed substrates was variable throughout the drawdown period depending on flows or discharge and pool operation. For example, during the Pool 8 2001 drawdown, water levels were increased in the lower portion of the pool in mid-August due to low flow conditions, while reduced water levels persisted throughout the mid portion of the pool through 15 September. In 2002 the lower portion of the pool was exposed which more closely approximated the anticipated results of a drawdown (Figure 1.3).

The extent of the exposed substances for each drawdown was:

- Pool 8 –1954 acres (791 ha) in 2001 and 2002;
- Pool 5 - 999.4 acres (404.5 ha) in 2005;
- Pool 6 -133 acres (54 ha.) in 2010.

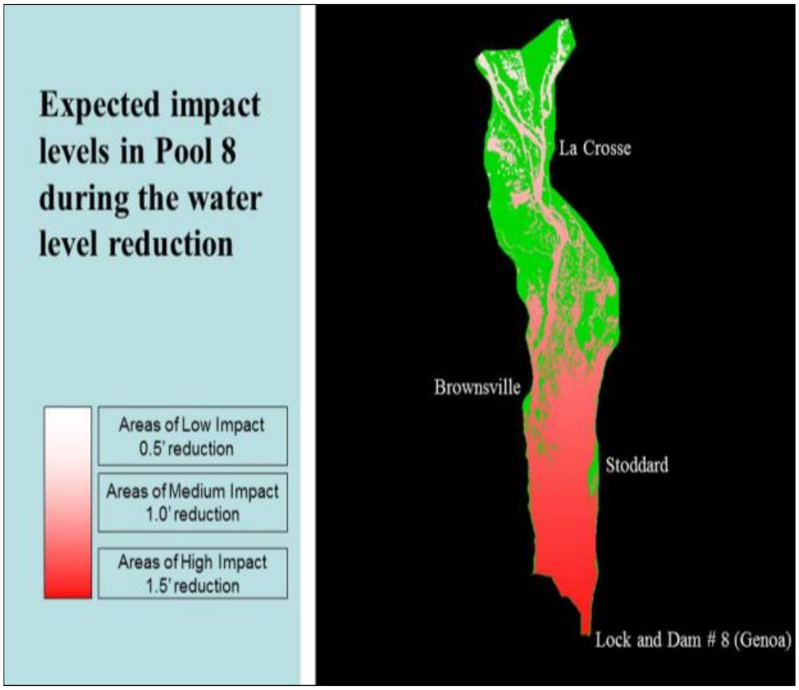


Figure 1.3. Estimated zones of impact for a 1.5-foot water level reduction at the Pool 8 Lock and Dam. USGS

During the weekend of August 11-12 the official La Crosse gage at Isle la Plume reached approximately 3.8 -4.0. Sand from the high floodwaters during spring filled the gage causing inaccurate readings. A minimum elevation at the La Crosse gage of 4.2 had been selected as one of the criteria for a drawdown to minimize adverse effects in the La Crosse area on commercial and recreational interests. The gage was repaired and the water level was remedied as quickly as possible.

2002 -The target reduction of 1.5-ft. at L&D 8 was reached on 03 July. Flows in the Mississippi River were high for much of the summer, therefore the maximum target drawdown level of 1.5-ft was maintained at the lower end of the pool. (Figure 1.5). Maximum extent of the drawdown in 2002 was similar to that of 2001. Because river discharge rates were generally higher in 2002, area exposed at any given time was generally less than that of 2001.

The drawdown was in effect in the lower portion of Pool 8 for 75 days rather than the prescribed time frame of 85-90 days. Refilling of the pool began on 16 September, reaching full pool level by 24 September.

Pool 8 Demonstration Drawdowns

2001—The pilot drawdown was scheduled for 2000 but water discharges were too low. Due to a late spring flood in 2001 (the second highest flood of record on the UMR) the elevation at Lock and Dam 8 did not reach normal pool levels until 30 June.

he 1.5-ft drawdown was achieved 06 July and was maintained near the target elevation level 628.5 at L&D 8 for 40 days until 14 August, or about half of the recommended 90-day period. An estimated 1,954 acres of river bottom were delineated as exposed on 21 July, 2001 (discharge 66800 cfs.). The predicted amount of exposed substrate for a 1.5- ft drawdown at a discharge of 40,600 cfs. was 1550 acres with a minimum elevation of 630.5 at the La Crosse gage.

As river flow rates dropped, the minimum pool elevation at the La Crosse gage could no longer be maintained, therefore pool levels at the dam were increased. From 16 August to 15 September, the pool level at L&D 8 was about .3 ft. below normal. Reduced water levels persisted throughout the mid-portion of the pool through 15 September (Figure 1.4).

Pool 5 Drawdown

The target water level reduction of 1.5-ft.was achieved on 29 June, 2005. During June and most of July river flows were higher than normal, consequently the target level was maintained until 25 July. On 15 July during the time of peak drawdown, approximately 999.4 acres (404.5 ha) of substrate were delineated as exposed at a discharge of 30,600 cfs. The predicted amount of exposed substrate at a discharge of 30,000 cfs. was 1357 acres.

In late July and through September low flows in the river necessitated water levels be increased at Lock and Dam 5 to maintain commercial navigation (Figure 1.6). In order to maintain required depths in the middle portion of the pool, the water level rose in the lower end due to the low slope of the water surface under low discharge conditions. This shift in pool operations

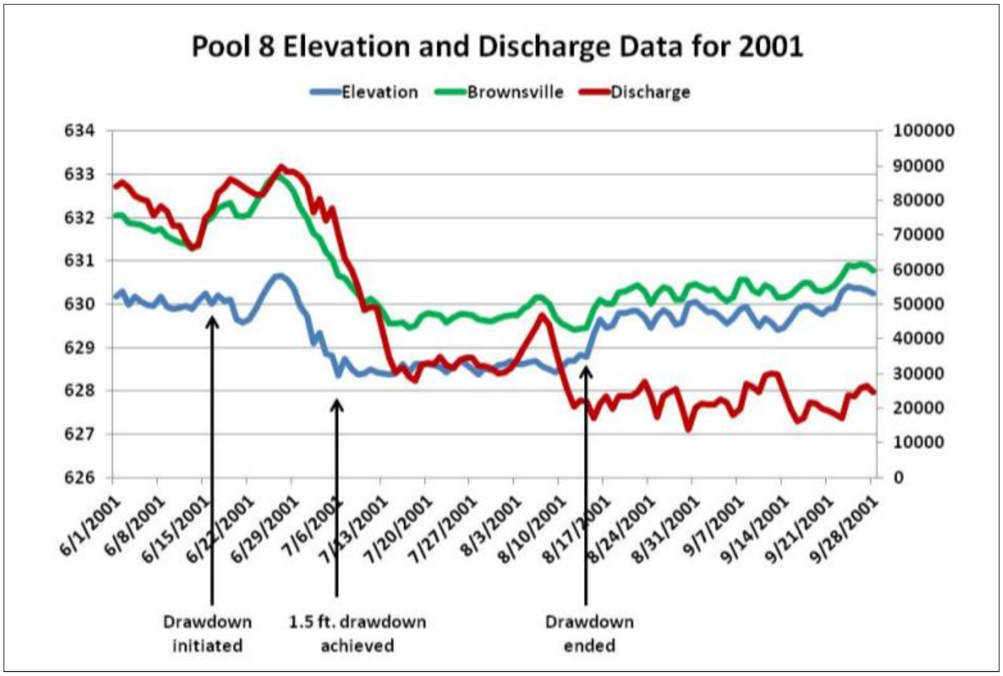
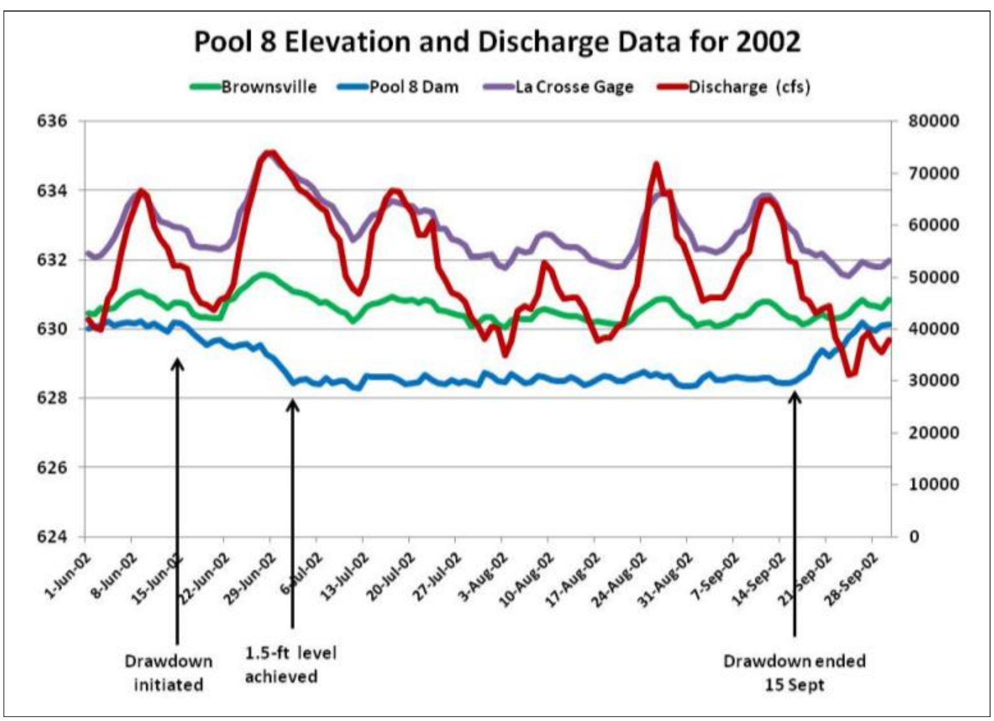


Figure 1.4. Upper Mississippi River Pool 8 water elevation (feet msl) at Lock & Dam 8, Brownsville, MN and La Crosse, WI gages, June through September 2001. The Brownsville water level represents the mid portion of the pool. On 21 July 2001 approximately 1,954 acres (791 ha) were delineated as exposed on aerial photography. Photos were obtained when L&D8 discharge was 66800 cfs. and elevation was 628.6. Target elevation for a 1.5-ft. drawdown at L&D 8 was 628.5. The drawdown lasted 40 days from 06 Jul to 4 August. WDNR

Figure 1.5. Pool 8 water elevation (feet msl) at Lock & Dam 8, Brownsville, MN and La Crosse, WI gages, June through September 2002. Although no aerial photography was available, it is estimated that a similar amount of substrate was exposed in 2002 as 2001 based on a similar elevation and discharge in early July. On 02 July 2002 elevation at L&D 8 was 628.44 and discharge was 68900 cfs. The drawdown lasted 75 days from 03 July to 16 September. WDNR



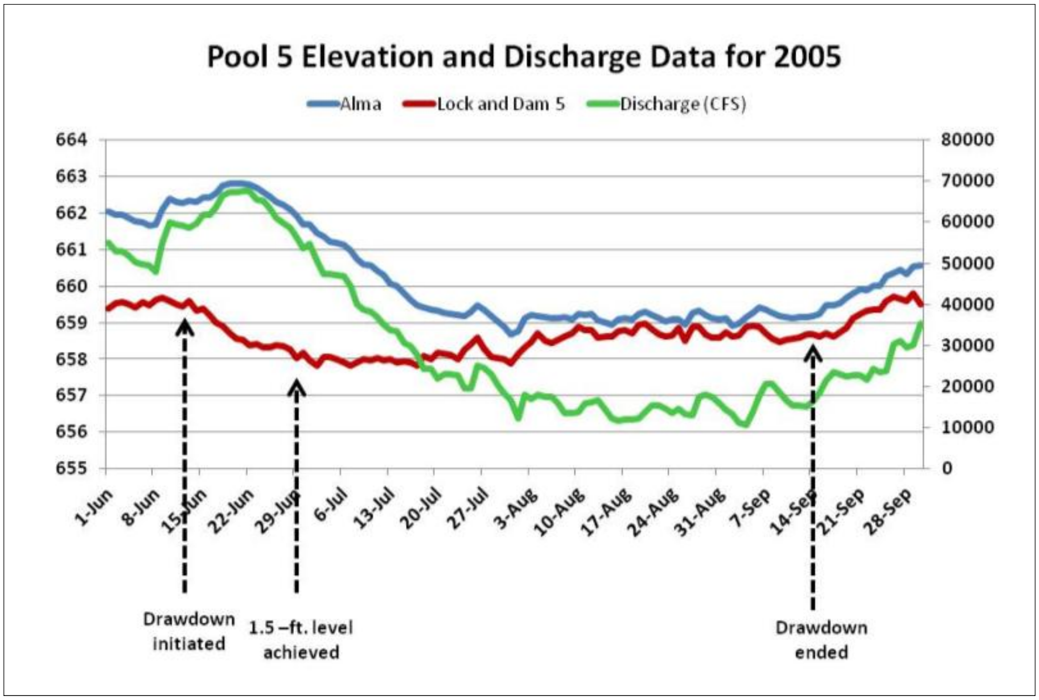
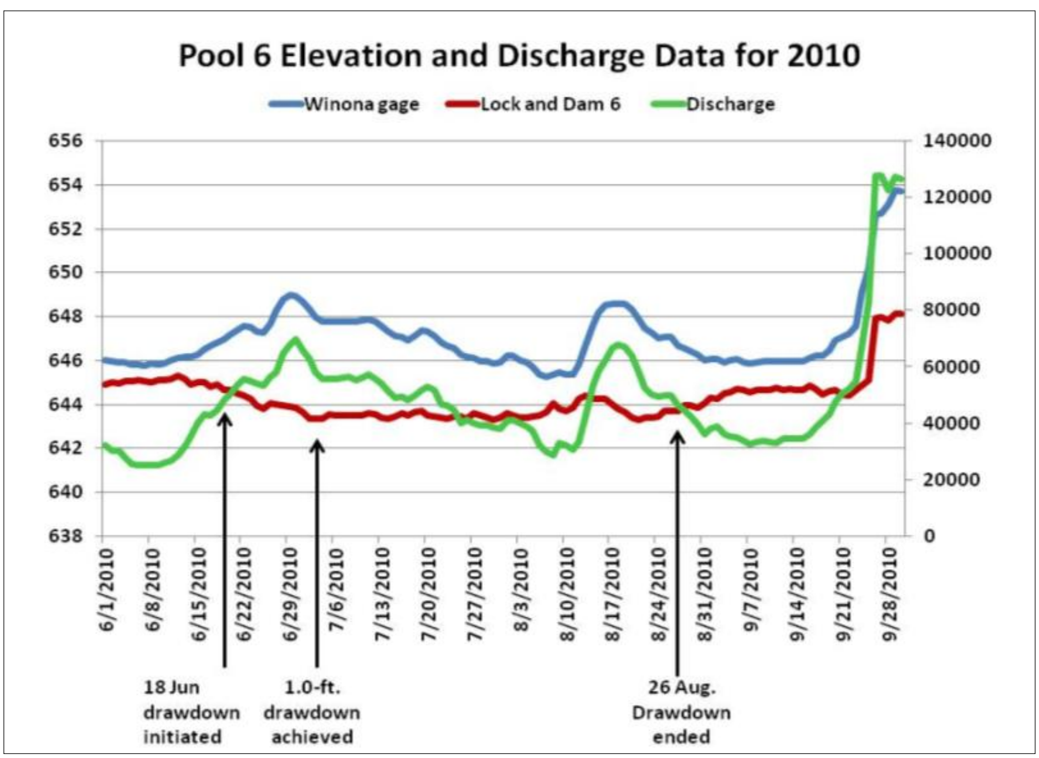


Figure 1.6. Pool 5 water elevation (feet msl) at Lock & Dam 5 and Alma, WI gages, during June through September 2005. Aerial photography obtained 15 July 2005. Lock and Dam 5 discharge was 30,600 cfs. and elevation was 657.94. An estimated 999.4 acres (404.5 ha) of substrates were exposed in 2005. The drawdown lasted 79 days from 29 June to 15 September. The 2006 drawdown was discontinued due to low discharge. WDNR

Figure 1.7. Pool 6 water elevation (feet msl) at Lock & Dam 6 and Winona, MN gages, during June through September 2010. Aerial photography obtained 27 July 2010. Lock and Dam 6 discharge 40,200 and elevation was 643.6 . An estimated 133 acres (54ha) of substrates were exposed in 2010. WDNR



exposed a different 1,000 acres in the middle and upper end of Pool 5 for the remainder of the drawdown, while previously exposed substrates in the lower pool were re-flooded. Refilling of Pool 5 began on 15 September reaching normal pool regulation by 30 September.

A second drawdown was scheduled for 2006. The drawdown was initiated on 12 June 2006. The target level of 1.5-ft. at L& Dam 5 was reached on 26 June. Due to low flows in the river the drawdown was discontinued after three days and the pool was back to operation levels by 09 July.

Figure 1.8. Aerial photo of Pool 6, 16 July 2010. Lock & Dam 6 discharge 49300 cfs. and elevation 643.6. The 1-foot drawdown was reached on 01 July. The large quantities of duckweed and algae that developed around the edge of exposed substrates made photo interpretation difficult for determining the amount of exposed substrate. Bottom right is the lock wall and the entrance to the marina that experienced the most difficulties with vegetation. Photo WDNR

On 08 July after the drawdown had been discontinued and the water level at the dam was reduced .2ft (instead of 1.5-ft.) a tow ran aground between Minneiska, MN and Buffalo City, WI. at mile marker 744, which is a dredge cut that had to be dredged five times from 2000 to 2006. The cause of the grounding was determined to be humps of sand on the bottom, and was not related to the effects from a drawdown.

Pool 6 Drawdown

After four cancellations (2003, 2004, 2008, and 2009) the Pool 6 drawdown was initiated on 18 June 2010. The target level of 1-foot drawdown at Lock and Dam 6 was reached on 01 July (Figure 1.7).

The extent of exposed substrates was determined to be 133 acres using 27 July photography (40,200 cfs discharge) (Figure 1.8). Prior to the drawdown there was insufficient bathymetric data available for Pool 6 to predict the amount of exposed substrates with a drawdown.

The target level was maintained until 09 August when low flows necessitated an increase in water levels at the dam. Mid-August rains increased discharge and by 20 August, the drawdown was again in effect. The drawdown was discontinued 26 August and the pool was gradually raised to normal operating levels by 03 September.

Unusual river conditions existed throughout the UMRS in August which was not conducive to a drawdown. Favorable light penetration conditions in spring contributed to an abundance of submersed aquatic vegetation throughout the UMRS. Heavy rains in mid-August increased discharge substantially which uprooted large quantities of aquatic vegetation. Large floating mats of vegetation (including emergent vegetation) floated downstream in the current. Some of this vegetation was carried into backwater areas including two marinas located in lower Pool 6, causing recreational access and boating problems. On 25 August inadequate flows to maintain the drawdown were projected for the next several weeks. This combined with the recreational access problems in the marinas led to the decision to end the drawdown and raise water levels to normal pool operation by Labor Day.

Chapter 2. Monitoring and Research Results

2.1 Maintenance of the Navigation Channel

Hydraulic analysis done prior to the Pool 8 and Pool 5 drawdowns suggested that dredging requirements during the first few years after a drawdown would be reduced, however the length of time this would last, and the overall effect on dredging quantities were uncertain.

2.1.1 Navigation Channel Dredging Summary

Jon S. Hendrickson, Dan Cottrell, Marv Hrdlicka
U.S. Army Corps of Engineers-St. Paul District

Introduction

This summary provides information on the dredging of sand-sized sediment (referred to hereafter simply as sediment) in the navigation channel of Pools 5, 6, and 8 where water level drawdowns have been done. The volume of sediment that has to be dredged in a river reach depends on the magnitude of upstream sediment loads and the sediment trap efficiency of the reach. Variation in upstream sediment loads occur due to seasonal patterns of river discharge or changes in hydraulic characteristics. The sediment trap efficiency, which is a measure of the percent of the sediment load that deposits in a reach, depends on the hydraulic and morphometric characteristics of the reach. Most river reaches never have to be dredged because their equilibrium depth is always deep enough to allow commercial navigation. However, some reaches have to be dredged on a regular basis because they periodically become too shallow for navigation. The channel maintenance dredging done in these reaches is considered "normal dredging" and represents a balance between providing adequate navigation channel depths, and minimizing the annual dredging volumes. To do a drawdown, these same reaches need "additional dredging" (ie. dredging to greater depths than normal) to maintain navigable water depths. The potential problem with this is that the deepened navigation channel has greater sediment trap efficiency, and fills in faster during ensuing high water events. To determine the effects of additional dredging on sediment trap efficiency, and dredging, records of annual dredging were analyzed for the years prior to and after the drawdowns that were initiated in 2001 in Pool 8, 2005 in Pool 5, and 2010 in Pool 6.

Spatial Scale, Time Scale, and Time Period for Analysis

Dredging volumes are described at the spatial scale of a navigation pool, in this case navigation Pools 5, 6, and 8 and for geomorphic reach 3(GR3), the reach from Lake Pepin to the Wisconsin River. Dredging volumes and hydrology are described annually and for the five year time period beginning with the first year (or initial year) of the drawdown, when additional dredging was required to deepen the navigation channel. In Pool 8, the first year was 2001, and the five year time period includes the years 2001 to 2005, while in Pool 5 the first year was 2005, and the five year time period spans 2005 to 2009. A five-year time period is used to determine whether the increased trap efficiency caused by the additional dredging affects longer term dredging volumes. Annual dredging volumes in Pool 6 are also discussed, though additional dredging was not done for this drawdown, which was considered a minor drawdown. Dredging volumes are compared to the average annual volumes for the pre-drawdown time period starting with the year 1981 and ending with the year prior to the drawdown. In Pool 8 this would be the years 1981 to 2000, in Pool 5 the years 1981 to 2004, and in Pool 6 the years 1981 to 2009. The year 1981 is used as a starting point because annual dredging volumes prior to this are not homogenous, being significantly higher than present day volumes prior to environmental regulations enacted in the early 1970s (NEPA and Clean Water Act) and being significantly lower in the mid to late 1970s when major changes in dredging practices first occurred.

Other Factors Affecting Dredging

To determine the effects of drawdowns on annual dredging volumes, it's necessary to separate the effects of channel maintenance programmatic factors and hydrologic variation from those caused by the additional dredging done for the drawdown. Programmatic factors that can affect dredging volumes include funding limitations, placement site capacity, length of the dredging season, and emergency operations in other river reaches. Since there is no quantitative way to account for all of these factors, the other navigation pools in Geomorphic Reach 3 (GR 3) not including Pools 5, 6, and 8 were considered reference pools. The total annual dredging for these five reference pools, which include lower Pool 4, 5A, 7, 9, and upper 10, was determined for the 1981-2012 time period, and for the five-year time periods associated with the drawdowns to gain insight as to whether dredging was normal or atypical elsewhere in GR 3. As shown in Figure 2.1. the average annual dredging in the reference pools was slightly below average for the five year period beginning with the Pool 8 drawdown (2001–2005), was well below average for the five year period beginning with the Pool 5 drawdown (2005–2009), and was well above average for the three year period beginning with the Pool 6 drawdown (2010–2012).

Hydrologic variation can be described using both average annual discharge and peak discharge. Figure 2.2 summarizes average annual Mississippi River discharge at the USGS gage at Winona, Minnesota for the years 1981 to 2012, the five year time periods following the Pool 8 and Pool 5 drawdowns, and the three year time period following the Pool 6 drawdown.   In addition, the peak discharge for each year from 2001 to 2009 is shown for the Mississippi, Root, and Zumbro Rivers. The Winona gage adequately represents the annual flow conditions in pools 5, 6, and 8. Compared to the 1981 to 2012 average annual discharge at Winona of 35,800 cfs, the river discharge was close to average for the five year period beginning with the Pool 8 drawdown (2001 – 2005), was well below average for the five year period beginning with the Pool 5 drawdown (2005 – 2009), and was well above average for the three year period beginning with the Pool 6 drawdown (2010 – 2012). The peak discharge in 2001 was exceptionally high (approaching 1-percent annual chance flood levels). This was followed by peaks in 2002 and 2003 approaching a 20-percent annual chance flood. Flood peaks for the five year period 2005 to 2009 were relatively low.

Tributaries can have a significant local influence on sediment loads, so hydrology on the Root River entering Pool 8 and the Zumbro River entering Pool 5 were also looked at. On the Root River, flood peaks were high in 2001 (5-year flood) and 2004 (15-year flood), but were relatively low during 2002, 2003, and 2005. On the Zumbro River, flood peaks were high in 2007 and 2008 (between a 5-year and 10-year event both years), but were low in 2005, 2006, and 2009.

Pool 8 Drawdown Dredging Summary

In 2001, 209,000 cubic yards of sand were dredged to deepen the navigation channel in Pool 8 so that commercial traffic could continue during the drawdown. This is 3.4 times higher than the average annual value of 62,000 cubic yards that was dredged in Pool 8 from 1981 to 2000 (Figure 2.3). In 2002, a small amount of dredging was required in upper Pool 8, that was not related to the drawdown, and no dredging was required in the middle reach of Pool 8 which had been deepened the year before. In 2003, 38,000 cubic yards were dredged in the middle reach of Pool 8. Dredging in 2004 was back up to 94,700 cubic yards, which might indicate that the additional dredging done in 2001 reduced dredging volumes until 2003 but not beyond. However dredging in 2005 was only 46,000 cubic yards. The average dredging for the five year time period 2001 to 2005 was 78,000 cubic yards which is 26-percent higher than the average annual value of 62,000 cubic yards from 1981 to 2000. This isn't necessarily an extreme 5-year average since there are other time periods (e.g. 1996-2000) that also had high dredging volumes, however dredging in the reference pools and discharge at the Winona gage during this five year time period were at below the 1981-2012 averages indicates that sediment trap efficiency and channel maintenance dredging were increased in Pool 8 due to the large amount of additional dredging done in 2001.

Pool 5 Drawdown Dredging Summary

In 2005, 362,000 cubic yards of sand were dredged to deepen the navigation channel in Pool 5 so that commercial traffic could continue during the drawdown. This is 4.4 times higher than the average annual value of 83,000 cubic yards that was dredged from 1981 to 2004 (Figure 2.4). From 2006 to 2009 dredging was below average, however the average dredging for the five year time period 2005 to 2009 was 120,000 cubic yards which is 44-percent higher than the1981-2004

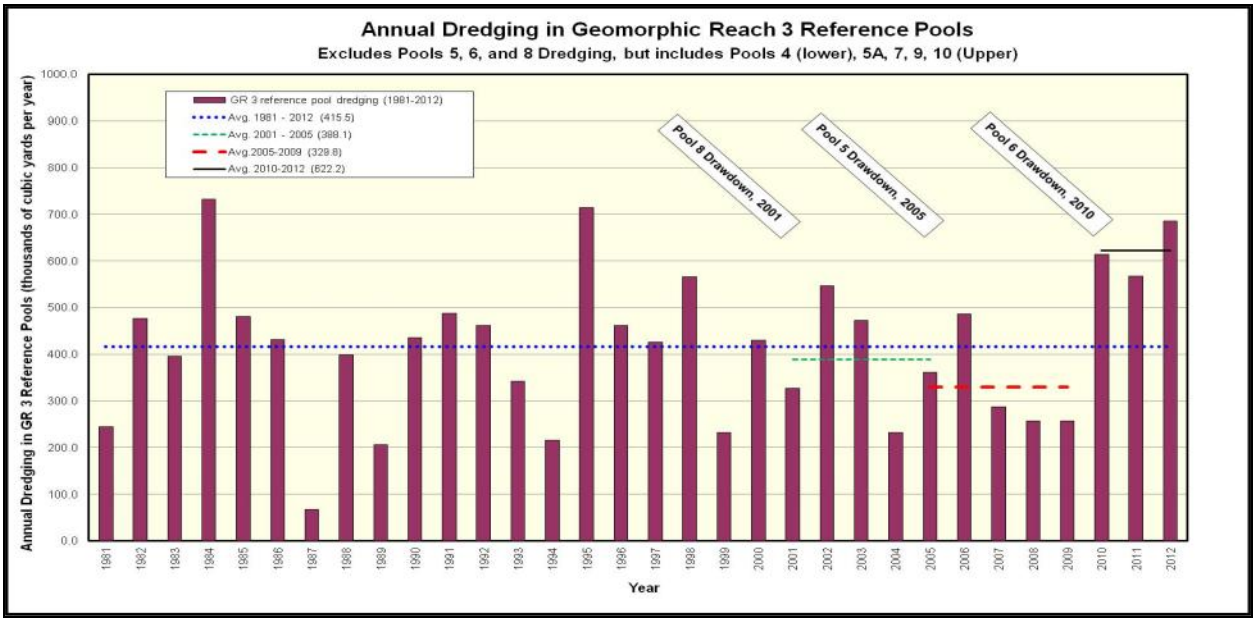
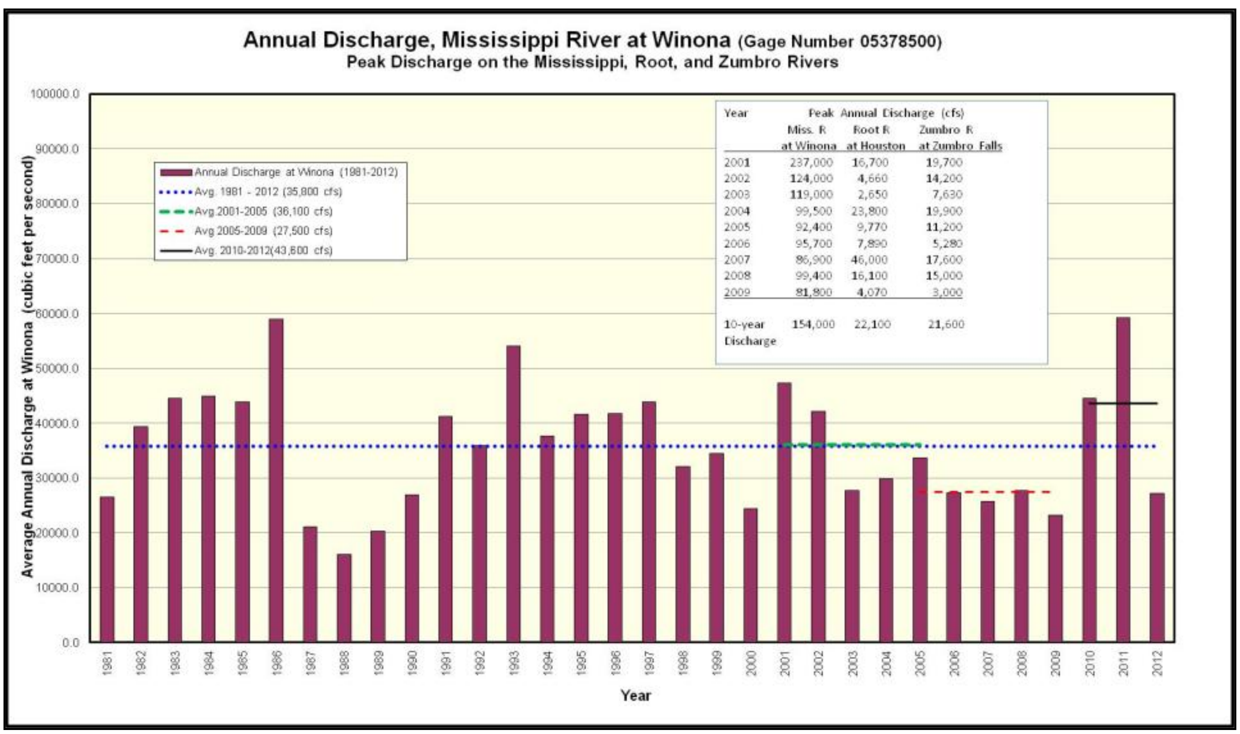


Figure 2.1. Annual dredging in Geomorphic Reach 3 reference pools. These pools included lower Pool 4, pools 5A, 7, 9, and upper Pool 10.



Year	Peak Annual Discharge (cfs) Miss. R at Winona	Root R at Houston	Zumbro R at Zumbro Falls
2001	237,000	16,700	19,700
2002	124,000	4,660	14,200
2003	119,000	2,650	7,630
2004	99,500	23,800	19,900
2005	92,400	9,770	11,200
2006	95,700	7,890	5,280
2007	86,900	46,000	17,600
2008	99,400	16,100	15,000
2009	81,800	4,070	3,000
10-year Discharge	154,000	22,100	21,600

Figure 2.2. Annual discharge on the Mississippi River at the USGS gage at Winona including peak discharge (inset table) on the Mississippi River at Winona, Root River at Houston, and Zumbro River at Zumbro Falls.

average annual value of 83,000 cubic yards.

One of the factors causing the larger increase in dredging in Pool 5 as compared to Pool 8 (44% compared to 26%) is that dredging beyond what was required for the drawdown was done at several dredge cuts. It is worth noting that if the total dredging done in 2005 is reduced by 72,000 cubic yards, the resulting dredging (290,000 cubic yards) is 3.5 times higher than the average annual value of 83,000 cubic yards from 1981-2004, which is almost the same ratio as Pool 8 (Table 2.1).

The increase in Pool 5 occurred even though dredging in the reference pools and discharge at the Winona gage during this same time period were 14-percent and 22-percent less than the long-term averages. This indicates that sediment trap efficiency and channel maintenance dredging volumes were increased in Pool 5 due to the large amount of additional dredging done in 2005.

Pool 6 Drawdown Dredging Summary

The Pool 6 minor drawdown was limited to 1 foot at the dam. With this amount of drawdown, there was no additional dredging required and all dredging conducted was considered normal. As shown in Figure 2.5 however, dredging in Pool 6 was relatively high during the two years prior to the drawdown (2008 and 2009) even though dredging in the reference pools and average annual discharge at the Winona gage was well below average (Figures 2.1 and 2.2). It's possible that anticipation of a pending drawdown influenced the amount of dredging done in Pool 6. Dredging continued to be high in 2010 and 2011, however both the annual river discharge at the Winona gage and the reference pool dredging volumes were high during these years also.

Predicting Dredging Based on Results from Pool 5 and 8

In other pools where large quantities of dredging are required prior to a drawdown, effects similar to those observed in Pools 5 and 8 are expected. Dredging should be reduced for several years following the drawdown, but an overall increase in dredging volumes affects costs and benefits associated with a drawdown, a way to predict this increase is desired. The ratio of dredging done during the initial year of a drawdown to the pre-drawdown average annual dredging is one factor that is known and may provide insight as to the overall increase in dredging. In Pool 8 and Pool 5 this ratio was 3.4 and 4.4 respectively and the increase in dredging

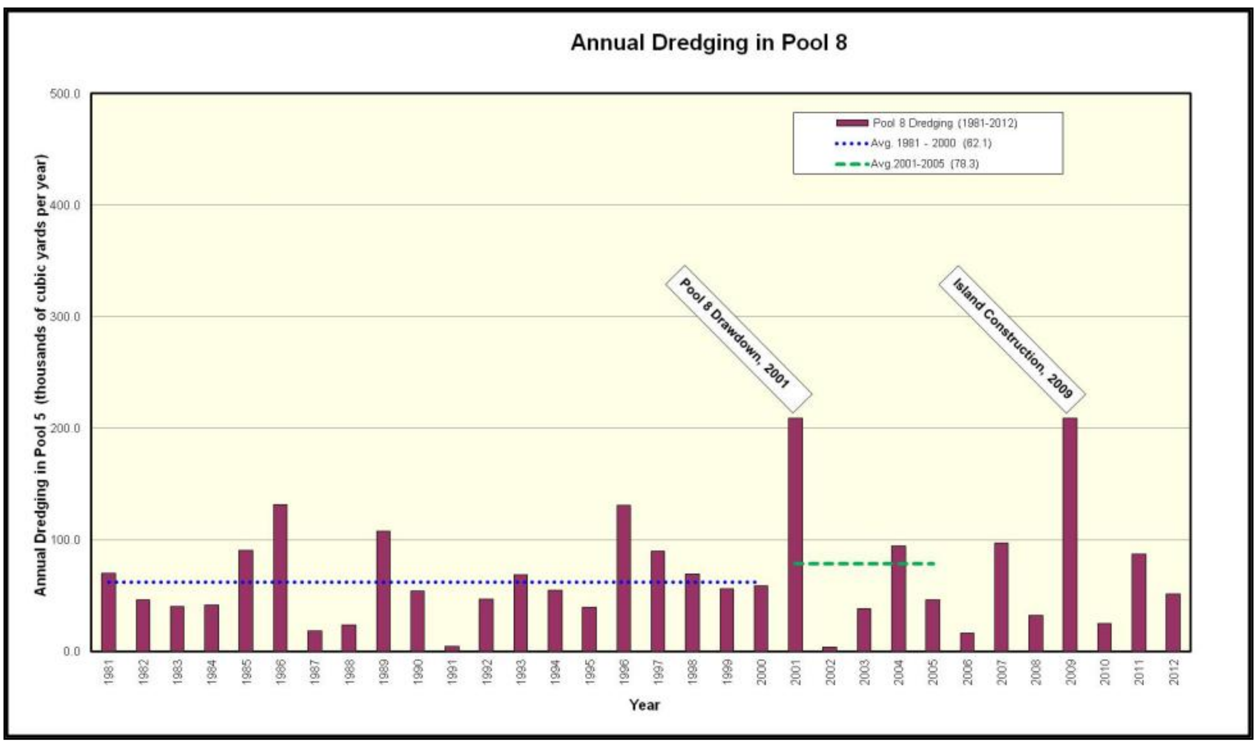


Figure 2.3. Annual dredging in Pool 8 for the years 1981 to 2012.

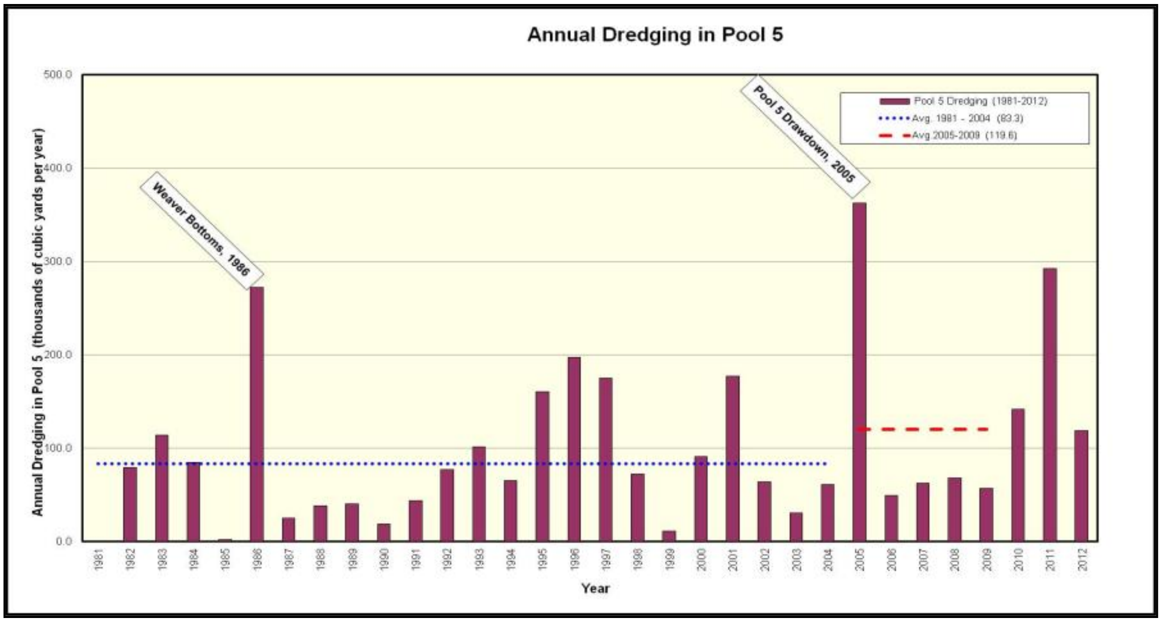


Figure 2.4. Annual dredging in Pool 5 for the years 1981 to 2012.

over the next 5 years was 26% and 44% respectively. If a third hypothetical data point is assumed for normal dredging where the ratio is 1.0 and the percent increase is zero the plot in Figure 2.6 can by made. This shows that as the amount of dredging done in the navigation channel during the initial year of the drawdown increases the five year average annual dredging increases. The implications of this are that sediment trap efficiency, sediment deposition and the 5 year average annual dredging in the navigation channel increases in proportion to the amount of additional dredging done for a drawdown. This is true whether the additional dredging is done for a drawdown, island construction or other efforts.

Conclusion

Hydraulic analysis done prior to the Pool 8 and Pool 5 drawdowns suggested that dredging during the first few years after a drawdown would be reduced, however the length of time this would last, and the one overall effect on dredging volumes were unknown.

In both pools the dredging required resulted in reduced dredging for several years following the drawdowns. In Pool 8, dredging was reduced at least through the third year after the initial drawdown year, while in Pool 5 reduced dredging lasted through the fifth year. In both pools other factors such as hydrology and channel maintenance programmatic decisions create uncertainty as to the period of reduced dredging. Because of this

Table 2.1. Comparison of estimated dredging based on pre-dredge surveys to actual dredging at three dredge cuts in Pool 5.

Dredge Cut	Estimated Dredging needed for a drawdown based on pre-dredge surveys (cubic yards)	Actual Dredging based on post-dredge Surveys (cubic yards)	Increase (cubic yards)
Mule Bend	67,000	100,000	33,000
West Newton	24,000	42,000	18,000
Sommerfield	37,000	58,000	21,000
Total			72,000

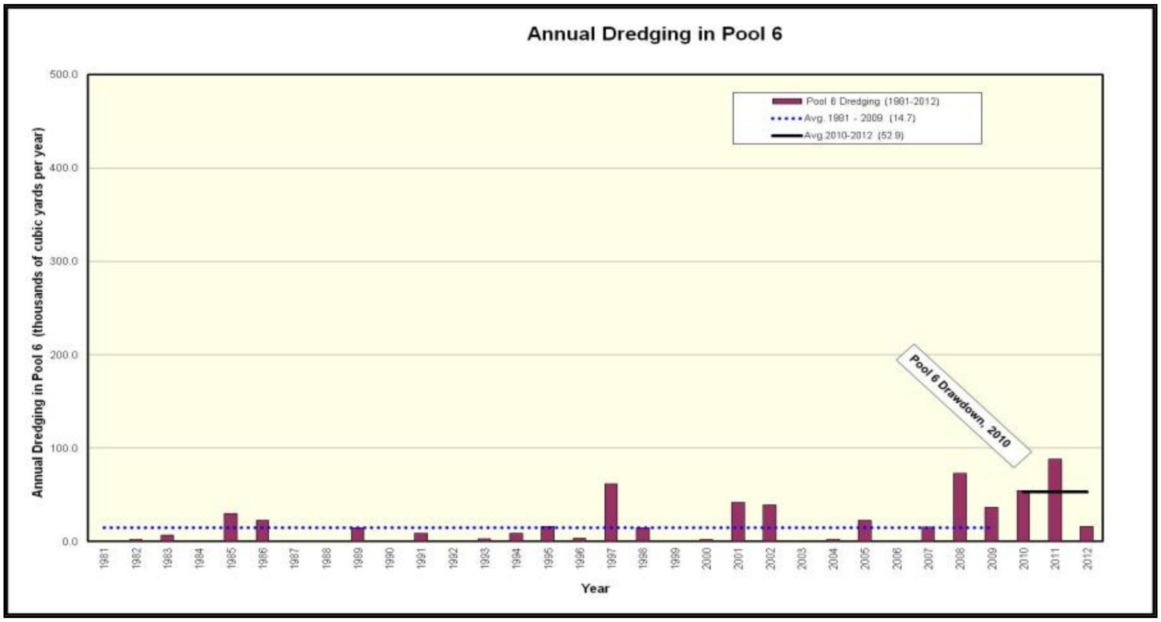


Figure 2.5. Annual dredging in Pool 6 for the years 1981 to 2012.

uncertainty a five year time period was assumed for determining impacts on dredging quantities in both pools. Because the large quantities of additional dredging during the initial year, the average dredging during the 5 year time period starting with the initial year of the drawdown were increased in both pools.

One explanation for the increased dredging is that the large amount of additional dredging done during the initial year of the drawdown increases the sediment trap efficiency of the dredge cuts, resulting in more rapid sediment deposition during ensuing flood events and overall increased dredging volumes.

In Pool 5, dredging was done in the navigation channel above what was required to do a drawdown, which is one of the factors causing the increase in five year dredging volumes to be so much higher in Pool 5 than in Pool 8. In reality, the results in Pool 5 would have probably been similar to Pool 8 without this extra dredging. While the Pool 6 minor drawdown was done assuming there would be no additional channel maintenance, dredging in 2008 and 2009 was significantly higher than the long-term average possibly because anticipation of a pending drawdown resulted in dredging being done that would have normally been deferred.

In other pools where large quantities of dredging are required prior to a drawdown, similar results are expected (i.e. reduced dredging for several years following the drawdown, but an overall increase in dredging. The ratio of dredging done during the initial year of a drawdown to the pre-drawdown average annual dredging may be a parameter that can be used to predict the overall increase in dredging.

2.1.2 Navigation Channel Hydraulics and Sediment Transport

Jon S. Hendrickson, Jonathan Peterson, Corby Lewis, Marvin Hrdlicka - *U. S. Army Corps of Engineers-St. Paul District*

This summary provides information on the effects of a drawdown on hydraulic conditions and the transport of sand-sized sediment in the navigation channel. The transport of sand-sized sediment is strongly influenced by river discharge and channel velocity. Significant sediment transport usually begins for a river discharge that is exceeded approximately 25-percent of the time annually (approximately 50,000 cfs in the Pool 5 to Pool 8 reach of the UMR) and continues to increase as river discharge increases. Since water level drawdowns can be done for discharges that exceed the 25-percent event, monitoring and modeling was done to determine

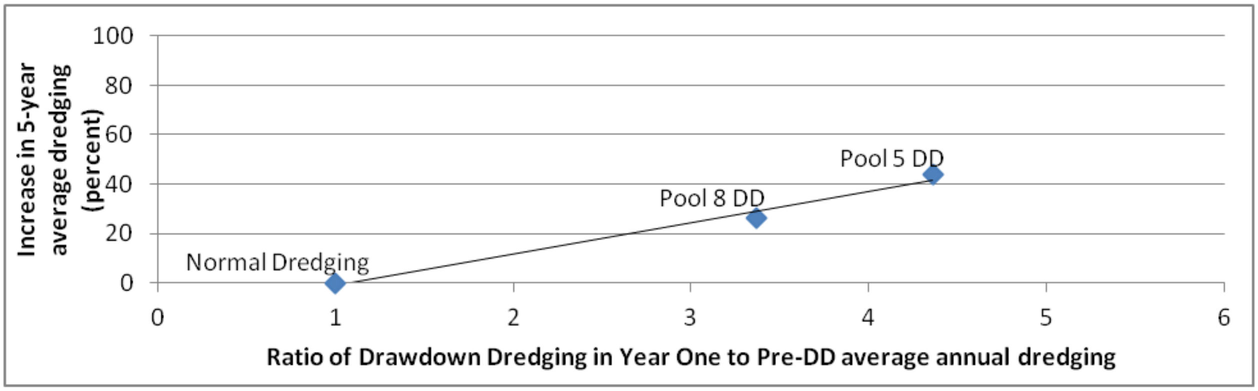


Figure 2.6. Increase in 5-year average annual navigation pool dredging based on the ratio of drawdown dredging in the initial year of the drawdown to the pre-drawdown average annual dredging.

the effects of drawdowns. The objective was to obtain measurements of changes in hydraulic conditions, sediment transport, and bottom configuration in the Mississippi River main channel and tributaries. Hydraulic and sediment transport monitoring and modeling that were done during the Pool 8 and Pool 5 drawdowns included:

- Discharge measurements in the main channel and secondary channels, were compared to discharge measurements without a drawdown. These measurements were obtained using an Acoustic Doppler Channel Profiler (ADCP).
- Bedload transport, was measured using the ISDOT (Integrated Surface Difference Over Time) method in Pool 8. This method was developed by personnel from the Engineering Research and Development Center (Abraham and Pratt, 2002), and was used for the first time in Pool 8.
- Total sediment load measurements in Pool 5 including suspended sediment concentration (SSC) using a Depth Integrated D-74 type sampler (with sieve analysis), bed material size mapping using a US BM-60 type sampler (with sieve analysis), and calculation of bed load transport.
- Hydrographic surveys were obtained in the main channel of Pool 8 and were compared to pre-drawdown surveys collected during 1998 and 1999 to assess bathymetry changes.
- Cross sections were obtained on two Pool 8 tributaries, Coon Creek and the Root River, before and after the drawdown in 2001 to assess changes due to the drawdown.
- Sediment transport modeling in Pool 5 using the one-dimensional hydraulic model HEC-RAS to determine sediment transport capacity for each cross-section in the model.
- Hydraulic modeling in Pool 5 using the two-dimensional Adaptive Hydraulics (ADH) two-dimensional model to determine the effects of drawdowns on flow velocity. Note that this was done at a later date.

Hydraulic and sediment transport processes that were analyzed included:

- Decreased cross sectional area and greater effects of boundary roughness during a drawdown should decrease the flow through secondary channels resulting in a greater percent of the total river discharge being conveyed in the main channel.
- Drawdowns will mobilize bed sediments and result in greater rates of sediment transport in the main channel.
- Tributary degradation could occur due to the lowered water levels in Pool 8, introducing additional sediment to the main channel in Pool 8.

Pool 8 Navigation Channel Hydraulics and Sediment Transport

The navigation channel reach in Pool 8 selected for this study extends from river mile 686 to 691 located near Brownsville, Minnesota (Figure 2.7). This is a highly divided reach with many secondary channels. The main channel discharge decreases from 70-percent to 25-percent of the total river discharge from the upstream to the downstream end of the reach, due to flow through the secondary channels to backwater areas. Because of the decrease in main channel discharge, a large amount of dredging is needed annually in this reach.

Table 2.2. Hydrodynamic Characteristics Near River Mile 688.9 with and without the drawdown. Data measured by ERDC personnel.							
Date	Drawdown (feet)	Total River Discharge (cfs)	Main Channel Discharge (cfs, percent total)	Water Surface Slope	Average Velocity (fps)	Average Depth (feet)	Top width (feet)
7/9-11/01	1.5'	49,000	35,900, 73	.00007	2.35	11.9	1259
6/12-15/02	0	53,000	32,000, 60	.00003	1.83	13.7	1249

Hydraulic Monitoring

Hydraulic data collected near river mile 688.9 by personnel from ERDC is shown in Table 2.2. The discharge is similar for both sets of measurements, however there was a drawdown of 1.5 ft in 2001 and there was no drawdown in 2002 when this data was collected. With a 1.5 ft drawdown in place, the measured slope through the study reach doubled. The percentage of water conveyed in the main channel increased from 60 to 73 percent of the total river discharge, which was due to decreased conveyance in secondary channels. These factors caused the average main channel velocity to increase from 1.83 to 2.35 fps.

Additional flow measurements were collected in the main channel and secondary channels throughout Pool 8 and compared to the data collected in previous years during normal water levels. These measurements indicated that secondary channels with entrances located further upstream in Pool 8 (e.g. the secondary channels flowing past Goose Island) were not affected significantly by the drawdown, while discharge was reduced in secondary channels further down in the pool. The flow through Crosby Slough was almost cut in half from 8.3- to 4.8-percent of the total river flow, while the flow in Wigwam Slough was not affected. Crosby Slough is located further downstream in Pool 8 and flows through a shallow delta into a backwater area, while Wigwam Slough is located further upstream in Pool 8 and is relatively deep along its length. It is also possible that drawdown conditions increased the effectiveness of the closing dam at the entrance to Crosby Slough thereby affecting flow conditions in the slough.

Sediment Transport Monitoring

The flow rate at bankful conditions is about 85,000 cubic feet per second (cfs) at Lock and Dam 8. If flows during the drawdown were between 50,000 cfs and 80,000 cfs it was speculated that the combination of flow and drawdown could result in velocities high enough to significantly increase sediment transport.

In 2001, flows were less than 50,000 cfs for 75 of the 84 days during which the pool was drawn down. A discharge of 60,000 cfs was exceeded for seven days at the start of the drawdown; however the pool wasn't completely drawn down at this point. In 2002, flows were in the lower portion of the drawdown range (less than 50,000 cfs) for 52 of the 101 days during which

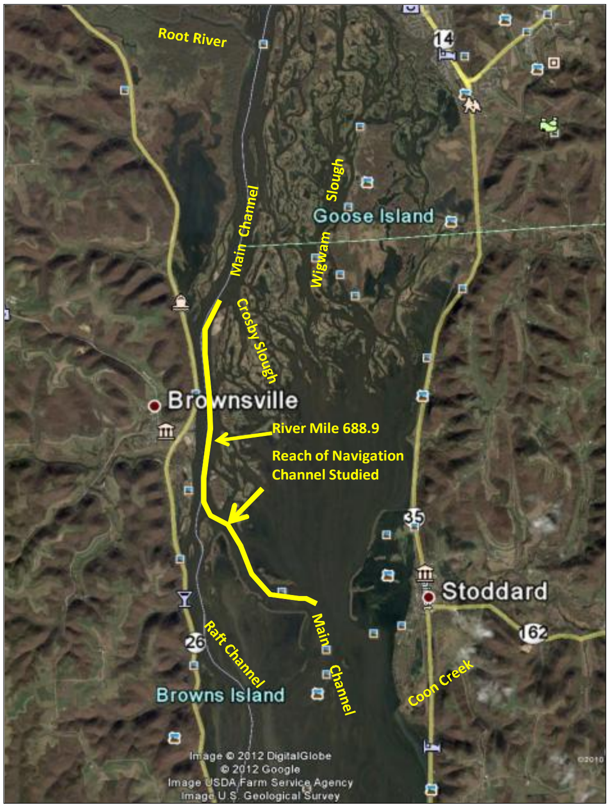


Figure 2.7. Pool 8 study reach map.

the pool was drawn down. A discharge of 60,000 cfs was exceeded for 29 days at several different times during the drawdown, and the pool was drawn down 1.5-foot for all but six of these 29 days.

Measurements of sand wave movement using the Integrated Surface Difference over Time Method (Abraham et al. 2003) indicated an increase in sediment transport during the drawdown in 2001. The potential for increased sediment transport was greater during the 2002 drawdown because of the higher flows, however sediment measurements weren't taken during this time period

Bathymetry Changes in the Main Channel
Hydrographic surveys were conducted in Pool 8 during the drawdowns for comparison to pre-drawdown surveys completed during 1998 and 1999 to determine whether any changes in the bottom contours in the main channel were induced by the drawdown. The results were used to determine if greater sediment transport rates in the main channel would cause main channel bed aggradation or degradation in the reaches where dredging is usually done.

A comparison of the surveys between river miles 686 and 691 indicated both deposition and erosion however some of the observed changes may have been due to normal sand wave migration through this reach. On an annual basis this reach normally aggrades to the point where main channel dredging is needed, however the high dredging volumes during 2001 maintained adequate navigation channel dimensions and resulted in a reduction in dredging in 2002 and 2003.

Tributary Changes

Due to the lowered water levels in Pool 8, a high flow event on a tributary creek or river during the drawdown could potentially have caused down-cutting of the tributary introducing additional sediment to the main channel in Pool 8. Cross sections were obtained on Coon Creek, located in lower Pool 8, and the Root River, located in upper pool 8, before and after the drawdown in 2001 to assess changes due to the drawdown. The amount of drawdown will be greater at the mouth of Coon Creek since it is located 10 miles further downstream in the navigation pool than the Root River.

A comparison of cross sections before and after the 2001 drawdown on Coon Creek indicated degradation of less than 0.5 feet. On the Root River, the cross section comparison indicated net aggradation exceeding 1 foot in the lower Root River; and degradation by as much as 2 feet along the upper cross sections. The Root River results are not consistent with those expected from a water level drawdown. If anything, bed degradation was expected at the downstream cross sections, with less degradation at upstream cross sections that are less influenced by the drawdown. Most likely these results are due to flow conditions on the Root River itself

Pool 5 Navigation Channel Hydraulics and Sediment Transport

The navigation channel reach selected for this study extends from river mile 743 to 750. This is a highly divided reach with many secondary channels. The main channel discharge decreases from 100-percent to 36-percent of the total river discharge from the upstream to the downstream end of the reach, due to flow through the secondary channels to backwater areas. Because of the decrease in main channel discharge, a large amount of dredging is needed annually in this reach.

Hydraulic Monitoring

Discharge measurements were obtained before and during the drawdown at river miles 746.0 and 744.8 (Figure 2.8) on 4 different dates (01 and 09 June for

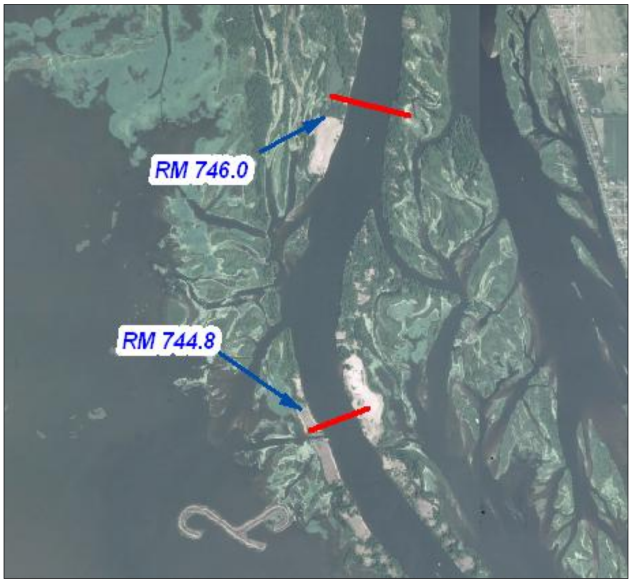


Figure 2.8. General Area Map. Locations where detailed hydraulic and sediment transport data was collected in Pool 5.

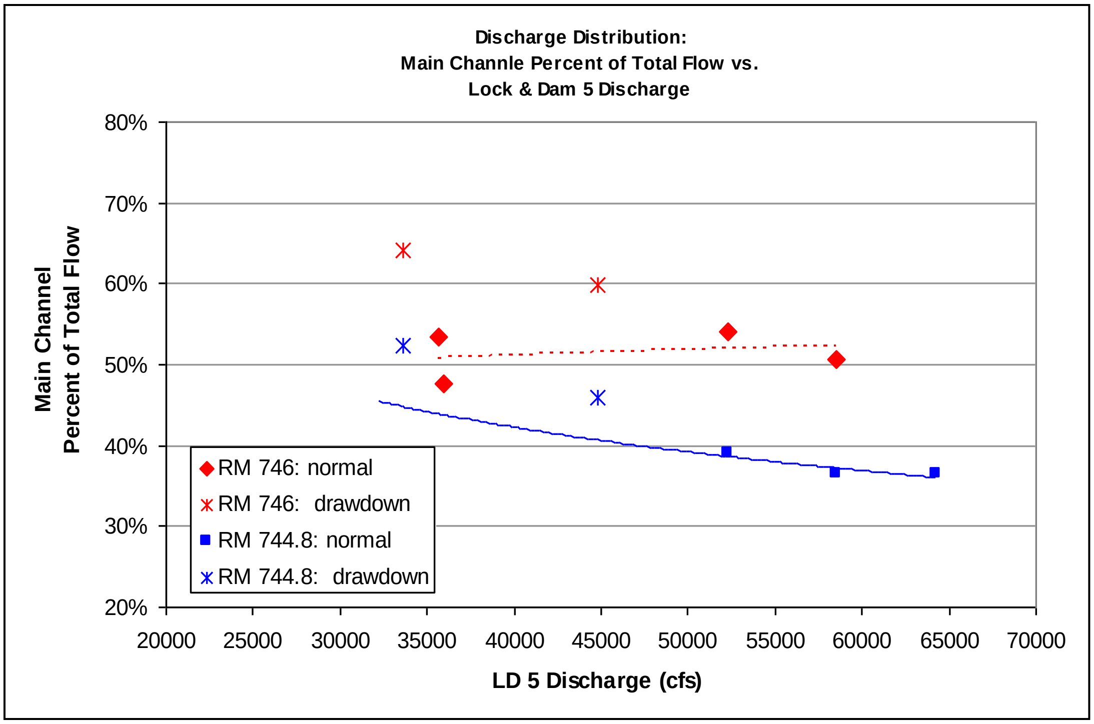


Figure 2.9. Main channel discharge given as percent of the total discharge at river miles 744.8 and 746, before and during the drawdown.

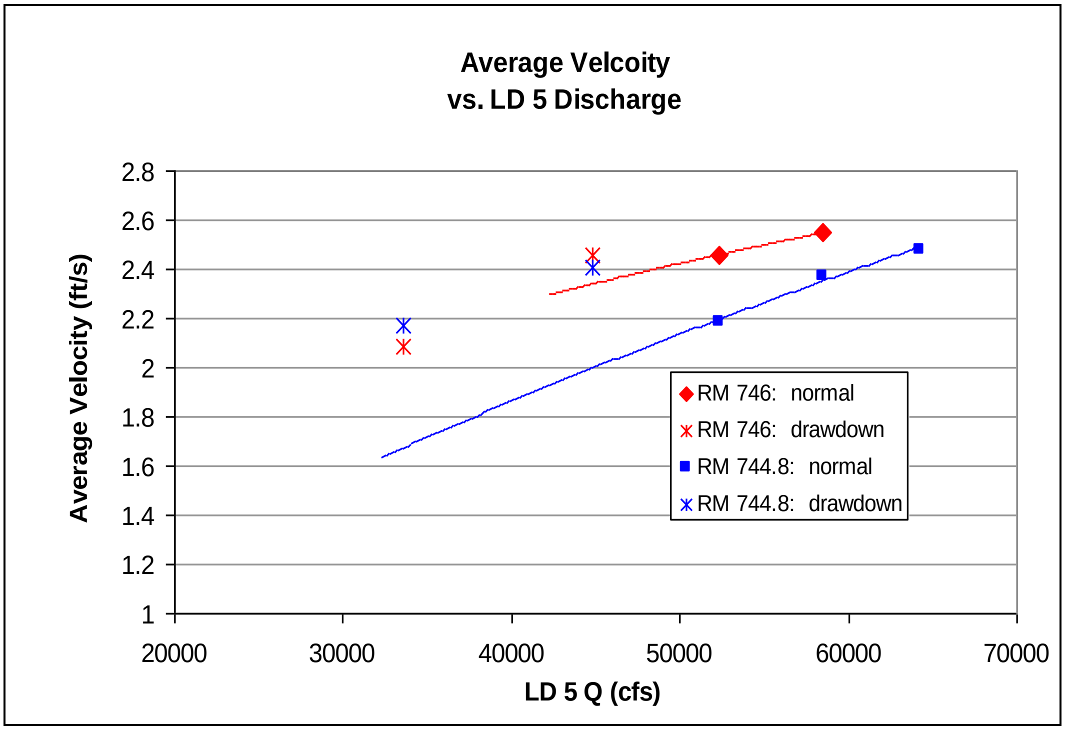


Figure 2.10. Main channel average velocity at river miles 744.8 and 746, before and during the drawdown

pre-drawdown conditions, 06 and 13 July for drawdown conditions). These measurements indicated a 12 to 20% increase in main channel discharge (Figure 2.9) compared to conditions when the pool isn't drawn down and a 5 to 30% increase in average channel velocities (Figure 2.10) depending on location and river discharge. The average velocity is lower at the downstream cross section (RM 744.8) because of a large loss of flow from the Main Channel into secondary channels between the two cross sections (Sand Run & MN-7).

Additional flow measurements were collected in the main channel and secondary channels throughout Pool 5 and compared to the data collected in previous years during normal water levels. As in in Pool 8, these measurements indicated that secondary channels with entrances located further upstream in Pool 5 were not affected significantly by the drawdown, while discharge was reduced in secondary channels closer to the dam.

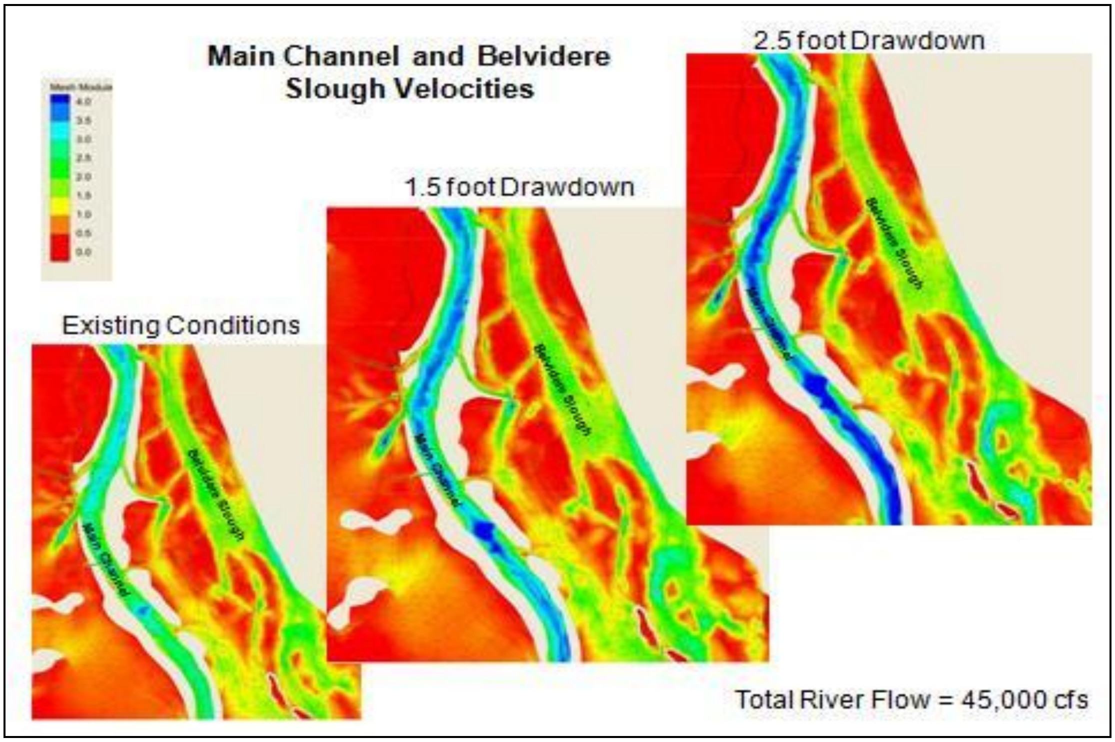
Two dimensional modeling was done several years after the Pool 5 drawdown for another study effort. The velocities simulated for a 1.5 foot drawdown (Figure 2.11) seem to match what was measured and observed during the drawdown in 2005 in that velocities were significantly increased during the drawdown. It is also interesting to see that velocities in Belvidere Slough, a large secondary channel aren't changed that much, apparently because even though the drawdown reduced water levels and cross sectional area in the Belvidere Slough, the reduced discharge into the slough results in minimal change in velocity.

Sediment Transport Monitoring

The data showed that finer material exists at the downstream cross section than the upstream cross section. Also, the downstream cross section showed a consistent trend of finer material on the right side of the channel compared to the left. There was basically no gravel in the bottom material, as the material is classified as medium to coarse sand.

The measured concentration of suspended sediment was generally dominated by the wash load (silt & clay) rather than the bed material (sand). This wash load is influenced by inputs from the Zumbro River where the concentration of suspended sediment is generally much higher than on the Mississippi. High flow events on the Zumbro contribute to high concentrations of suspended sediment in Pool 5.

Figure 2.11. Simulated velocities using a two-dimensional model in the Pool 5 study reach.



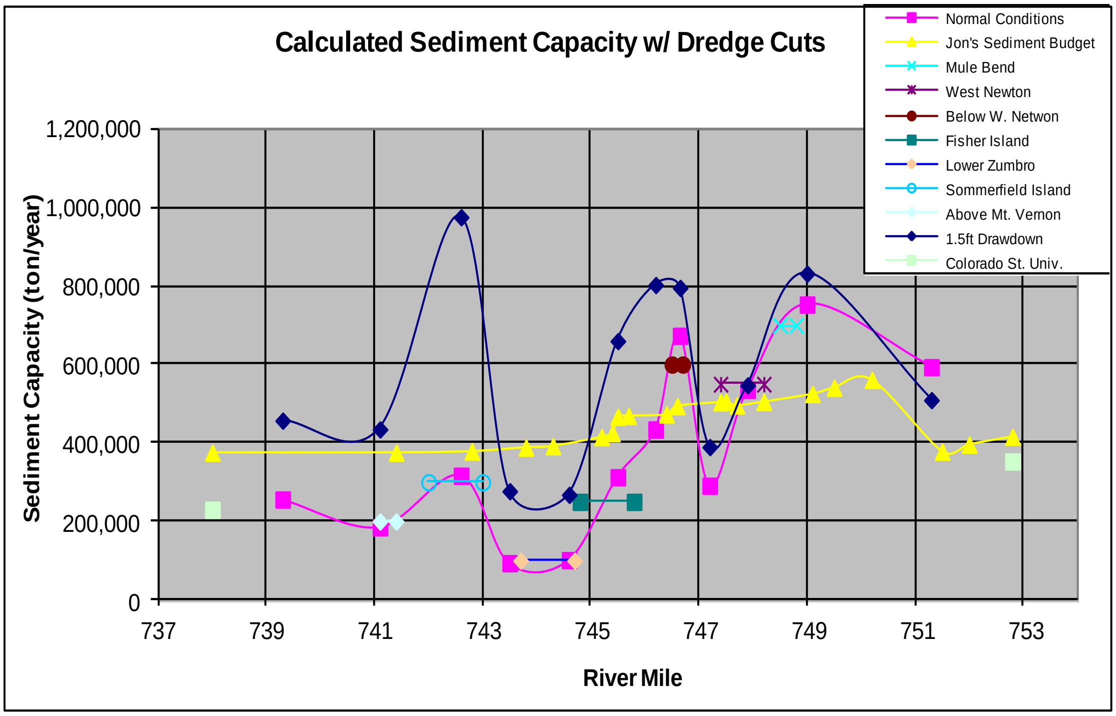


Figure 2.12. Calculated sediment capacity in Pool 5 using HEC-RAS

The hydraulic and sediment transport data was used to estimate the magnitude of sediment transport. This showed a significant increase in total bed material load during drawdown conditions. The sand load increased by 75 to 125% for the flow rates measured. It is important to remember that this represents only instantaneous sand transport, and does not represent an annual sand load. In most navigation pools, the majority of the sediment transport occurs at higher discharges which are not affected by drawdowns. However, this analysis shows that a pool-wide drawdown can effect sand transport in the main channel during the time when the pool is drawn down.

Analysis of the data shows that the majority of the bed material load (ie. sand load) moves through the system as bed load. The percent of sand moving as bed load is on the order of 90% for average flows, but is somewhat lower for larger flows.

Sediment Transport Modeling

The hydraulic model HEC-RAS was used in conjunction with ArcMap 8.0, geographic imaging software to model sediment transport in Pool 5. Using this calibrated model along with grain size distribution data of sediment (St. Paul District Data), the HEC-RAS hydraulic design function was used to determine sediment transport capacity for each cross-section. The sediment yield in each reach was determined by integrating the sediment capacity curves and flow duration to obtain average daily and yearly sediment yield (EM 1110-2-4000, 15 Dec 89).

The comparison of calculated yearly sediment capacity using the Englund-Hansen method for normal conditions and for conditions with a 1.5 foot drawdown is shown in Figure 2.12 along with results of a sediment budget for Pool 5 (Hendrickson, 2003) along with the results of research done by Colorado State University (Colorado State University, 1979) based on sediment transport equations and field data.

The results show that sediment capacities increase throughout Pool 5 with a drawdown, however the increases are greatest in reaches where sediment capacity is high (see peaks in the plot above). Most of the dredge cuts are located in reaches where sediment capacity is low (see valleys in plot above). This indicates that the drawdown has the potential to mobilize more sediment into the dredge cut causing more rapid filling.

Conclusion

During the drawdowns in both Pool 5 and Pool 8, measured field data indicates that a greater percentage of the total river flow was conveyed in the main channel, and main channel flow velocity increased. This was also simulated with one and two dimensional hydraulic models. This is due to the fact that in secondary channels, cross section area is decreased and roughness is increased as the water surface is lowered. Discharge measurements in secondary channels indicates that flow in the secondary channels is decreased to a greater extent in those channels closer to the dam, and that at some point upstream the effect of the drawdown isn't even measurable. The results of the two dimensional hydraulic model indicate that while velocities in the main channel are increased, velocities in secondary channels are not changed significantly.

The increase in channel velocity caused increased bed material (sand) sediment transport in the main channel. This is based on detailed surveys of the river bed obtained in Pool 8 (Abraham, et al. 2006) and measurements of suspended sediment concentration (SSC) and bed material properties, which were used to calculate bed material transport in Pool 5. Based on the 1-D HEC-RAS model results in Pool 5, the drawdown increases the sediment transport capacity throughout the main channel with greater variations at both dredge and non-dredge locations. This causes slightly increased deposition in existing dredge cut reaches and increased scour in non-dredge cut reaches. According to the Bed Evolution Model, during and after a drawdown, overdredged cuts will fill in faster leaving minimal advantages in following years, however downstream scour is much greater. While the original hypothesis was that degradation might occur in the dredge cut areas because of the increased sediment transport, the one-dimensional model simulations indicate that this process might actually mobilize sediment and transport it into the dredge cuts at a faster rate.

Tributary degradation was not significant. Some degradation occurred on Coon Creek near the mouth of the creek; however it was generally less than 0.5 feet. Changes occurred on the Root River also, however these changes were not consistent with what would be expected from a drawdown and were probably caused by flow events on the Root River.

Figure 2.13. Location of sampling stations in Weaver Bottoms. USACE

The lack of change in the main channel bed elevations in the Pool 8 study reach may be due to the fact that while the sediment transport rate increased, inputs balanced outputs. This is a desirable condition, since normally the study reach would be aggrading until dredging was needed.

Weaver Bottoms 2005 Sediment Data Collection, Summary & Analysis

Corby Lewis, *US Army Corps of Engineers-St Paul District*

Automated surface water samplers were used to collect daily composite samples for total suspended solids and total volatile solids at major inlets and outlets to Weaver Bottoms from June 1 to September 30, 2005 (Figure 2.13). The intent of this effort was to develop a total suspended solids "budget" for the Weaver Bottoms area.

A similar study was done in 1993 &1994 as part of the Resource Analysis Program for The Weaver Bottoms Rehabilitation Project. Although the scope of the previous study was larger than in this 2005 study, the same sampling locations were used and comparisons can be

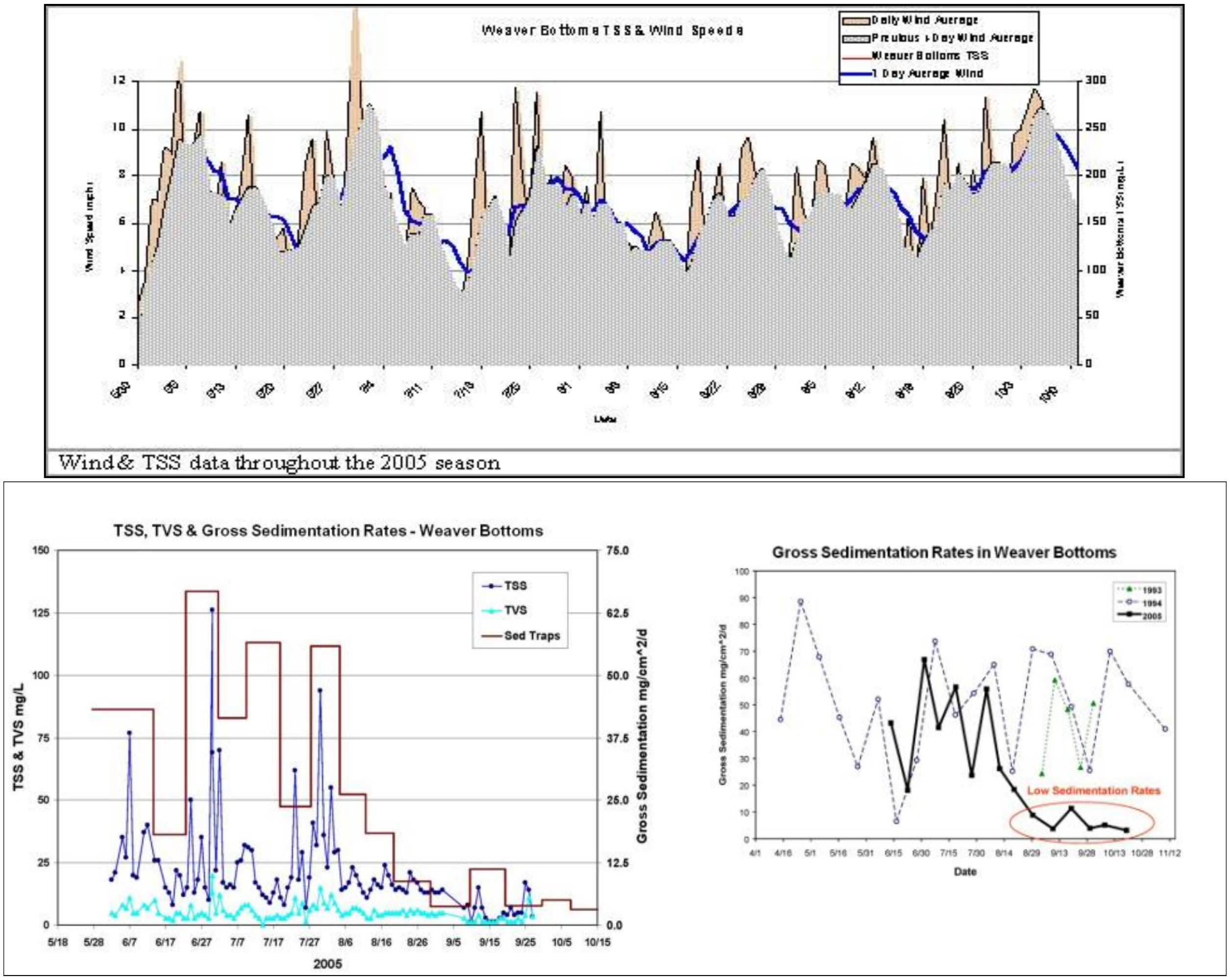


Figure 2.14 Low TSS concentrations were observed during September. Gross sedimentation rates declined during August and very low rates were measured during September, consistent with the low TSS levels. Wind data collected by WDNR. USACE

made. The comparison will address the long term trends as well as effects of the 2005 pool-wide drawdown.

The sampling units were set up on accessible shorelines. Intake tubes set were fixed to temporary posts placed in areas where water depths were generally about 4-5 feet. The intakes themselves were set about 2 -3 feet above the river bottom. Flow rates for all inlets and outlets to Weaver Bottoms were determined based on measured flow data. The data were used to develop a sediment budget for Weaver Bottoms.

Wind, Weaver Bottoms TSS, and SAV Growth

Wind and wave action within Weaver Bottoms are considered the most important factors in the re-suspension of fine sediments. Wind data combined with the TSS data shows high TSS concentrations coincided with windy periods from June through mid-August, but that the TSS concentration fell to lower levels and were not affected by windy periods in September (Figure 2.14). This non-responsiveness to wind also coincides with the growth of submerged aquatic vegetation (SAV), which has the affect of protecting bottom sediment from re-suspension.

Sediment Budget:

A daily inventory of sediment inputs and outputs to Weaver Bottoms from 01 June to 30 September was developed based on flow rates and TSS concentrations. This "sediment budget" showed a net outflow of TSS from Weaver Bottoms of just over 5,000 tons. Much more sediment was being moved in the area during the early part of the season before mid-July due to higher

Figure 2.15. Large sand delta formation at MN-7 inlet of Weaver Bottoms. USGS

Mississippi River Flow and the effects of the draw-down.

Drawdown Effects:

The 2005 drawdown clearly had the effect of reducing the percentage of river flow being carried through the backwaters. This resulted in less sediment being carried into Weaver Bottoms. The influence on the net sediment accumulation in the backwaters is not so clear, as reduced inputs are offset by reduced outputs. Factors that are not directly affected by the drawdown such as wind & submersed aquatic vegetation (SAV) growth play a significant role in net sediment accumulation in Weaver Bottoms.

A distinction must be made between fine and coarse sediments. This TSS budget does not attempt to estimate the movement of coarse material (sand). Nearly all coarse material (sand) that is transported into the backwaters is deposited in deltas at the mouth of the inputs. An example of this is the large sand delta formation at the MN-7 inlet to Weaver Bottoms (Figure 2.15).

The drawdown may reduce coarse sediment deposition in the backwater deltas near the inlets as overall flow into the backwaters is reduced. However, sand transport is weighted heavily during high flows and a significant percentage of the deposition normally occurs during high flow/flood conditions when the Lock and Dams are operated in an "open river" condition (i.e. when the drawdown operation has no effect).

Comparison to 1993/94 Data:

Several major changes have taken place in Weaver Bottoms since the 1993-4 TSS work was done. The three major alterations are:

- Major erosion at MN-7 resulting in higher flows, making it the largest source of TSS into Weaver Bottoms.
- Modification of site MN 14-1 (WBOE)—this site now accepts a larger percentage of the total outflow from Weaver bottoms (94%). This project was aimed at improving main channel navigation conditions and has some local effect on sediment transport, but very little influence on the overall sediment movement through Weaver Bottoms.
- Recovery of SAV in late 1990's (after crash in late 1980's).

The recovery of SAV in Weaver Bottoms reduces sediment re-suspension by wind and wave action. This effectively improves that trap efficiency of the backwater area, so that a larger percentage of the sediment entering Weaver Bottoms is deposited. SAV reduces TSS concentrations and improves water clarity.

2. .2 Biological Parameters

2.2.1 Vegetation Monitoring

Pool 8 Drawdown

Composition of the Seed Bank in Draw-down Areas of Navigation Pool 8 of the Upper Mississippi River

Kevin Kenow, J. E. Lyon, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

The drawdown was expected to dry and consolidate bottom sediments and, thereby, increase the area of emergent and submersed aquatic vegetation by natural seed germination. However, much of the river sediments that would be exposed during a drawdown had not been above water for over 60 years. The study was conducted to determine if a viable seedbank of desirable plants existed in the exposed area.

To quantify the availability of seed, the potential seed bank of selected areas of Pool 8 from substrate samples collected in spring, 2000 was assessed. Fifty species of plants were identified in the seed bank samples. This included 29 wetland (10 submersed aquatic, 6 emergent, and 13 moist soil), 11 facultative wetland, and 10 upland species. Dominant taxa included arrowheads (*Sagitaria sp.*) false pimpernel (*Lindernia dubia*), flat-sedges (*Cyperus sp.*) water star-grass (*Heteranthera dubia*), love grasses (*Eragrostis* sp.) and rice cut-grass (*Leersia oryzoides*). Submersed and emergent aquatic species were widely distributed, occurring in more than 90% of the samples. The plant response to the drawdown was very similar to the results of the seed bank study.

Vegetation Response to Demonstration Drawdowns in Pool 8 of the Upper Mississippi River, 2001 and 2002

Kevin Kenow, James E. Lyon, Randy K. Hines, Larry R. Robinson, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

In an effort to enhance aquatic plant production and habitat diversity on the Upper Mississippi River a pilot water level reduction on Pool 8 was conducted during 2001. A second year drawdown was prescribed for 2002. The vegetation response to the water level reduction during the drawdowns was assessed through:

- Determine changes in distribution of aquatic vegetation through the use of high-resolution aerial photography and land cover data generated from that photography;
- Determine the compositions, distribution diversity and biomass of submersed aquatic vegetation;
- Determine the composition, diversity, biomass and seed/tuber production of moist soil, rooted floating and emergent perennial vegetation.

Extent of Plant Coverage

Aerial photography of Pool 8, south of the Root River, was obtained during late July and August 2000-2003, to map the extent of aquatic plant coverage. On 21 July 2001 during the period of maximum drawdown, a total of 1,954 acres (791 ha) were exposed (8.2 % of the area assessed) (Figure 2.16). Maximum extent of the drawdown in 2002 was estimated to be similar to that of 2001. However, because river discharge rates were

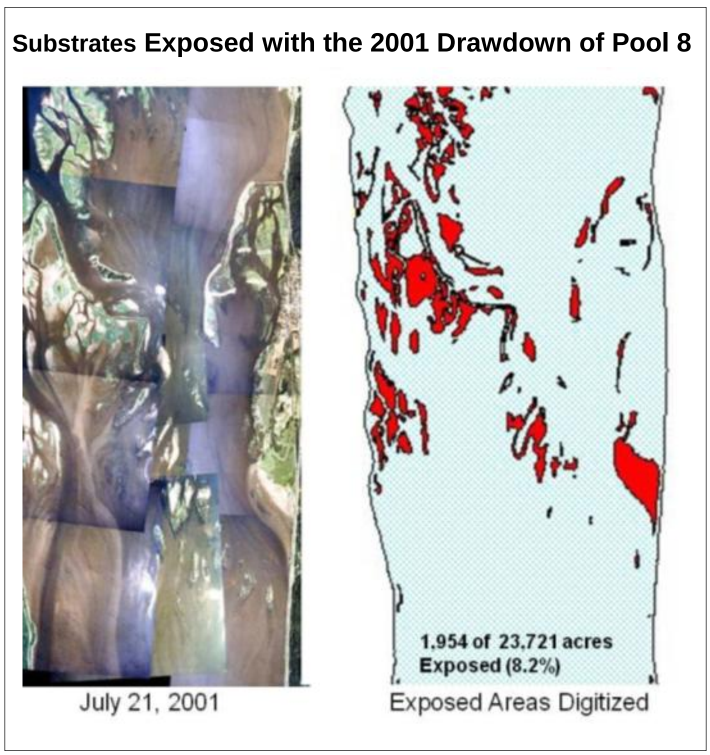


Figure 2.16. Delineation of substrates exposed with the 2001 drawdown of Pool 8. Photo 21 July 2001, USGS

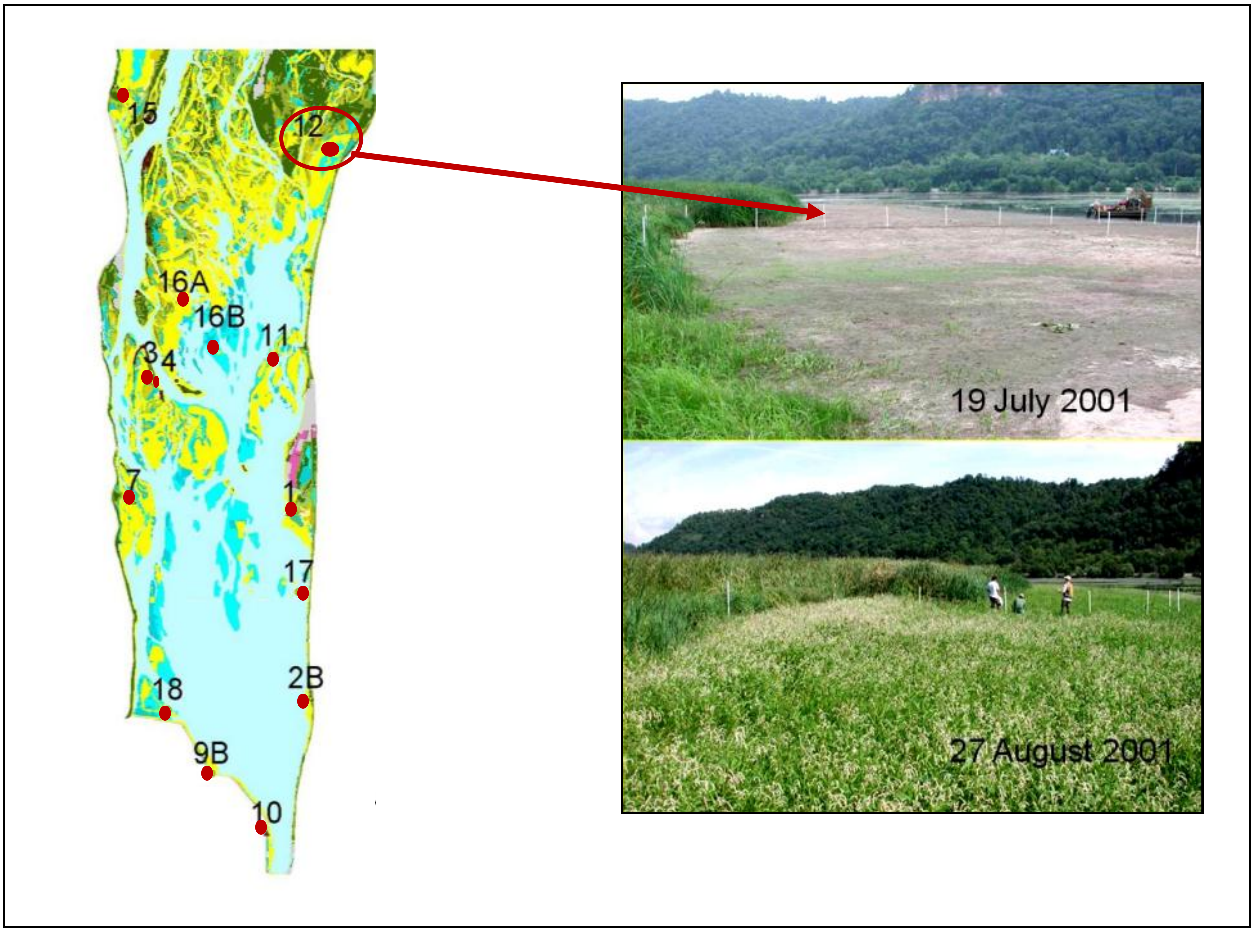


Figure 2.17. Pool 8 Vegetation Transect Locations. The development of vegetation on exposed substrates was monitored along permanent transects at 13 sites throughout Pool 8. Plant response 2001 on Pool 8 Transect 12 (below right) was dominated by nodding smartweed, rice cutgrass, teal lovegrass and flatsedges. USGS

generally higher in 2002, area exposed at any given time during 2002 was generally lower than that of 2001.

Substantial expansion in the area of desirable aquatic plant communities were documented in the lower third of Pool 8, following the 2001 and 2002 drawdowns. In 2003, increases in deep marsh perennial (209 acres), rooted-floating aquatic (310 acres), and submersed aquatic vegetation (851 acres) communities were notable. Open water habitat was reduced by 1,362 acres (551 ha) during the same period.

Vegetation Response on Exposed Substrates

The response of vegetation on exposed substrates was monitored along 13 transects throughout Pool 8 (south of Root River) in 2001 and 2002 (Figure 2.17).

More than 50 taxa of moist soil (26), perennial emergent (6) and aquatic species (2) were identified. Rice cut-grass *(Leersia oryzoides)*, broadleaf arrowhead *(Sagittaria latifolia)*, water stargrass *(Heteranthera dubia)*, nodding smartweed (*Polygonum lapathifolium)*, chufa flatsedge, (*Cyperus esculetnus*), false pimpernel *(Lindernia dubia)*, and teal love grass *(Eragrostis hypnoides)* were the dominant species that developed on exposed substrates. The plant response to the drawdown was very similar to the results of the seed bank study.

Plant density was related to the duration of substrate exposure, with higher plant densities and more plant development occurring on substrates exposed for a good portion of the growing season (i.e., mid-pool sites that remained exposed through mid-September) and low plant density on those substrates that were re-inundated in mid-August 2001. For example, plant density ranged from less than 5 plants per m² on substrates exposed in the lower end of the pool to more

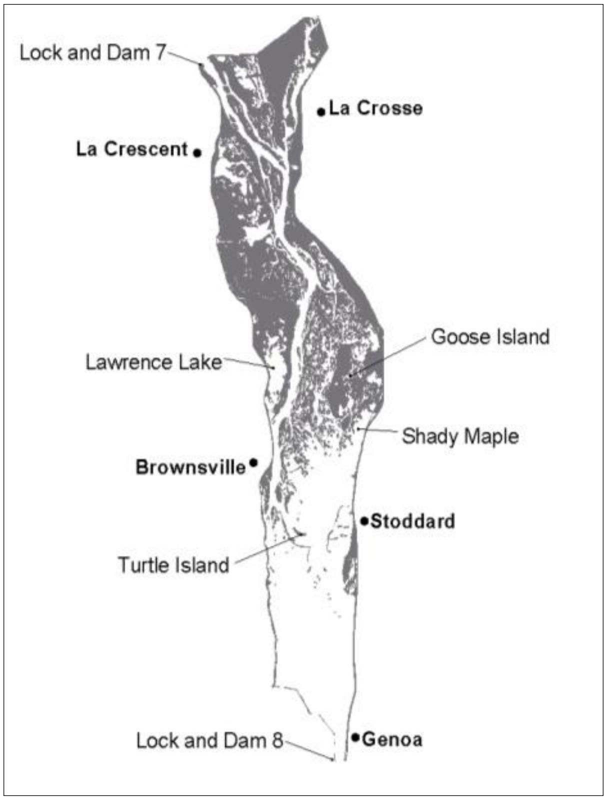


Figure 2.18. Plant density in 2001 was highest in substrates exposed in the mid portion of Pool 8, e.g. Turtle Island, Shady Maple, Stoddard Island Project. WDNR

than 100 plants per m² in the mid portion of the pool. (e.g., north of Turtle Island and Shady Maple) (Figure 2.18.). Similarly, arrowhead tuber production ranged from none on substrates exposed in the lower end of the pool to 30 tubers per m² in other areas (e.g., Shady Maple, Stoddard Island Project Area.)

A shift from a plant community dominated by annuals in 2001 to one dominated by perennials in 2002 was observed (Figure 2.19).

In some areas, the perennial emergent response persisted through summer 2005. For example, vegetation change within a 500-acre (202 ha) area along the Raft Channel was monitored annually from 2000-2005. Following the drawdowns, the return of an important deep marsh perennial component to the Raft Channel area and a return to the aquatic plant community diversity that had been present in 1975 was observed (Figure 2.20).

Seed and Tuber Production

A variety of moist soil and emergent plant species, important food resources to wildlife, grew on substrates exposed during the drawdown. Seed production in 2001 was dominated by annual plants including: rice cut-grass

Figure 2.19. Vegetation response to 2001 and 2002 summer drawdowns of Pool 8. The plant community on the exposed sites shifted from one being dominated by annuals in 2001 to one dominated by perennials such as arrowhead, water stargrass, rice cutgrass and chufa flatsedge in 2002. Photo—Raft Channel West, USFWS.

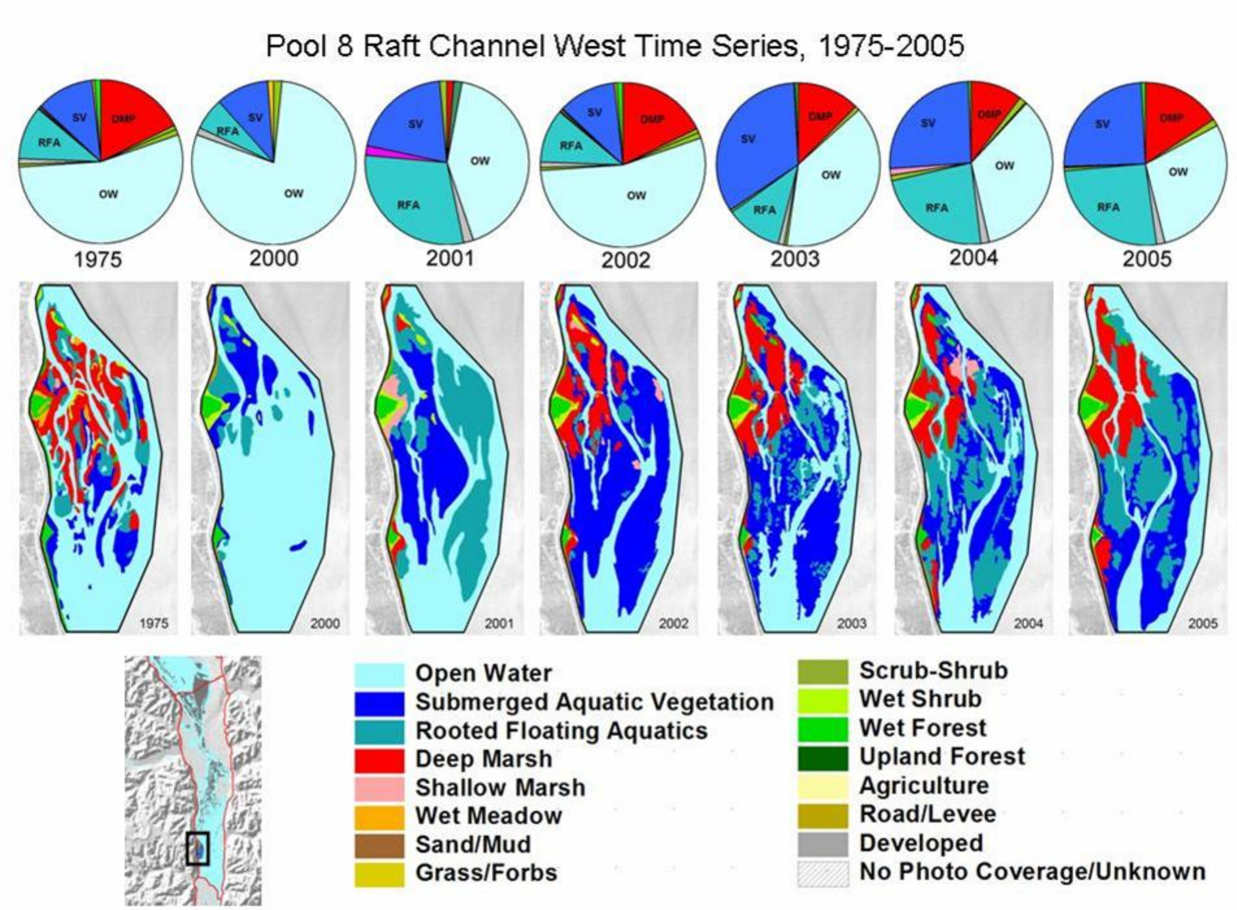


Figure 2.20. The deep marsh perennial plant community, essentially absent in 1999 and 2000, occupied 79 acres (16% of the area) in summer 2005. Rooted-floating aquatics occupied 97 acres and submersed aquatic vegetation 72 acres more in 2005 than prior to drawdown. USGS

(51% of total production), chufa flatsedge (13%), barnyard grass (*Echinochloa crusgalli*) (13%), and nodding smartweed (11%). Tuber production in 2001 was dominated by arrowhead (52%) and sago pondweed (*Potamogeton pectinatus*) (44%). In 2002, arrowhead made up 94% of total tuber production. Arrowhead tuber production increased 16-fold (average = 3.4 g/m^2 in 2001 vs. 55.3 g/m^2 in 2002) across transects we examined during the two years.

Conclusion

Much of the plant response observed on exposed substrates was directly influenced by the drawdown. Many emergent, moist-soil, and terrestrial species that require exposed substrates or shallow water (i.e., < 5 cm) for germination and development would not have become established under the normal flooding regime in Pool 8.

Pool 5 Drawdown

Vegetation Response to a Water Level Drawdown in Pool 5 of the Upper Mississippi River, 2005

Kevin P. Kenow, James T. Rogala, and Larry R. Robinson, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

The primary objective of the drawdown, as established by the WLMTF was to improve conditions for the growth of aquatic vegetation with special emphasis on perennial emergent species. A combination of field sampling and interpretation of aerial photography was used for evaluating the vegetation response during the first year of the drawdown, including:

- Determine changes in distribution of emergent vegetation through the use of interpretation of high resolution aerial photography from pre- and post-drawdown years.

- Determine vegetation response/growth on exposed substrates during the drawdown at peak biomass through field measures of the composition and productivity of moist soil and emergent perennial
- vegetation on exposed substrates using a random sampling design. The extent of substrates exposed was determined using a GIS coverage generated from photography acquired during the time of peak drawdown (15 July 2005.)
- Determine changes in distribution and abundance of submersed aquatic vegetation through repeated annual surveys using a random sampling design. (Results are addressed in Submersed Aquatic Vegetation Monitoring 2.2.2.)

Extent of Plant Coverage

On 15 July 2005 during the time of peak drawdown approximately 405 ha (999.4 acres) of substrate were delineated as newly exposed on aerial photography (Figure 2.21). The drawdown of Pool 5 was not optimum over the target period in the summer of 2005. Low discharge restricted the drawdown during the period August to September. Nonetheless, water levels in 2005 were lower than those levels found during the previous ten years.

Changes in the distribution of vegetation communities as interpreted from aerial photographs indicate an expansion of submersed aquatic vegetation and shallow marsh plant communities in 2005. A large increase in submersed aquatic vegetation was documented in the Weaver Bottoms portion of Pool 5. Approximately 1,000 acres of the 1,435 acre pool-wide increase in submersed vegetation occurred here.

De-watered shallow areas occupied by rooted floating species in 2004, were supporting shallow marsh annuals and perennials in 2005. This change occurred primarily among the islands bordering the main channel. Overall, land cover classification changed on 2,314 of 13,626 acres (17%) from 2004 to 2005. Open water habitat was reduced by 2,054 acres (-30.4% within-class change) and the rooted-floating aquatic community decreased by 178 acres (-15.5%). Increases were observed in the shallow marsh annual (370 acres, 2077.1%), shallow marsh perennial (225 acres; 54.5%), and submersed aquatic vegetation (1,435 acres; 106.7%) (Figure 2.22).

Vegetation Response on Exposed Substrates

Vegetation response on exposed substrates was determined at 166 randomly selected locations within the delineated exposed area. Sampling was conducted between 24 August and 15 September 2005. The 166 sites averaged 33 days exposed, with an average starting date of 19 July and average ending date of 29 August. Average maximum elevation above the water surface (i.e., drawdown) on these sites was 0.18 m (0.6 ft.), with a maximum of 0.40 m (1.3 ft.). Response was evaluated by measuring the above- ground biomass, and percent cover within a 1-m^2 quadrat.

Seventy–two plant species were identified in sampling quadrats on exposed substrates of Pool 5. These areas were dominated by moist-soil and emergent species. The most frequently observed species were rice cutgrass, common arrowhead *(Sagittaria latifolia)*, sandbar willow (*Salix exigua*), grassleaf mudplantain

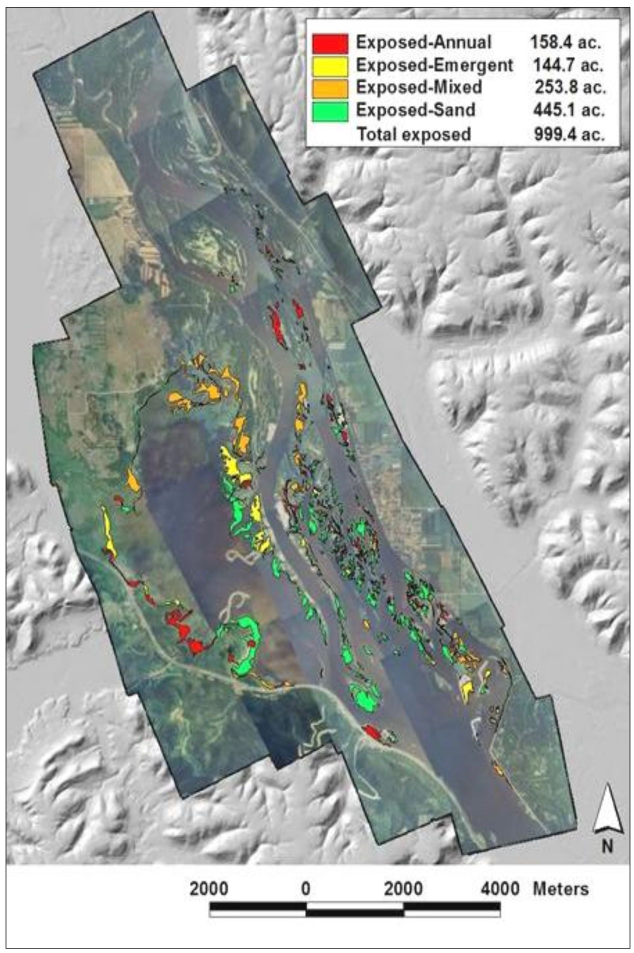


Figure 2.21. Delineation of substrates exposed with the 2005 drawdown of Pool 5, Upper Mississippi River. Photo 15 July 2005, L&D discharge 30,600, L&D Elevation 657.94 USGS

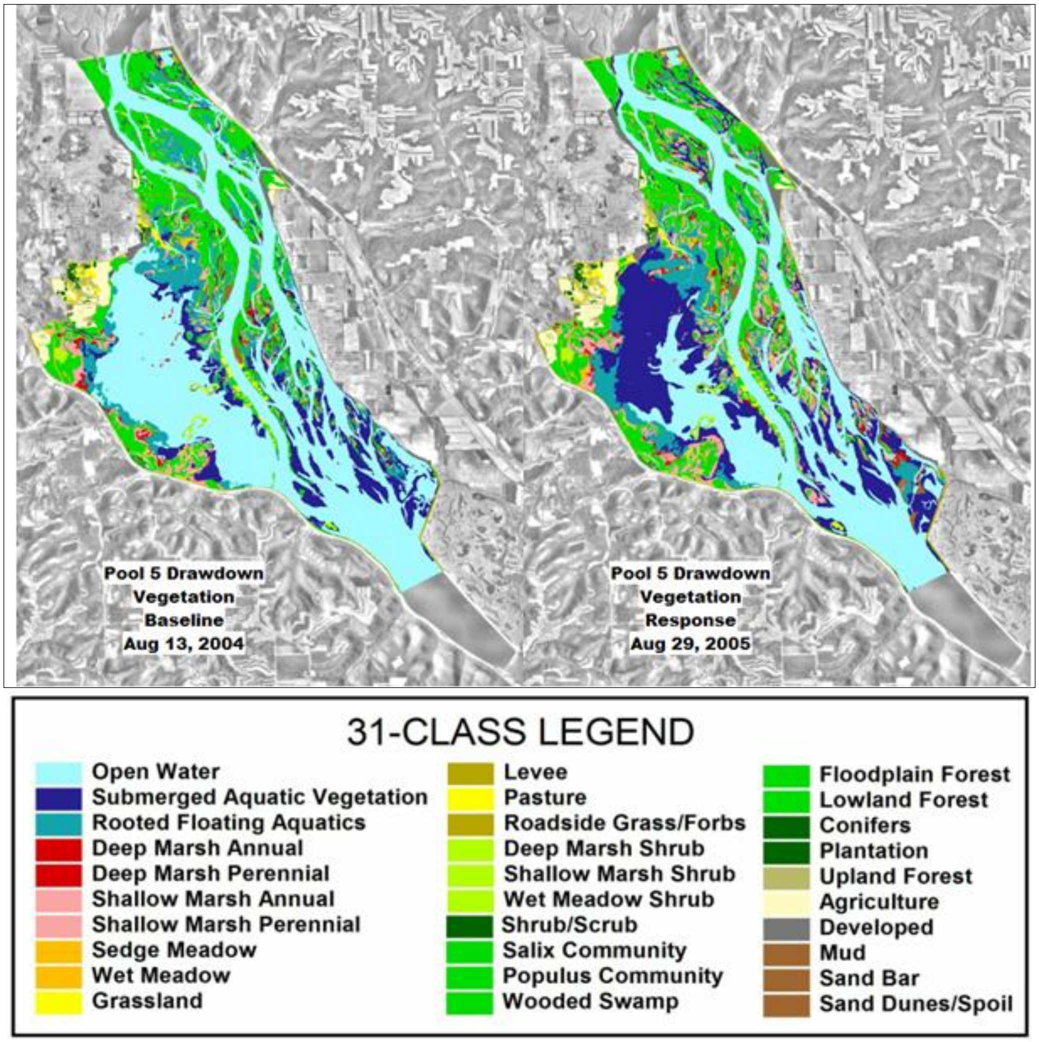


Figure 2.22. Pool 5 study area land cover data for 2004 and 2005 overlying a mosaic of digital orthophoto quadrangles. USGS

(*Heteranthera dubia*), and chufa flatsedge. Growth progressed well despite the increase in water levels that occurred in late July in the lower end of the pool.

Plant species diversity (number of species) of sample quadrats was related to amount of time the mudflats were exposed as well as the elevation above water surface and the reduction in soil moisture level.

Submersed species (e.g., coon's tail [*Ceratophyllum demersum*] and Canada waterweed [*Elodea Canadensis*] were observed on sites dewatered for short periods (mean = 5 to 7 days exposed). Floating-rooted aquatic types (e.g., American lotus [*Nelumbo lutea*]) were more common on sites with an intermediate dewatering (i.e., mean = 22 to 32 days exposed).

Common arrowhead tended to occur on sites with slightly longer periods of dewatering (mean = 37 days), with soft-stem bulrushes (*Schoenoplectus tabernaemontani*) and rice cutgrass also more commonly found on sites exposed for a longer duration (mean = 45 days).

Species considered more terrestrial (e.g., willows [*Salix spp*.] and flatsedges [*Cyperus spp])* were most prevalent among the list of most common species and were observed on sites dewatered longer than 50 days.

Above Ground Biomass

American lotus (18.3 g/m^2), white waterlily (*Nymphaea odorata*) (12.4 g/m^2), teal lovegrass (11.6 g/m^2), rice cutgrass (11.4 g/m^2), common arrowhead (9.8 g/m^2), sandbar willow (7.4 g/m^2), redroot flatsedge (6.6 g/m^2), and chufa flatsedge (6.3 g/m^2) dominated biomass production across all quadrats.

The mean number of days exposed and the magnitude of exposure (i.e., elevation above water surface and reduction in soil moisture level) were highly correlated ($r^2 = 0.94$) for plant species diversity and biomass production of sample quadrats, so the relations described above need to be interpreted with caution when weighing effects of magnitude verses duration of drawdown.

Conclusion

Much of the plant response observed on exposed substrates was directly influenced by the drawdown. Many emergent, moist-soil, and terrestrial species that require exposed substrates or shallow water (i.e., < 5 cm) for germination and development would not have become established under the normal flooding regime in Pool 5 (Kenow, et al. 2009).

Evaluation of 2006 Vegetation Response on Areas Exposed during the 2005 Drawdown of Navigation Pool 5, Upper Mississippi River

Kevin P. Kenow, James T. Rogala, Pete J. Boma *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

The drawdown conducted in Pool 5 in 2005 exposed about 405 ha (1,000 acres), mostly in the lower and midpool areas. A second drawdown was prescribed for 2006 to enhance productivity of perennial emergent aquatic plants. The drawdown was initiated on 12 June 2006 and water levels were gradually reduced to about 1.5 feet below the normal secondary pool elevation of 659.5 feet above mean sea level (msl) at Lock and Dam 5 by 26 June. However, because of the low and declining river flows during summer 2006, river managers were only able to hold a full 1.5-foot drawdown at the dam for a couple of days before having to shift to "primary control" and the pool water level was raised to the project pool elevation of 660.0 feet msl.

Despite the lack of a 2006 drawdown of Pool 5, UMR resource managers were interested in plant community change on those areas dewatered with the 2005 drawdown. The WLMTF partners were also interested in the long-term effects of drawdown on vegetation dynamics. The finding from the studies in Pool 5 across multiple years, along with vegetation monitoring in other drawdown pools, is expected to improve our understanding of vegetation response to periodic drawdowns on the UMR.

Vegetation above-ground biomass and per cent cover were measured at 217 randomly selected locations within areas of substrates exposed during the 2005 drawdown that are not exposed under normal pool operations. At each sample location, percent cover was determined by species, and stem counts obtained for most emergent, moist-soil, and terrestrial species occurring with a 1-m^2 quadrat. General substrate class, and evidence of herbivory (i.e., grazing by Canada geese [*Branta canadensis*] or muskrat [*Ondatra zibethicus*]) were recorded for each site. Vegetation sampling was conducted between 21 August and 14 September 2006.

Vegetation Response on Exposed Substrates

Fifty-one plant species were identified in sampling quadrats on exposed substrates of Pool 5, approximately 70 percent of the number of taxa that appeared within the same sampling frame during sampling in August-September 2005 (i.e., sampling during the 2005 drawdown).

In 2006 these areas were dominated by emergent perennial and submersed aquatic species**.** The most frequently observed species were coon's tail, common arrowhead, Canada waterweed, grassleaf mudplantain, rice cutgrass, white waterlily, and soft-stem bulrush. Growth progressed well in these species despite the lack of a drawdown in 2006.

Above Ground Biomass

Plant biomass was 260 percent higher than that measured on the same area in 2005 (108.4 ± 9.7 g dry wt/m^2). Common arrowhead (64.5 g/m^2), rice cutgrass (53.8 g/m^2), white waterlily (29.0 g/m^2), sandbar willow 23.1 g/m^2), reed canary grass (*Phalaris arundinacea*; 19.3 g/m^2), and broadfruit bur-reed (*Sparganium eurycarpum*; 18.0 g/m^2) dominated plant biomass across all quadrats.

Plant biomass among sample quadrats in 2006 was positively associated ($r^2= 0.14$, $P < 0.0001$) with estimated number of days that the quadrat was dewatered in 2005 (determined from the water elevation model). Those quadrats that were exposed earliest in 2005 and were higher on the elevation gradient tended to have higher plant biomass in 2006.

Evidence of grazing was evident in 8 of the 217 sites (3.7 percent). However, plant biomass did not differ significantly between grazed and ungrazed.

Plant biomass was also assessed only among those quadrats that contained a given species to better illustrate potential productivity of individual species. The rank order in biomass among sites where a species occurred was wild rice (*Zizania aquatica*; 526.4 g/m^2), sandbar willow (218.0 g/m^2), purple loosestrife (*Lythrum salicaria*; 204.1g/m^2), reed canary grass (199.1 g/m^2), rice cutgrass (149.8 g/m^2), and common arrowhead (142.9 g/m^2).

A general pattern of increase was observed in emergent and submersed aquatic plant species and decrease in moist-soil and terrestrial species in 2006 compared to the vegetation composition of the same area in 2005 (Kenow et al. 2007). Noteworthy were large reductions in the occurrence of sandbar willow (34 percent versus 12 percent frequency of occurrence in 2005 and 2006, respectively) and black willow (*Salix nigra*; 34 percent versus 7 percent), chufa flatsedge (37 percent versus 1 percent) and redroot flatsedge (*C. erythrorhizos*; 29 percent versus 1 percent), false pimpernel (*Lindernia dubia*; 32 percent versus 1 percent), nodding smartweed (*Polygonum lapathifolium*; 27 percent versus 5 percent), and teal lovegrass (27 percent versus 0 percent). Rice cutgrass occurred at 45 percent of sites sampled in 2005 and 38 percent of sites sampled in 2006.

The occurrence of common arrowhead was about the same (45 percent versus 47 percent) in both years, while sessilefruit arrowhead (*Sagittaria rigida*; 6 percent versus 20 percent) and broadfruit bur-reed (4 percent versus 15 percent) increased in 2006.

An increase in the occurrence of several submersed aquatic species (grassleaf mudplantain, Canada waterweed, coon's tail, Eurasian watermilfoil [*Myriophyllum spicatum*], wildcelery [*Vallisneria americana*], and sago pondweed [*Potamogeton pectinatus*]) was also observed.

Compared to the biomass of emergent species in 2005, large increases were evident in the average aboveground biomass of common arrowhead, rice cutgrass, soft-stem bulrush, and broadfruit bur-reed.

Conclusion

Much of the emergent vegetation that occurred within the sampling area (substrates exposed in 2005) was likely established with the 2005 drawdown. Emergent species, such as arrowhead, that arose from seed where suitable conditions were created during the 2005 drawdown were small in stature but produced small tubers or rhizomes. Plants arising from these structures in the subsequent growing season tended to be much more robust, as observed on other UMR drawdowns at Peck Lake on Pool 9 and at Pool 8 (Kenow et al., 2001).

Evaluation of 2009 Vegetation Response on Areas Exposed during the 2005 Drawdown of Pool 5, Upper Mississippi River

Kevin P. Kenow *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

A long-term evaluation of vegetation response to the 2005 drawdown of Pool 5 is important because river managers are particularly interested in the persistence of vegetation established with periodic drawdowns of varying duration, timing, spatial extent, and magnitude. A long term evaluation is also important as the magnitude of response of some plant species may not be evident during the initial year. For example, arrowhead plants that arise from seed where suitable conditions are created during a drawdown, are typically small in stature but produce small tubers. Plants arising from tubers in the subsequent growing season tend to be much more robust.

Vegetation response on Pool 5 substrates exposed during the 2005 summertime water level reduction was evaluated by measuring the above- ground biomass, and percent cover within a 1-m^2 quadrat on 192 randomly selected sample sites located within areas of substrates exposed during the 2005 drawdown that were not exposed under normal pool operations.

General substrate class and evidence of herbivory were also recorded for each site. Vegetation sampling was conducted between 24 August and 09 September 2009.

Vegetation Response on Exposed Substrates

Thirty plant species were identified in sampling quadrats on inundated substrates of Pool 5, approximately 42% of the number of taxa that appeared within the same sampling frame during sampling in August-September 2005 (i.e., sampling during the 2005 drawdown).

In 2009, these areas were dominated by emergent perennial and submersed aquatic species. The most frequently observed species were Canada waterweed (*Elodea canadensis*), coon's tail, common arrowhead , grassleaf mudplantain, sessilefruit arrowhead, white waterlily (*Nymphaea odorata*), and broadfruit bur-reed.

Above Ground Biomass

Above-ground biomass of submersed aquatic plants averaged 72.0 ± 11.1 g dry wt/m^2 (median = 16.9; range = 0 to 643.5 g/m^2) in 2009. Broadfruit bur-reed (mean biomass = 71.8 g/m^2), common arrowhead (65.4 g/m^2), cattail (*Typha spp*.; 38.5 g/m^2), Canada waterweed (35.8 g/m^2), soft-stem bulrush (29.6 g/m^2), and sessilefruit arrowhead (21.9 g/m^2) dominated plant biomass across all quadrats.

Evidence of grazing was observed in 21 of the 192 sites (10.9%) included in the analysis. However, emergent, moist soil, and floating-leaved aquatic plant biomass did not differ significantly between grazed and ungrazed).

Changes Observed from 2005 to 2009

A general pattern of increase was observed in submersed aquatic plant species and a decrease in moist soil and terrestrial species in 2009 compared to the vegetation composition of the same area in 2005-2007.

The pattern in emergent aquatic vegetation varied by species. Figure 2.23 illustrates the change in frequency of occurrence of terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic vegetation during 2005 through 2009.

Large increases were noted in the occurrence of coon's tail (23% vs. 77% frequency of occurrence in 2005 and 2009 respectively), Canada waterweed (34% vs. 78%), sessilefruit arrowhead (6% vs. 32%) and broadfruit bur-reed (4% vs. 28%).

Frequency of occurrence of common arrowhead (45% vs. 34%), soft-stem bulrush (27% vs. 17%), American lotus (*Nelumbo lutea*; 23% vs. 10%), rice cutgrass (45% vs. 2%), and reed canary grass (24% vs. 3%) generally declined over the same time period.

Several terrestrial/moist soil species that were prevalent in 2005 (sandbar willow [*Salix exigua*], black willow [*Salix nigra*], chufa flatsedge [*Cyperus esculentus*], redroot flatsedge [*C. erythrorhizos*], false pimpernel [*Lindernia dubia*], nodding smartweed [*Polygonum lapathifolium*], and teal lovegrass [*Eragrotis hypnoides*]), were not detected among sample sites in 2009.

Compared to the biomass of emergent species in 2005, large increases were evident in the average above-ground biomass of broadfruit bur-reed, sessilefruit arrowhead, cattail, and soft-stem bulrush in 2009. Much of the emergent vegetation that occurred within the sampling area (substrates exposed in 2005) was likely established with the 2005 drawdown. Emergent species, such as arrowhead, that arose from seed where suitable conditions were created during the 2005 drawdown were small in stature but produced small tubers or rhizomes. Plants arising from these structures in the subsequent growing season tended to be much more robust, as observed on other UMR drawdowns at Peck Lake on Pool 9 and at Pool 8 (Kenow et al., 2001).

Despite an increase in 2006, the average above ground biomass of common arrowhead remained relatively stable in 2009; rice cut grass and reed canary grass exhibited a pattern of declining biomass over the same time period.

Compared to the biomass of submersed aquatic plant species collected at even-numbered sites in 2007 and 2009, an increase in average above-ground biomass was noted in coon's tail, Canada waterweed, and grassleaf mudplantain.

Conclusion

A number of desirable plant species that were established on exposed substrates during the 2005 drawdown persisted, and in some cases flourished, through 2009. The dominant emergent species are recognized for their value as wildlife food and habitat structure for aquatic organisms.

Pool 6 Drawdown

Evaluation of Vegetation Response on Areas Exposed During the 2010 Drawdown of Pool 6, Upper Mississippi River

Kevin P. Kenow, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

During August and September 2010 the response of

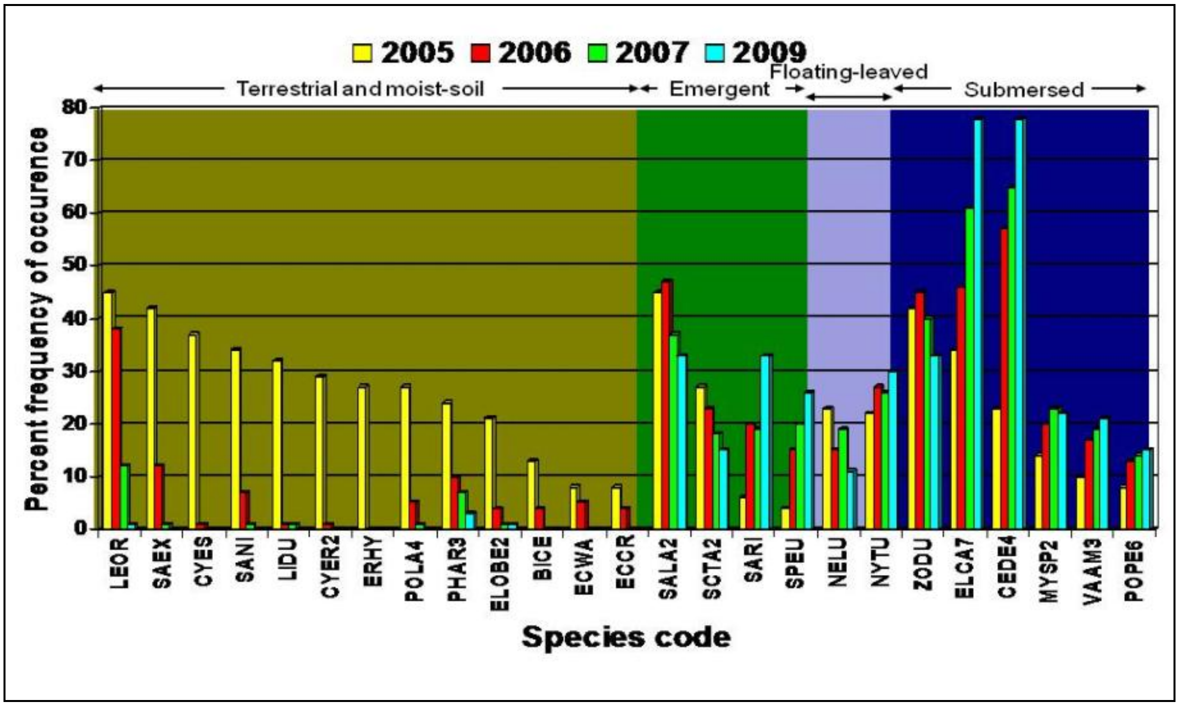


Figure 2.23. Frequency of occurrence of dominant terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic species in 2005 (yellow), 2006 (red), 2007 (green), and 2009 (cyan) found among Pool 5 sites that were exposed during the 2005 drawdown. Species codes are defined as follows :

LEOR	*Leersia oryzoides*	(rice cutgrass)
SAEX	*Salix exigua*	(sandbar willow)
CYES	*Cyperus esculentus*	(chufa flatsedge)
SANI	*Salix nigra*	(black willow)
LIDU	*Lindernia dubia*	(false pimpernel)
CYER2	*Cyperus erythrorhizos*	(redroot flatsedge)
ERHY	*Eragrostis hypnoides*	(teal lovegrass)
POLA4	*Polygonum lapathifolium*	(nodding smartweed)
PHAR3	*Phalaris arundinacea*	(reed canary grass)
ELOBE2	*Eleocharis obtusa*	(blunt spikerush)
BICE	*Bidens cernua*	(nodding beggartick)
ECWA	*Echinochloa Walteri*	(walter's millet)
ECCR	*Echinochloa crusgalli*	(barnyard grass)
SALA2	*Sagittaria latifola*	(common arrowhead)
SCTA2	*Schoenoplectus tabernaemontani*	(soft-stem bulrush)
SARI	*Sagittaria rigida*	(sessilefruit arrowhead)
SPEU	*Sparganium eurycarpum*	(broadfruit bur-reed)
NELU	*Nelumbo lutea*	(American lotus)
NYTU	*Nymphaea odorata*	(white waterlily)
ZODU	*Heteranthera dubia*	(grassleaf mudplantain)
ELCA7	*Elodea Canadensis*	(Canada waterweed)
CEDE4	*Ceratophyllum demersum*	(coon's tail)
MYSP2	*Myriophyllum spicatum*	(Eurasian watermilfoil)
VAAM3	*Vallisneria Americana*	(wild celery)
POPE6	*Potamogeton pectinatus*	(sago pondweed)

vegetation on substrates exposed during the 2010 summertime one-foot drawdown of Pool 6. was monitored similar to Pool 5.

A number of vegetation characteristics were monitored in the drawdown zone, including above ground biomass, species composition, frequency of occurrence, stem density, and cover class at randomly selected locations within areas delineated as exposed substrate during the drawdown that were not exposed under normal pool operations (Figure 2.24). General substrate class and evidence of herbivory were also recorded for each site. Vegetation sampling was conducted between 18 August and 8 September 2010.

The extent of exposed substrates was based on a geographical information system (GIS) coverage generated from true color aerial photography acquired on 27 July 2010 (Lock and Dam 6 Discharge- 40,200 cubic feet per second (cfs), Lock and Dam 6. The drawdown was initiated on 18 June and a full 1-foot drawdown (at Lock and Dam 6) was achieved on about 01 July.

The drawdown initiated on 18 June was maintained through 26 August, when the pool level was gradually raised to normal level by 3 September. An area of about 286 acres was identified as 'exposed' from the 27 July 2010 aerial photography, but extensive coverage of duckweed made interpretation difficult and some submersed aquatic beds were misclassified as exposed substrate.

During sampling within the "exposed areas" only 46.5% of the sites fell on substrates exposed during the drawdown. Consequently, our best estimate of substrate exposed as a result of the drawdown is 133 acres (286 * 0.465=133) or 54 ha. Preferably, the photography would have been collected on about 01 July, but the U.S. Fish and Wildlife Service plane and pilot were not available for the photography mission until 27 July.

Data collected at 141 sample sites regarded to have been exposed during the drawdown was used in the subsequent analyses. The average length of exposure for the 141 sites was 22 days, and ranged from 1 to 66 days.

Vegetation Response on Exposed Substrates

Researchers identified about 66 plant species. The most frequently observed species were grassleaf mudplantain, Canada waterweed, coon's tail, rice cutgrass, curly-leaved pondweed (*Potamogeton crispu*s), reed canary grass, and white waterlily. Other common moist soil species included redroot flatsedge, chufa flatsedge, and nodding smartweed. Emergent perennial species such as sessilefruit arrowhead, common arrowhead, and broadfruit bur-reed were less frequently observed.

Above Ground Biomass

Above-ground biomass of emergent perennial, floating-leaved aquatic, and moist-soil vegetation averaged 119.5 ± 13.4 g dry wt/m^2 (median = 47.4; range = 0 to 866.9 g/m^2) among the 141 sites used in the analysis.

Above-ground biomass of submersed aquatic plants averaged 18.7 ± 5.1 g dry wt/m^2 (median = 0.4; range = 0 to 444.7 g/m^2).

Broadfruit bur-reed (mean biomass = 23.4 g/m^2), rice cutgrass (16.0 g/m^2), chufa flatsedge (12.2 g/m^2), grassleaf mudplantain (9.6 g/m^2), and redroot flatsedge (9.6 g/m^2) dominated plant biomass across all quadrats.

The rank order in mean biomass among sites where a species occurred was broadfruit bur-reed (165.2 g/m^2), barnyard grass (*Echinochola crusgalli*; 92.4 g/m^2), pickerelweed (*Pontederia cordata*; 63.8 g/m^2), chufa flatsedge (57.3 g/m^2), redroot flatsedge (43.6 g/m^2), and rice cutgrass (42.7 g/m^2).

Evidence of grazing was observed at 23 of the 141 sites (16%) included in the analysis. However, emergent and moist soil plant biomass did not differ significantly between grazed and ungrazed plots ($P > 0.12$).

Figure 2.24. Location of sample sites (red dots) for evaluating vegetation response on substrates exposed (indicated in yellow) during the 2010 drawdown of Pool 6, Upper Mississippi River (random distribution based on exposed area depicted on 27 July 2010 photography). USGS

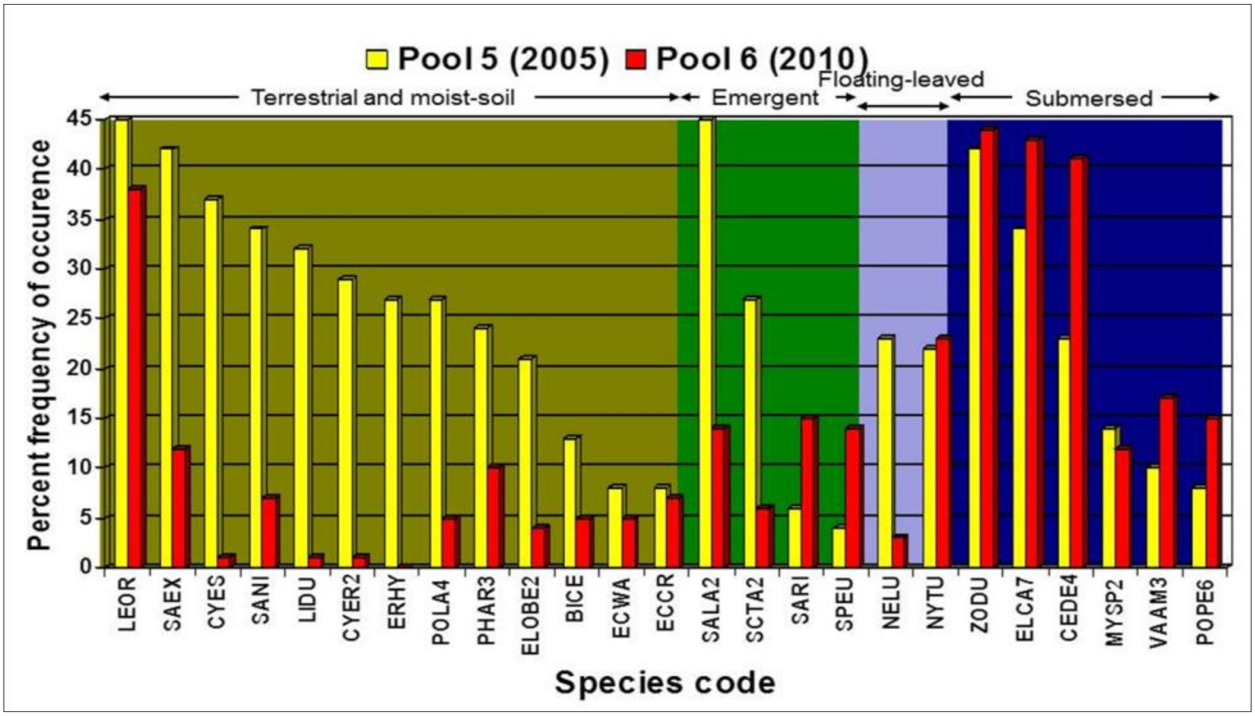


Figure 2.25. Frequency of occurrence of dominant terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic species in Pool 5 (2005; yellow) and Pool 6 (2010; red) found among sites that were exposed during the respective drawdowns. Species codes are defined in Figure 2.20 . USGS

Comparison with Pool 5

A comparison of frequency of occurrence of plant species observed during the Pool 6 drawdown to that occurring during the 2005 drawdown on Pool 5 indicate some notable differences. Moist soil species were not as prevalent, common arrowhead and soft-stem bulrush occurred less frequently, and submersed aquatic species were generally more widespread among Pool 6 sample sites compared to Pool 5 sites (Figure 2.25). We expect this pattern was related to the re-inundation of much of the exposed area of Pool 6 due to the bounce in the elevation (and river discharge) during mid-August. Several of the sites sampled were inundated at the time of inspection, and terrestrial/moist soil plants that are intolerant to flooding (especially small plants) may not have persisted. Also, wave action and fish activity may have dislodged susceptible plants.

Conclusion

A number of desirable plant species were established on exposed substrates during the 2010 drawdown. Growth of broadfruit bur-reed, barnyard grass, chufa flatsedge, redroot flatsedge, and rice cutgrass was robust in some areas. These dominant moist soil and emergent species are recognized for their value as wildlife food and habitat structure for aquatic organisms.

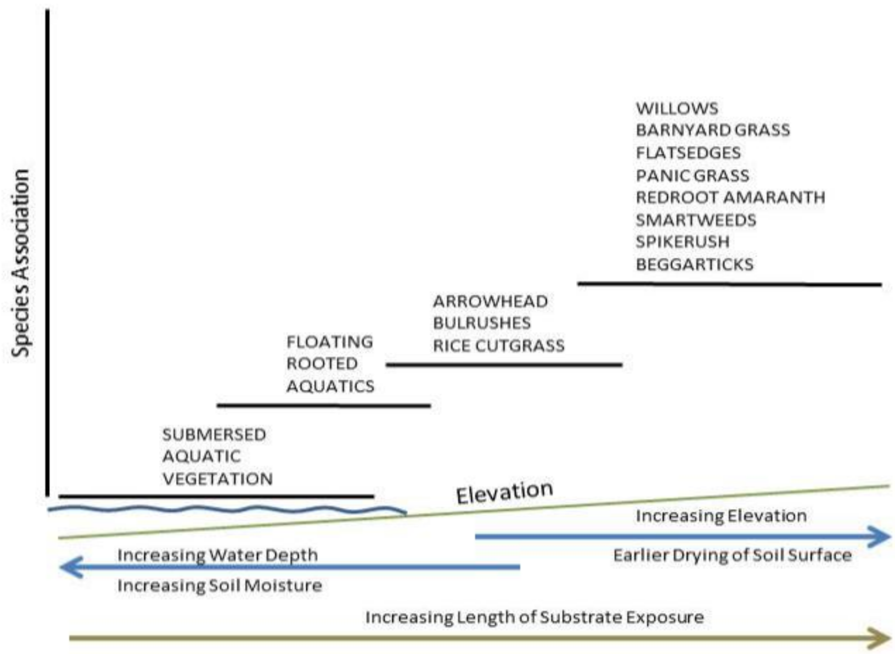
Vegetation Response for Drawdowns of Pools 5, 6 and 8 Conclusion

Much of the plant response observed on exposed substrates was directly influenced by the drawdowns. Many emergent, moist-soil, and terrestrial species that require exposed substrates or shallow water (i.e., < 5 cm) for germination and development would not have become established under the normal flooding regime.

The mean number of days exposed and the magnitude of exposure (i.e., elevation above water surface and reduction in soil moisture level) were highly correlated for plant species diversity and biomass production of sample quadrats, so the relations described above need to be interpreted with caution when weighing effects of magnitude verses duration of drawdown (Figure 2.26).

Emergent species, such as arrowhead, that arose from seed where suitable conditions were created during the drawdown were small in stature but produced small tubers or rhizomes. Plants arising from these structures in the subsequent growing season tended to be much

Drawdown Plant Species Association Related to Elevation, Exposure and Reduction in Soil Moisture



Example: Species Association for Pool 5 Drawdown in 2005

- Submersed species on sites dewatered for short periods (mean = 5-7 days exposed)
- Floating rooted aquatics -intermediate exposure (mean = 22-32 days exposed)
- Common arrowhead (SALA2) (mean = 37 days exposed)
- Softstem bulrush (SCTA2) and rice cutgrass(LEOR) (mean = 45 days exposed),
- Terrestrial species including willows and flatsedges (mean = longer than 50 days exposed).

Figure 2.26. Plant species diversity is related to the length of substrate exposure as well as the elevation above water surface and reduction in soil moisture levels. Drawdown results need to be interpreted with caution when weighing effects of magnitude versus duration of drawdown.

more robust. A summary of the plant response for the different drawdowns is provided in Table 2.3.

Plant monitoring data indicated some of these desirable species persisted and in some cases flourished, at least four years after the drawdown. The dominant emergent species are recognized for their value as wildlife food and habitat structure for aquatic organisms.

2.2.2 Submersed Aquatic Vegetation Monitoring

Pool 8

Pool 8 Submersed Aquatic Vegetation Monitoring

Kevin Kenow, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

Baseline information was collected on more than 200 open water sites in 1999 and 2000 to determine distribution and the quantity of submersed aquatic vegetation present prior to the drawdown. This monitoring was continued through 2004. In general, submersed

Table 2.3. Summary of drawdown data and vegetation response for each pool.

Pool - Year	Target Depth (feet)	Duration of Draw-down	Average Exposure of Sites	Major Water Level Fluctua-tions during Drawdown	Vegetation Primary Response	List of Dominant Species	Post Response- 3-4 years
Pool 8 2001	**1.5**	40 days	Informa-tion not available	Drawdown ended in lower pool 15 Au-gust, maintained in mid portion of pool to 15 Sept.	Annual moist soil plants dominated. Plant Density differed- lower pool < 5 m^2, mid pool > 100 m^2	50 species rice cutgrass common arrowhead grassleaf mudplantain nodding smartweed chufa flatsedge	See Pool 8-2002 results
Pool 8 2002	**1.5**	75 days	Informa-tion not available	Drawdown in lower end of pool entire duration.	Increase of deep marsh perennial and submersed aquatic vegetation (SAV).	Dominated by emer-gent perennials	Submersed and rooted- floating increase, Deep marsh emergent decreased from 2002, but greater than prior to drawdown.
Pool 5 2005	**1.5**	79 days	33 days	Low discharge in late July and Au-gust, drawdown shifted to mid and upper pool.	Increase in frequency of shallow marsh annuals, perennials and SAV. Biomass dominated by: A. lotus, wh. waterlily, teal lovegrass, rice cutgrass, common arrowhead, sand-bar willow and flatsedges.	72 species rice cutgrass, common arrowhead grassleaf mudplantain sandbar willow chufa flatsedge	2009 Increase in SAV, further decrease in moist soil and terrestrial plants, emergent plant response varied by species. Frequency : Increase- sessilefruit arrowhead, broadleaf bur-reed, Decrease– common arrowhead, soft stem bulrush, lotus, rice cut-grass and reed-canary grass.
Pool 6 2010	**1.0**	57 days	22 days	Mid August bounce and increase in river discharge inundated exposed sites.	Biomass dominated by: broadfruit bur-reed rice cutgrass grassleaf mudplantain and flatsedges Comparison with Pool 5: moist soil not as prevalent, common arrowhead and soft stem bulrush less fre-quent, SAV more wide-spread.	66 species grassleaf mudplantain canada waterweed coon’s tail rice cutgrass curly leaved pond-weed reed canary grass white water lily	

aquatic vegetation did not appear to be negatively effected by the drawdown. Submersed aquatic vegetation standing crop biomass was significantly lower in 2000 and 2001 (0 <20 g/m²) from 1999 levels (35 g/m²) and rebounded to 32 g/m² in 2002. By 2004, the average standing crop increased to 44 g/m².

Long Term Resource Monitoring Program-Submersed Aquatic Plant Trends 1998-2005

Heidi Langrehr, *Wisconsin Department of Natural Resources*

Through the Long Term Resource Monitoring Program, submersed macrophyte data was collected from 1998 to 2005 in Navigation Pools 4, 8, and 13, Upper Mississippi River System.

In Pool 8, submersed macrophytes were recorded at 49% of the sites visited in 1998, 58% in 1999 and 48% in 2000. Since 2000, the percent of sites where submersed macrophytes were recorded has steadily increased to 71.4% in 2006. The number of species recorded each year ranged from 14 to 16 species.

In comparison, submersed macrophytes were recorded at about 41% of the sites in Pool 13 from 1998 through 2003. The number of sites increased to 47% in 2004 and 61% in 2006. Twelve to 16 species were recorded each year. In Pool 4, submersed macrophytes were recorded at about 37.5% of the sites visited in 1998 through 2002. (No data was available for 2003.) In 2004, the frequency was 31% and it steadily increased to 43.7% in 2006.

Islands built in 1998 and drawdowns conducted in 2001 and 2002 most likely contributed to increased water clarity and the increase in submersed macrophytes in Pool 8.

Modeling Submersed Aquatic Vegetation in the Upper Mississippi River

Yao Yin, Becky Kreiling -*U.S. Geological Survey - Upper Midwest Environmental Sciences Center*, and Heidi Langrehr, -W*isconsin Department of Natural Resources*, Megan Moore" *Minnesota Department of Natural Resources*

The Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System initiated a pool-scale, stratified random sampling protocol in 1998 to monitor aquatic plants. Since then the program has accumulated 12 annual increments of an unbroken string of data in Pools 4, 8 and 13. We are analyzing this data set to reveal and estimate the effects of recent adaptive management actions of island constructions (HREP) and water level reductions (Drawdown).

We developed a statistical model to predict probability of submersed aquatic vegetation (SAV) occurrence at individual sites based on a few site-specific and a few pool-wide variables. Vegetation data used for model development were LTRMP stratified random sampling data from lower Pool 4 (1998-2003), Pool 8 (1998-2000), and Pool 13 (1998-2003). We validated the model in several ways using the rest of the LTRMP dataset. The model met statistical criteria for goodness of model fit and withstood critical scrutiny based on our understanding of the river.

Our model revealed detectable effects of both HREP and Drawdown in Pool 8. After construction completion in 1998, the Stoddard HREP in Pool 8 demonstrated an immediate enhancement of 170 acres of SAV in 1999. Enhancement peaked in 2002 when approximately 370 acres of SAV were attributable to HREP. As SAV growth in Pool 8 trended up thereafter, the net effect decreased. By 2009, Stoddard HREP accounted for approximately 30 acres of SAV.

During the 2001 Drawdown (first year), Pool 8 had 240 acres loss of SAV due to dewatering. In 2002, the loss on dewatered sites was offset by gains in deep water regions and the pool as a whole had a net gain of approximately 1,300 acres. Approximately 1,200 acres of SAV in 2003 were attributable to the drawdown. Our model revealed no significant drawdown enhancement in later years.

Pool 5 Drawdown

Pool 5 Submersed Aquatic Vegetation Monitoring

Kevin P. Kenow, James T. Rogala, and Larry R. Robinson, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

We anticipated that a drawdown would enhance conditions for submersed aquatic vegetation (SAV) growth on uncolonized substrates, due to an overall reduction in water depths that would allow sufficient light penetration to promote SAV germination and growth. However, short-term reduction of SAV was expected in areas that would be dewatered (i.e. SAV would not tolerate desiccation). Enhancing growth of SAV was not a primary goal of the drawdown, but SAV monitoring was included in this study for the purpose of obtaining a more comprehensive understanding of drawdown effects on vegetation.

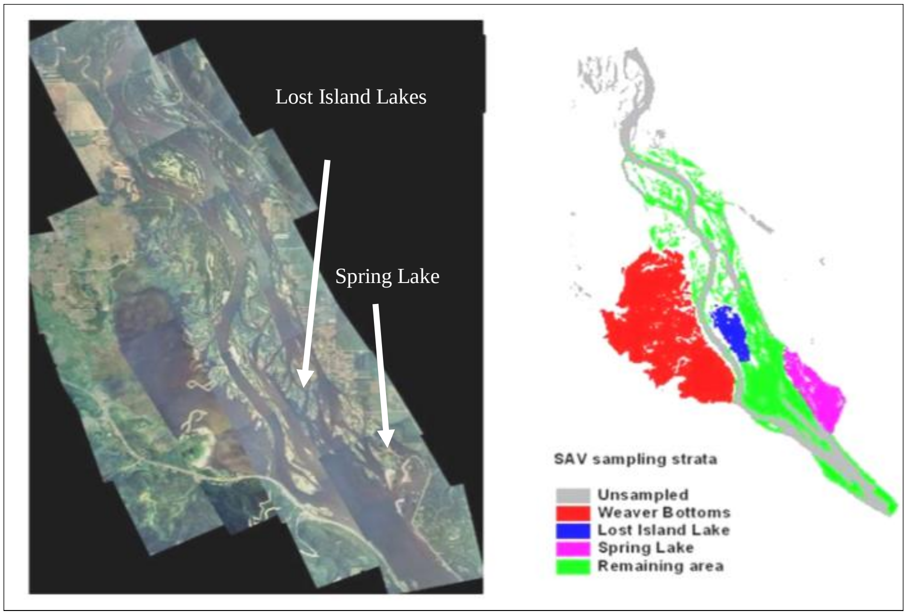


Figure 2.27. Location of Submersed Aquatic Vegetation Sampling Strata, Pool 5. USGS

Submersed aquatic vegetation response to the drawdown during the summer of 2005 was determined by comparing estimated frequency of occurrence through pool-wide random sampling during the period 1999 to 2005. Sampling surveys were conducted using the standard procedures (Yin et.al. 2000). The total number of sampling locations ranged from 145 to 400 sites per year during the period 1999 to 2005. These data were stratified into four areas (Figure 2.27). However, not all areas were sampled all years. Data from 2002 were post-stratified into the selected strata.

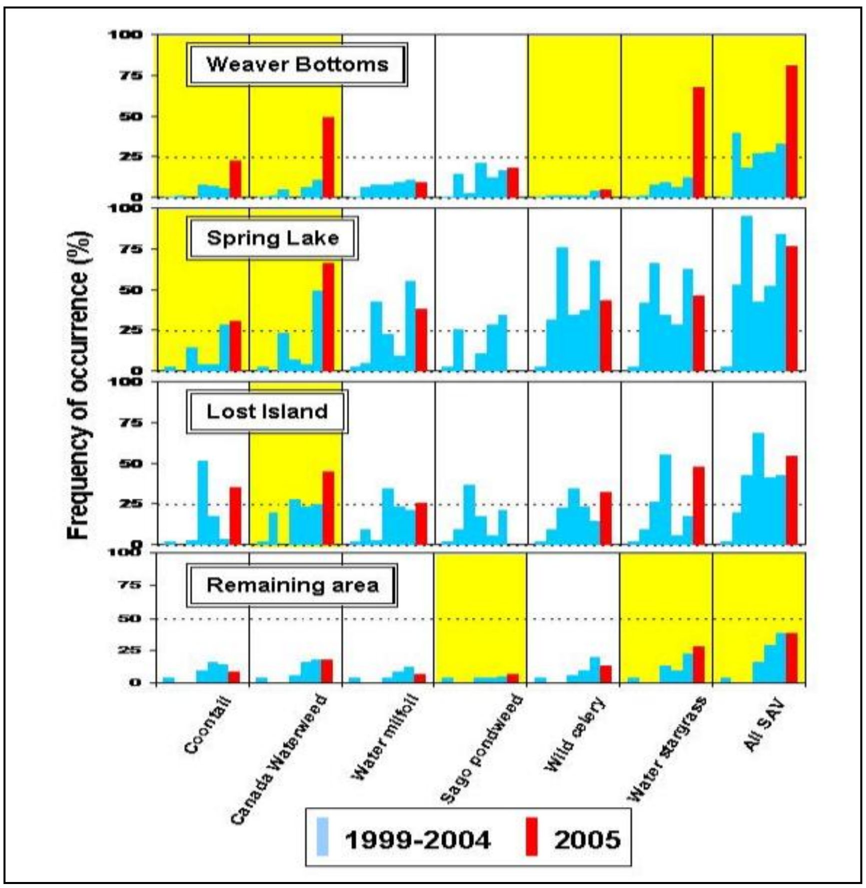


Figure 2.28. Frequency of occurrence for the six most common submersed aquatic species and all submersed aquatic species combined (SAV) found during the annual sampling between 1999 and 2004 (blue; 2003 not sampled) and during the 2005 drawdown (red) on Pool 5 of the Upper Mississippi River. Highlighted (in yellow) are species that had the greatest frequency of occurrence among years in the year 2005 for the respective strata. USGS

Sampling surveys indicated an increase in SAV in Weaver Bottoms (a large backwater lake) during summer 2005 (Figure 2.28). The increase observed in SAV was largely due to increases in coon's

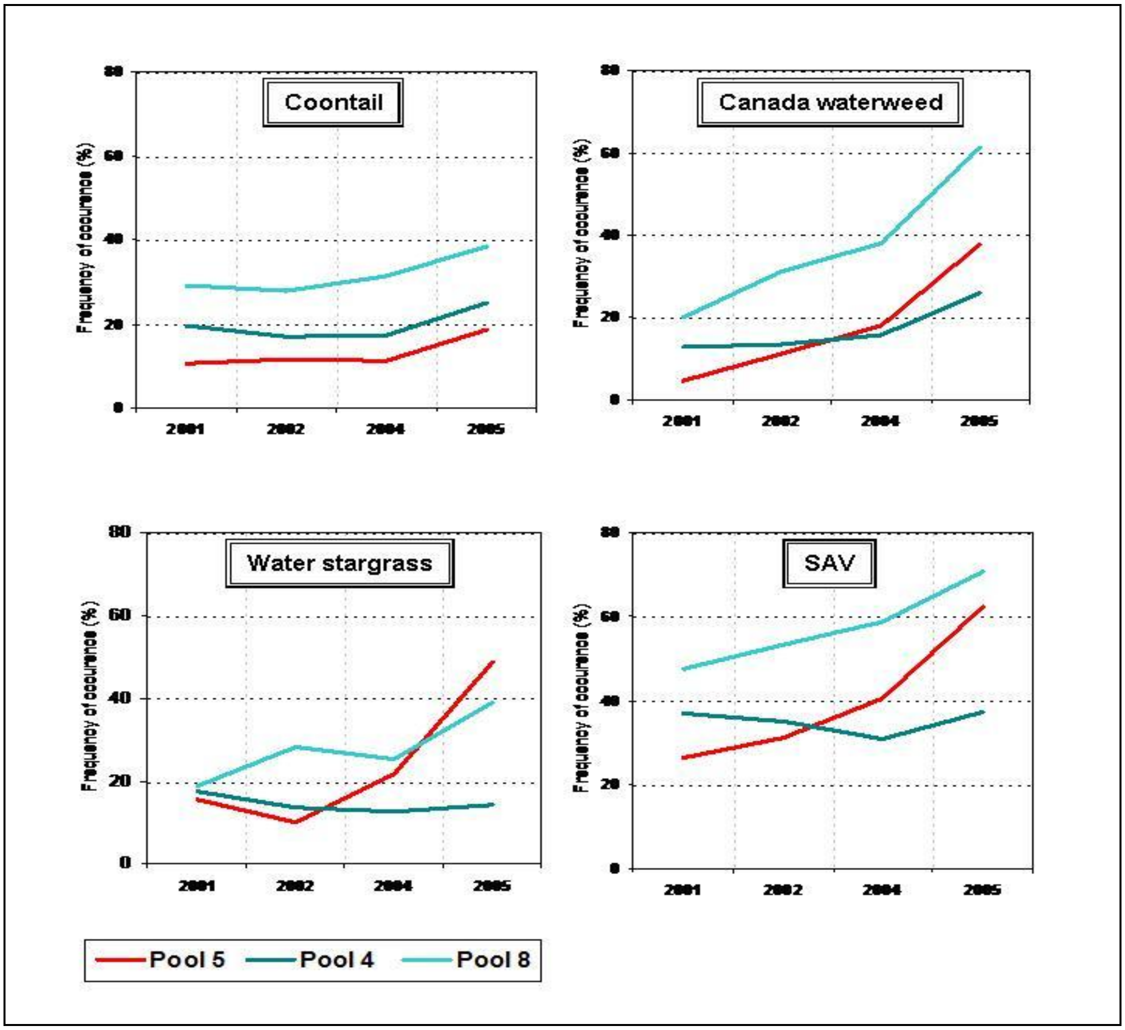


Figure 2.29. Comparison of percent frequency of occurrence by selected species and total submersed aquatic vegetation (SAV) in each year among Pools 4, 5 and 8. The drawdown occurred in Pool 5 in 2005 and Pool 8 in 2001 and 2002. USGS

tail (*Ceratophyllum demersum*), Canada waterweed (*Elodea canadensis*), and grassleaf mudplantain (*Heteranthera dubia*). In contrast, the percent frequencies of SAV in 2005 in the other Pool 5 strata were not convincingly different than what was observed in previous years. However, the two other backwater strata (Lost Island Lake and Spring Lake) had higher occurrences of SAV prior to the drawdown, and the frequency of occurrence in 2005 was similar to that found in Weaver Bottoms. The remaining area that was monitored had comparable occurrence of SAV prior to and during the drawdown.

It is difficult to attribute the observed change in the distribution and abundance of SAV directly to the drawdown. Reference information on the dynamics of SAV is available over the same period (1999-2005) for Pool 4 and Pool 8 as part of the standard monitoring under the Upper Mississippi River System Long Term Resource Monitoring Program.

While increased distribution of SAV in Pool 5 (particularly in Weaver Bottoms) was observed with drawdown, SAV increased on reference pools as well (Figure 2.29). Consequently, differences in observed SAV dynamics might be part of normal annual variability, or perhaps even a short term trend, as well as result of the drawdown. The increase in SAV can not be attributed completely to drawdown effects, although the drawdown probably contributed to some degree. Conservatively, the conclusion at this point is that the drawdown did not negatively impact SAV.

All LTRMP data are a product of the U.S. Army Corps of Engineers' Upper Mississippi River Restoration-Environmental Management Program, Long Term Resource Monitoring Program (LTRMP) element, as distributed by the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin.

2.2.3 Fish Response

Background

Prior to the drawdown it was anticipated that a drawdown could impact fisheries in a variety of ways, both positive and negative. Possible negative impacts identified included:

- Fish strandings,
- Disruption of spawning by species that spawn during late spring and summer, therefore recruitment of nest spawning species may be reduced during drawdown year.
- The drawdown could force many young of the year and smaller fish out of vegetated areas into open water making them more vulnerable to predation.
- Generally higher velocities during the drawdown would reduce the amount of suitable habitat for lenthic fishes, such as bluegills, largemouth bass, many minnow species, crappies, and yellow perch.

Positive impacts included:

- Backwater species could benefit as improved vegetation and water clarity increase cover, food supply, and spawning habitat.
- Fish could rapidly recolonize the drawdown zone following reflooding. The standing vegetation should provide good cover for young of the year and small fish.
- Smaller macroinvertebrates and zooplankton thrive in the flooded vegetation, an effect that may last into the first part of the growing season in the year following the initial drawdown.
- Increased extent and density of emergent and submersed aquatic plants that may result from the drawdown could have a positive effect on fish in future years, by providing more cover, shelter from current, and a more abundant macroinvertebrate forage base.

To reduce the potential negative impacts to fish, the water level reduction in both pools 5 and 8 did not begin until mid June to protect spawning beds, and water levels were gradually lowered (.2 ft/day) to reduce the likelihood of fish strandings.

Pool 8

Evaluation of the Fish Response to the Pool 8 Drawdown

Andy Bartels, Ruth Nissen -*Wisconsin Department of Natural Resources*

Although fisheries impacts from a drawdown were expected to occur, monitoring was limited to surveillance for fish strandings and fish kills. Fish monitoring data from the Long Term Resource Monitoring Program (LTRMP) was assessed for the time period (1993 -2004) for evidence of short term negative impacts. The LTRMP data for the time period 1997-2010 was utilized to evaluate any long-term effects in Pool 8. These results were compared to the long term results for the same time period for Pool 5 data.

Fish Strandings

The possibility existed that during a drawdown many small backwaters would become landlocked for a certain amount of time, some of which could dry up completely or become unsuitable for fish life. Backwater areas that could become isolated were incidentally monitored for dead and dying fish during the drawdown by field crews performing monitoring work in Pool 8.

No fish kills or strandings were reported in the backwaters, however one fish kill consisting of about 1000 bluegill in the 2-4 inch range, was reported in a pond connected to the Mississippi River by a ditch. The fish apparently were trapped in the pond as result of an artificial blockage to the culvert and died as the water levels receded during the drawdown. While the relatively quick lowering of water elevation from a near record spring flood to a full implemented drawdown may have contributed to this fish kill, the primary cause was the absence of an unobstructed escape route which left the fish vulnerable to entrapment and dewatering.

Long Term Resource Monitoring Program Fisheries Assessment

Because Pool 8 is a trend pool for the Long Term Resource Monitoring Program, data on fish abundance were available from 1993- 2004. The following evaluation of LTRMP data was conducted using the online graphical fish browser .

Community Response

Fish species were selected to represent a variety of communities across different habitat types and were evaluated by comparing post drawdown catch rates in Pool 8 to pre- drawdown catch rates from 1993-2004 in order to detect evidence of short term negative impacts (Table 2.4). Sampling methods selected included day electro-fishing, fyke netting, hoop netting and mini fyke netting, which were used for the periods of 01 August - 04 September and 15 September – 31 October for all years except 2003. In 2003 sampling was conducted only by electro fishing during late September and October due to significant funding reductions.

Overall, there were no negative short term trends or differences in catch rates that could be credited to the drawdown. An increase was observed in the catch rate for bluegill in mini fyke nets, largemouth bass in fyke nets and in the forage fish group surrounding the drawdown period which may warrant further investigation during a future drawdown.

All LTRMP data are a product of the U.S. Army Corps of Engineers' Upper Mississippi River Restoration-Environmental Management Program, Long Term Resource Monitoring Program (LTRMP) element, as distributed by the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin.

Pool 5

Evaluation of the Fish Response to the Pool 5 Drawdown

Dan Dieterman, Tim Schlagenhaft, *Minnesota Department of Natural Resources*

Impacts to fish can be difficult to assess because while there may be observable immediate impacts such as fish strandings, impacts to reproduction, whether negative or positive, may take several years of sampling before change can be documented and assessed.

Similar to the Pool 8 drawdown, monitoring the effects of the drawdown included surveillance for fish strandings and fish kills associated with the drawdown process. Fish monitoring data was available for Pool 5 be-

Table 2.4. Fish community response in Pool 8.

Community Group	Species List	Community Response
Main Channel	Channel catfish *(Ictalurus punctatus)* Freshwater drum *(Aplodinotus grunniens)* Shorthead redhorse (*Moxostoma macrolepidotum)* Sauger *(Stizostedion canadense)* Walleye (*Stizostedion vitreum)*	No short term trends or differences in catch rates surrounding the drawdown were observed.
Backwater	Bluegill *(Lepomis macrochirus)* Yellow Perch *(Perca flavescens)* Black crappie (*Pomoxis nigromaculatus)* Largemouth Bass *(Micropterus salmoides)*	Some short term differences in catch rates for day electro-fishing existed, but were within the observed variation or trend patterns outside the buffered drawdown period (e.g. bluegill, yellow perch, and black crappie). There were increases in the catch rate for bluegill in mini fyke nets and largemouth bass in fyke nets.
Forage Fish	Spotfin shiner (*Cyprinella spiloptera*) Emerald shiner (*Notropis atherinoides*) River shiner (*Notropis blennius*)	An increase in catch rates for day electro-fishing was observed in Pool 8 surrounding the drawdown.
Exotic Species	Common Carp (*Cyprinus carpio)*	An increase in catch rates for common carp in fyke nets was observed.

cause annual fish sampling has been conducted by the Minnesota Department of Natural Resources (MDNR) on Pools 3, 5, 5a, 6, 7, and 9 since 1993.

Fish Strandings

During the drawdown, backwater areas were periodically checked to document stranded fish or fish kills. No fish kills were documented during the 2005 drawdown. The 2006 drawdown ended prematurely due to insufficient flow in the river and the pool was back to operation levels by 09 July 2006. Dead fish were observed at a number of sites during 2006 but the cause was most likely due to very low flows which occurred throughout the system combined with warm temperatures.

Fisheries Assessment

The evaluation focused on bluegill and largemouth bass as these are backwater species that could benefit as improved vegetation and water clarity increase cover, food supply, and spawning habitat. These species could also be impacted negatively because of potential impacts from the drawdown on late spawning and reduced survival of young of the year during the drawdown.

Shoreline seining (50 feet, ¼ inch mesh bag seine) for Young of Year (YOY) fish and forage species was conducted throughout Pool 5 in August. Electrofishing (boat mounted electrofishing gear) for all sizes of sport

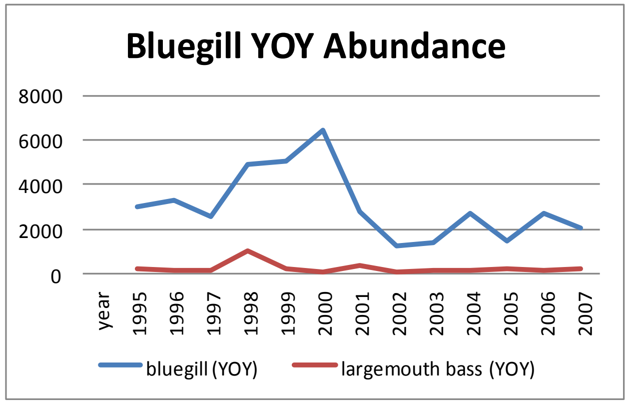
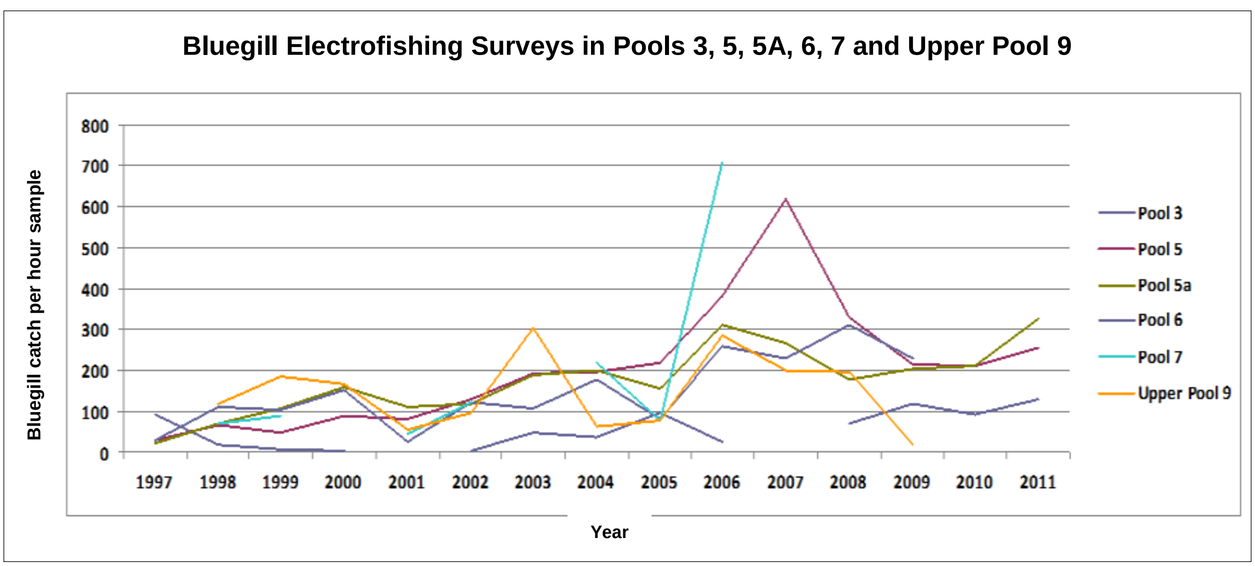


Figure 2.30. Pool 5 seining summary for Young of Year (YOY) bluegill and largemouth bass.   Unit of measurement = number / acre. MN DNR

-fish was conducted late October and early November.

In Pool 5, seining results indicate a decreasing trend in bluegill Young Of Year (YOY) abundance from 2000-2005 (Figure 2.30). While the decrease in 2005 from 2004 YOY numbers may imply there were potential impacts from the drawdown to that year class of bluegills (centrarchids), electrofishing sampling results from 2006 showed an increase in bluegill abundance similar to the other pools, indicating no detectable negative effect on the 2005 year class from the 2005 drawdown. Electrofishing results indicate a large increase in bluegill abundance two years post drawdown in Pool 5 (Figure 2.31).

Figure 2.31. In 2007 a spike occurred in bluegill abundance in Pool 5, two years post 2005 drawdown. This increase was not observed in the other pools sampled, but wasa withn the normal range of l fluctuation as per Pool 7 in 2005.   Pools 4 and 8 were not included in the comparison because they are sampled slightly different as part of the LTRMP. See Figure 2.32 for results from pools 4 and 8.



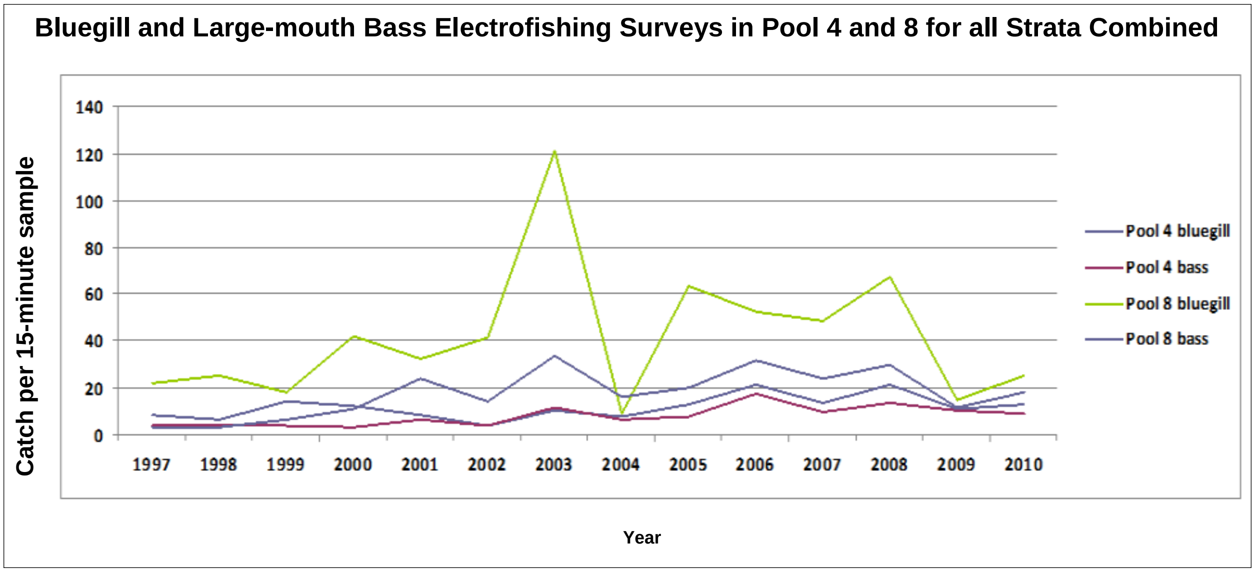


Figure 2.32. Bluegill and largemouth bass catch per 15-minute sample from Long Term Resource Monitoring Program electrofishing data in all strata for Pool 4 and Pool 8. In 2003 a spike occurred in bluegill abundance in Pool 8. A smaller increase also occurred in large mouth bass abundance in Pool 8 in 2003. This 2003 spike occurred two years after the first drawdown in Pool 8 in 2001. MN DNR

The 2007 spike in Pool 5 bluegill abundance was not reflected in the other pools sampled, but was within the range of normal fluctuation and magnitude. For example, a similar spike was partially recorded for Pool 7 in 2005 and a three fold increase was observed in upper Pool 9 in 2003. These increases reflect the effect of natural environmental factors that can impact reproductive success such as timing of floods, aquatic vegetation and water quality. However a similar spike also occurred in Pool 8 two years after the 2001 drawdown (Figure 2.32). Although the increase may be due in part to normal annual variability, the increase in abundance which occurred in both drawdown pools two years after the drawdown suggests the drawdown may have had a positive effect on habitat., The possibility warrants further investigation in future drawdowns.

2.2.4 Freshwater Mussels

Pool 8 Drawdown

Pool 8 Mussel Summary

Gretchen Benjamin-*Wisconsin Department of Natural Resources*, Ken Lubinski-U.*S. Geological Survey-Upper Midwest Environmental Sciences Center*

Prior to the Pool 8 drawdown no formal monitoring was planned during the drawdown to determine the effect on mussels. A multi- agency survey was conducted in 1999 of known mussel beds that might be impacted during a drawdown. The results of that survey indicated limited numbers of mussels in the drawdown zone. Conditions in winter including ice cover, freezing, and ice scouring of these shallow areas can make it difficult for mussels to survive. This was a consideration for the choice of the 1.5–ft. drawdown.

Volunteer Rescue Effort – July 2001

A volunteer rescue effort was organized by Mississippi River Revival to move stranded native mussels to deeper water when the water levels had been lowered 9 -12 inches, about 50% of the 1.5-ft. drawdown. This timing was chosen to minimize excessive exposure of the mussels to the direct air, while also providing volunteers with the ability to move mussels in shallow water out to deeper water. The effort was concentrated in the lower portion of Pool 8 and along areas where mussel beds were previously identified, similar to the pre-monitoring effort in 1999. Volunteers, including Ken Lubinski, U.S. Geological Survey-Upper Midwest Environmental Sciences Center, and Marian Havlik, Malacological Consultants, enumerated, sorted by species and moved over 5000 mussels to deeper water.

More mussels were observed on the exposed sites than expected. This may be due to the effects of the extended flood of 2001 because mussels moved into shallow water during the flood period. As a result of this monitoring, questions arose for future drawdowns, including:

- How to minimize future mussel mortality during a drawdown?
- Can mussel risk to a drawdown be anticipated?
- How fast do mussels colonize shallow water areas?

Pool 5 Drawdown

Background

Based on observations from the Pool 8 drawdown, project planners concluded that a pool drawdown strands some mussels in the drawdown zone. Studies conducted in 2005 and 2006 were designed to evaluate the effects of the drawdown on native mussels in shallow water and to determine a pool wide population estimate.

Preliminary Report on the Effects of the 2005 Pool 5, Mississippi River Drawdown on Shallow-water Native Mussels

Dave Heath, *Wisconsin Department of Natural Resources*, Mike Davis, *Minnesota Department of Natural Resources* and Dan Kelner, *U. S. Army Corps of Engineers, St. Paul District*

Experimental plots were established in Pools 4 (control) and 5. Survival of marked mussels was compared for different water depths and bottom slopes. Unmarked mussels were also sampled along transects in dewatered areas of Pool 5. A pool-wide visual survey was also conducted to observe stranding and mortality. The study found that:

Survival of marked mussels in Pool 5 was:

- 72% in Pool 5 compared to 100% in Pool 4 (control).
- 98% for those placed in deep water (three feet) and 30% in shallow water (1-foot).
- three times higher for those placed in sloping shoreline areas than on shallow flats.

Survival varied by species and was 1.6 times higher for Ambleminae (three ridge) than Lampsilinae (plain pocketbook, fat mucket). Some mussels have the ability to close their valves tightly sealing in water whereas other species have a noticeable gape, which exposes tissues to water loss. Mussels exposed or partially exposed to the air were subject to lethal temperatures for an extended time period. This suggests that high temperatures contributed to observed mussel mortality.

Based on transect data, a large number of mussels may have been killed by the drawdown. However, the total number of mussels that died in Pool 5 as a result of the drawdown could not be estimated due to the limited scope of the study.

Recommendations for Future Work

Very little is known about the effects of water elevation fluctuations in riverine systems on mussels. For example, a second year drawdown in 2006 was expected to cause less mortality to mussels than in 2005 because mussels were not likely to re-colonize the dewatered area in the short time frame between drawdowns. Potential positive and negative effects of water level drawdowns on mussels warrant further investigation.

Some possible positive effects identified include:

- improvement of water quality,
- improvement of filterable food quality and quantity,
- cleaning of substrates of fine material through scouring,
- gradation riverbed material to form and maintain gravel bar habitat,
- improvement of overall productivity,
- improvement of conditions for host fish species.,
- concentration of mussels into dense beds and fish into narrower channels where they are more likely to be infected with glochidia,
- increased recruitment into channel habitat due to fish host concentration,
- reducing mussel recruitment/colonization in areas that are vulnerable to winterkill and/or low water events.

Some potential negative effects could include:

- reduction of long-term recruitment via stranding and loss of reproductive age adults,
- elimination of shallow habitats, which are less affected by zebra mussels,
- destabilization of substrates,
- increasing vulnerability to predators,
- other unknown changes to habitat.

Conclusions from this study were used to implement measures to minimize the effects of the planned second year drawdown on the mussel population. Some of the methods or techniques discussed to minimize the effects include:

- A focused mussel rescue in locations containing rarer species, high population densities, or high species richness of stranded mussels.

On 21 June 2006, during the second planned drawdown in Pool 5, a mussel rescue focused on areas of high quality mussel habitat was conducted. One particularly rich area for mussels was at RM 740, south of Minneiska, as over 4000 mussels were rescued at this location.

- Reducing the rate and initiating the drawdown slightly earlier. An earlier starting date may help to reduce mussel colonization of the areas dewatered in 2005.
- Reducing the depth of the drawdown as there was a significant relationship between water depth and survival.

Population Estimates of Native Freshwater Mussels in Pool 5 of the Upper Mississippi River, 2006

Mike Davis, *Minnesota Department of Natural Resources*

A post-drawdown study was conducted in 2006 to estimate the total number of mussels in Pool 5, and the 95% confidence interval for that estimate. Managers were hoping to obtain a relative error of less than 20%. A second objective was to estimate total live mussels within the area expected to be dewatered in 2006 in order to estimate the proportion of the total population that could be impacted by dewatering. The study was the first on the UMR to evaluate techniques for assessing mussel abundance on a pool scale.

A systematic grid with a random starting point was used to estimate the total number of mussels in the shallow water zone (area dewatered in 2005 plus all depths 0-0.5m) and the deeper zone (> 0.5m) deep under normal pool elevation.

Results

A total of 669 live mussels were collected from 716 samples representing 16 species. Five common species accounted for 90% of the mussels.

The study estimated 189 million mussels in Pool 5 (95% CI range = 152 - 221million), with a relative error of less than 20%. Of this total, 2.3 million mussels were estimated in the shallow dewatered zone (95% CI range = 1.0 - 3.6 million).

Recruitment of native mussels was evident; abundant species were represented by individuals of age one or less and every species collected in the sampling was represented by at least one individual less than 5 years of age.

Zebra mussels were found on 66% of live mussels, but only 9% had more than 10 zebra mussels attached.

Conclusion

It appears systematic sampling at the pool scale was an efficient way to obtain pool-wide mussel population data, as the sample size was more than adequate to determine population size within our objective of less than 20% error. These data are also useful for identifying high-density sites to focus additional research on in the future.

The estimate in the shallow zone had a relative error much greater than 20%. No mussels were collected in 2006 at depths less than 10 inches (0.25-meter) possibly due to a combination of increased aquatic vegetation in the shallow dewatered zone and mortality of mussels during the 2005 drawdown. Subsequent population estimates in Mississippi River pools similarly depth stratified would help to quantify this.

Sites Identified for Future Research

Mussel distribution in shallow water may be limited by winter ice cover and freezing, summer anoxia associated with still water, summer heat exhaustion, high BOD organic substrates, and species preferences and tolerances for these and other conditions. Areas that are shallow but do not freeze during winter due to constant flows across them often support mussels. Typically these areas are sandy or gravelly because currents carry the silt fraction away during most discharges. Some of these areas can support large populations of mussels.

Large sand deposits on the east side of Weaver Bottoms support mussels where the main channel flow enters and deposits bed load. This is true also where side channels enter the impounded area and drop their bed load and flow continues over them year round reducing the amount of ice that forms most winters. Sand bars in the upper end of the pool, especially tailwaters area, fit this pattern also and support mussels in shallow water.

In contrast, most of Weaver Bottoms' shallow zone fails to support mussels, especially the area around the Whitewater River deltas and the former Zumbro River and East Indian Creek deltas in the NW and N of Weaver Bottoms where shallow water is pretty much devoid of mussels.

Pool 6 Drawdown

Population Estimates of Native Freshwater Mussels in Pool 6 of the Upper Mississippi River, 2007

Mike Davis, *Minnesota Department of Natural Resources*

The survey objective was to estimate total live mussels within Pool 6 in order to estimate the proportion of the total population that could be impacted by dewatering. As in the 2006 Pool 5 survey, a systematic grid with a random start was used to estimate the total number of mussels. Samples were collected between June 18 and June 29, 2007 from a total of 534 quadrats at 267 of the 304-targeted sites within the Pool 6 aquatic area.

Results

In total, 380 live mussels representing 16 species were collected from 534 quadrats. Five common species accounted for 83% of the mussels. Three state listed mussel species were collected live including; *Pleurobema sintoxia* – Threatened in MN, *Ligumia recta* – Special Concern in MN, and *Obovaria olivaria* – Special Concern in MN. The study estimated 60,530,422 mussels in Pool 6 (95% CI range = 45,551,530 – 75,509,313).

Mussel presence by primary substrate type differed. While sand substrate was the most frequent primary type reported, quadrats with clay and silt primary substrate types had greater maximum mussel numbers in them than sand or gravel.

Mussel recruitment in Pool 6 varied by species. While individuals ten or more years old accounted for 30% of all mussels, age one individuals (23%) represented the largest single year class in Pool 6.

Shallow Water Surveys of Native Freshwater Mussels in Pool 6 of the Upper Mississippi River: Population Estimates and Sampling Design Evaluation

James T. Rogala and Teresa J. Newton *U.S. Geological Survey, Upper Midwest Environmental Sciences Center*

The survey objective was to obtain an estimate of total live mussels in the dewatered areas that could be impacted during a drawdown of Pool 6. Given that the systematic design used in the 2006 survey in Pool 5 did not produce acceptable estimates in the dewatered area, a different design was tested in Pool 6 in 2007. Due to the low density of mussels in the shallow water areas (i.e., areas less than 0.5 m at low river discharge), a complex sampling design was implemented that incorporates a rapid assessment of mussel density in the shallow water zone.

A one-stage cluster double sampling design was selected for surveying mussel populations in shallow areas. The clusters are transects extending out from the shoreline to a depth of 0.5 meters. The double sampling included semi-quantitative sampling at the surface for all sampling locations, and collecting a quantitative excavated sample at a subset of locations to determine detection probabilities. There were a total of 128 quantitative quadrats and 517 semi-quantitative quadrats sampled along 96 transects. Total population size can be estimated several ways from these data:

- First, a simple inflation estimate can be obtained from the 128 quadrats that were excavated.
- Second-a single ratio can be obtained from the semi-quantitative data from 517 quadrats.
- Third, a species-specific ratio estimator can be obtained for each species, and then sums the

totals across species for an overall population estimate.

Shallow Water Population Estimates

Shallow water estimates were attained using all the data from the transects that met the depth criteria of less than 0.5 m. (Table 2.5.)

- Simple inflation estimate of 1,110, 617 mussels, with a 95% confidence interval of 412,003 to 1,809,230.
- A single ratio estimate of 1,414,968 mussels, with a 95% confidence interval of 351,244 to 3,193,474.
- A species-specific ratio estimate of 1,266,650 mussels, with a 95% confidence interval of 50,607 to 4,579,433.

Dewatered Zone Population Estimates

The shallow water area sampled in Pool 6 was much larger (about 121 ha) than the area expected to be drawdown (about 69 ha). Population size in the expected dewatered areas was calculated using similar methods, but only uses the subset of data attained in the predicted dewatered area. Using quantitative data, the total population size of the dewatered area was estimated to be 333,278 mussels (Table 2.6.)

- Simple inflation estimate of 333, 278 mussels, with a 95% confidence interval of 130,717 to 535,839.
- A single ratio estimate of 204,351 mussels, with a 95% confidence interval of 46,095 to 474,103.
- A species-specific ratio estimate of 312,359 mussels, with a 95% confidence interval of 101 to 1,420,619.

Conclusion

Using species-specific ratio estimators would be the most appropriate method if the number of mussels collected was large enough to generate good ratio estimators, but few individuals of most species were collected. Therefore the estimates from the quantitative data (termed "simple inflation estimates') were considered to be the best estimates from this survey. The density of mussels in the study area was 1.17 mussels/m², as compared to a density of 0.30 mussels/m² in the dewatered zone. This disparity probably reflects a simple depth relation, with more mussels in deeper areas. The other potential reason for the lower density in the dewatered area is the effect of location in the pool, but the mussel densities in the upper portion of Pool 6, which would not be dewatered as much, were not observed to be higher. The fraction of the total mussel population that might be affected during dewatering was one of the important estimates desired from this study.

A population estimate of 61 million (95% CI = 45 to 76 million) was obtained from the pool-wide survey of Pool 6 (Mike Davis, MN Department of Natural Resources, published data). Using the total population estimates in dewatered area from the quantitative sampling (total = 333,278; 95% upper confidence limit = 535,839), the percent of mussels that were in the predicted dewatered area was about 0.55% (95% upper confidence limit of 1.19%).

Mortality, Movement, and Behavior of Native Mussels during a Planned Water Level Drawdown in Pool 6 of the Upper Mississippi River

Teresa Newton, Steve Zigler, Robert Kennedy, Ashley Hunt, Patty Ries, U.*S.Geological Survey -Upper Midwest Environmental Sciences Center*

Systematic, pool-wide surveys of mussels in Pools 5, 6, and 18 have showed that there are considerable mussel populations in these pools including a small, but significant fraction that resides in shallow water- the area potentially affected by a drawdown. This research aims to estimate the fraction of mussels that are able to move, either vertically or horizontally, to avoid short-term mortality during a water level drawdown.

Movement behavior of mussels is likely to be species-specific. A study of mortality of native mussels associated with water level drawdown in Pool 5 of the UMR indicated that Amblemini mussels had higher survival rates than Lampsilini mussels (WDNR et al. 2006). Thus, we hypothesized that Lampsilini mussels would be more likely to respond to water level drawdown by moving horizontally across the sediment surface to reach deep water, whereas Amblemini mussels would be more likely to burrow vertically into sediments.

Movement of mussels may also be influenced by physicochemical variables including discharge, water temperature, day length, water level, low dissolved oxygen concentrations in deeper sediment and perhaps by sedi-

Segment of population	Simple inflation estimate			Estimated with ratio estimators*		
	Total	Confidence interval		Total	Confidence interval	
	population	lower	upper	population	lower	upper
all mussels	**1,110,617**	412,003	1,809,230	**1,414,968**	351,244	3,193,474
mussels ≥25mm	**617,911**	19,547	1,216,275	**671,101**	204,082	1,387,956
mussels ≥50mm	**442,223**	0	892,456	**266,457**	91,707	483,321
Toxolasma parvus	**258,195**	77,553	438,837	**527,384**	12	2,236,189
Pyganodon grandis	**296,780**	0	605,200	**150,892**	25,148	369,982
Leptodea fragilis	**64,493**	5,174	123,813	**29,545**	1	165,189
Amblema plicata	**164,346**	0	370,066	**310,141**	12,840	919,977
Fusconaia flava	**112,529**	0	236,722	**117,886**	12,596	324,314
Lampsilis cardium	**41,698**	0	86,129	**16,841**	3	57,047
Utterbackia imbecillis	**32,024**	0	83,707	**84,415**	4	304,449
Obliquaria reflexa	**92,848**	0	236,740	**16,883**	1	88,175
Potamilus ohiensis	**12,454**	0	37,489	**8,442**	1	63,607
Lampsilis siliquoidea	**35,249**	0	105,447	**4,221**	1	50,504

*For totals across species, an overall ratio estimator was used.

Table 2.5. Total population estimates within the 121-ha study area (and associated 95% confidence intervals) obtained for methods without ratio estimators (simple inflation) and with ratio estimators (double sampling).

Table 2.6 . Total population estimates within the 69-ha dewatered area (and associated 99% confidence intervals) obtained for methods without ratio estimators (simple inflation of quantitative data) and with ratio estimators (double sampling).

Segment of population	Simple inflation estimate			Estimated with ratio estimators*		
	Total	Confidence interval		Total	Confidence interval	
	population	lower	upper	population	lower	upper
all mussels	**333,278**	130,717	535,839	**204,351**	46,095	474,103
mussels ≥25mm	**109,781**	12,959	206,603	**91,348**	36,572	146,124
mussels ≥50mm	**60,069**	4	134,030	**28,107**	5,314	50,900
Toxolasma parvus	**128,837**	3,818	253,856	**257,692**	6	1,231,508
Pyganodon grandis	**16,260**	2	41,402	**25,279**	90	72,598
Leptodea fragilis	**42,670**	4	90,837	**0**	0	0
Amblema plicata	**41,012**	1	122,030	**0**	0	0
Fusconaia flava	**16,053**	2	40,815	**11,755**	2	44,186
Lampsilis cardium	**22,267**	3	56,534	**0**	0	0
Utterbackia imbecillis	**21,749**	2	65,841	**11,755**	2	44,694
Obliquaria reflexa	**11,599**	1	35,012	**0**	0	0
Potamilus ohiensis	**32,831**	1	98,081	**0**	0	0
Lampsilis siliquoidea	**0**	0	0	**5,878**	1	27,633

*For totals across species, an overall ratio estimator was used.

ment temperatures. Slope of the sediment surface may also be important in predicting survival of mussels as water levels recede during a drawdown. Survival of mussels on sloped sites during a 2005 drawdown of a reach of the UMR appeared to be greater than on un-sloped sites (WDNR et al. 2006). Highly sloped surfaces might cue directional movement and provide easier access to deeper water than un-sloped surfaces.

A mussel tagging and telemetry experiment using a Before-After-Control-Impact (BACI) design was selected to characterize the effects of water level drawdown on the mortality, movement, and behavior of a common Lampsilini species (*Lampsilis cardium*) and a common Amblemini species (*Amblema plicata*) in Pool 6 of the UMR during 2009 and 2010. Researchers attached PIT tags to the mussels' shells that allowed them to track individual mussels in 12 study plots, including control areas unaffected by the draw-down, and areas likely to be dewatered. The research plots were located in areas with high slope and low slope areas. The positions of the mussels were located weekly from June through November 2009 (non-drawdown year) and from June through September 2010 (drawdown year). The study was the first to use PIT tags on mussels in a large river.

PIT Tag Success

We developed methods of rapidly applying PIT tags and buoyant line markers to mussels (Figure 2.30). Tag loss due to glue failure was negligible (<1%) over the 2 year study.

In preliminary experiments, unmarked, buried mussels in a sand substrate using the PIT tag reader and antenna indicated that mussels could typically be relocated within about 30 cm and to a depth of at least 20 cm. Most mussels detected with PIT tag equipment were subsequently observed with a viewing bucket, which allowed very precise location.

We tagged and followed ~460 mussels, which were relocated about weekly during June to November 2009 and during June to September 2010. The total number of observations was >6,100.

Recovery of tagged mussels was excellent and ranged from 88 to 100% in both years.

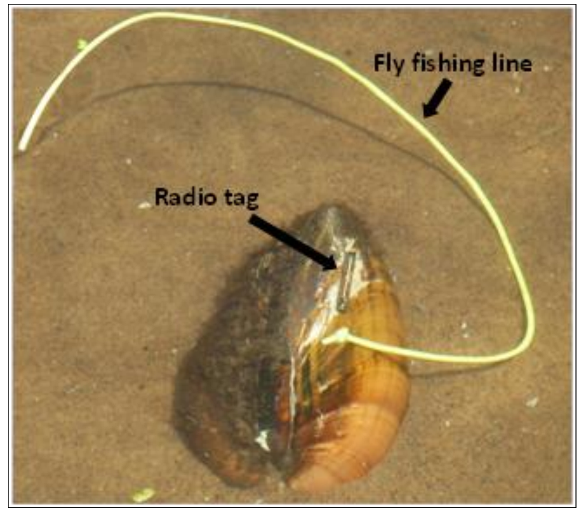


Figure 2.33. Mussel (*Lampsilis cardium*) showing the radio tag and buoyant line marker (fly fishing line). The fly fishing line is used to measure how deep the mussel is burrowed into the substrate. USGS

Mussel Movement and Mortality

Estimated mortality was 5% during the non-drawdown year (2009) and 11% during the drawdown year (2010) Mortality estimates in *L. cardium* were ~2 times higher than those in *A. plicata* (2% in *A.plicata* and 7% in *L. cardium* in 2009; 7% in *A. plicata* and 15% in *L. cardium* in 2010). In both years, about 18% of the mussels were completely buried in river sediments. However, during 2009 (non-drawdown year), most of the buried mussels were *L. cardium* and in 2010, most of the 11 buried mussels were *A. plicata*   This is consistent with the hypothesis that *L. cardium* would move horizontally and follow the receding water, whereas *A. plicata* would burrow vertically.

Background net movement of marked mussels, estimated from reference sites in 2009 and 2010, averaged 3.4 ± 0.2 m (1 SEM) and ranged from 2.1-3.7 m in *A. plicata* and from 3.2-5.1 m in *L. cardium.*

Net movement of tagged mussels at treatment sites averaged 5.2 ± 0.4 m and was similar between species. Thus, overall mussel movement was ~1.5 times higher at the treatment sites than the reference sites in 2010.

The mean weekly movement of mussels ranged from 0-15 m/wk and was similar between species, but varied between lower and higher slope sites. For example, movement ranged from 0-12 m at the lower slope sites and 0-5 m at the higher slope sites in 2009. In 2010, mussels moved more at the treatment sites (0-15 m/wk) than at the reference sites (0-4 m/wk) and the magnitude of this effect was generally greater for *L. cardium*.

The timing of mussel movement was coincident with the initiation of the water level drawdown.
Thus, the rate of mean weekly movement was significantly correlated with the change in water elevation in 2010 but not in 2009.

All mussels generally moved perpendicular to shore (mean angle of movement 100.9 ± 2.7°) into deeper water regardless of year, treatment, or slope.

Results from this study can be used by resource managers to better evaluate the effects of water level management on native mussel populations.

Mississippi River Pool 6 Drawdown – Survival Rates of Lampsiline and Amblemine Mussels Confined to Dewatered Areas - 2010

Dan Kelner, *St. Paul District-U.S. Army Corps of Engineers*, Mike Davis, *Minnesota Department of Natural Resources*

The study objective was to obtain periodic non-predatory mortality estimates of Lampsiline spp. (pocketbook, fat mucket) and *Amblemine pilicata* (three ridge) exposed in dewatered areas during the 2010 water level drawdown of Pool 6.

Prior to the start of the drawdown five marked mussels of each species were placed in predator proof plastic corrals located on randomly selected sites located in < 1 ft. water depth under normal pool elevation in lower Pool 6. Twelve control corrals were placed in 3-5 ft. water depth. Corral checks to assess the status and determine mortality were conducted on three different dates - July 12, 27, August 26.

Results
Both species of mussels were found buried 37-39 % of the time during the final check on 26 August. Mortality of buried *Amblema plicata* was less than mussels located at or on the surface of the substrate. A similar number of Lampsiline mussels were burrowed in but none survived regardless of position.

Although mortality increased with length of exposure, more Amblemine mussels survived in the shady sites than those exposed to more sunlight. Lampsiline mortality was relatively unaffected by sunny or shady locations.

As might be expected, burrowing into the substrate and being in the shade increased survival of *Amblema plicata*, but apparently afforded no apparent survival advantage to the Lampsiline species in this experiment despite similar burrowing behavior. Without the ability to move to deeper water these animals perished. Aestivation by sealing in moisture and avoiding temperature extremes brought on by exposure to direct sunlight is probably impossible for many Lampsilines due to shell morphology but was still only a marginally effective survival strategy for *Amblema plicata*. Without the ability to move to deeper water most mussels perished while those positioned in deeper water during the time of this study (reference groups) enjoyed 98% survival among those recovered.

2.2.5 Shorebird Response

The Upper Mississippi Valley/Great Lakes region is a diverse area that provides important habitat for shorebirds. The Atlantic and Pacific coasts are well known as important migration corridors for shorebirds but the importance of the interior regions of the continent, such as the Upper Mississippi River is gaining recognition. Before the Upper Mississippi River was altered for commercial navigation the floodplain and tributaries provided numerous sandbars, mudflats and oxbows that were ideal habitat for shorebirds. The floodplain still serves as an important corridor for shorebirds.

Pool 8

An Evaluation of Shorebird Response to Demonstration Drawdowns of Upper Mississippi Navigation Pool 8, 2001 and 2002

Lara Hill, *U.S. Fish and Wildlife Service*, Ruth Nissen, *Wisconsin Department of Natural Resources*

The drawdowns exposed approximately 1954 acres (791 ha) of substrates in the lower portion of the pool that had not been exposed since the completion of the Pool 8 Lock & Dam in 1937, therefore the extent of the shorebird response in terms of species richness and abundance was unknown.

To determine shorebird use of new habitats created during the drawdown a shorebird census was conducted weekly on lower Pool 8 during June-September 2001 and May– September 2002 with the following objectives:

- Quantify and compare species richness and abundance during the drawdown to a pool operating under normal conditions.
- Assess the relative importance of a large scale drawdown by comparing survey data to regional data.
- Evaluate spatial variation in composition of shorebird assemblages as related to EMP-HREP projects.
- Examine patterns of migrating assemblages of shorebirds to understand the temporal relationship between water levels and shorebird use.

2001 Drawdown

Due to low river discharge rate in 2001, the target level drawdown of 1.5 feet at the lock and dam was achieved for a period of only 40 days, from 06 July–14 August. Fifteen surveys were conducted from 11 June to 26 September. The results were:

- Observations of 1255 shorebirds, comprising 23 species, were recorded during the 15 surveys. The maximum number of shorebird species observed during any given survey in 2002 was 14, with a peak of 393 shorebirds on 24 July.
- The most numerous shorebird observations were of Spotted Sandpiper (*Actitis macularia*), followed by Pectoral Sandpiper (*Calidris melanotos*) and Least Sandpiper (*Calidris minutilla*).
- During the 40 days the drawdown was in effect 921 (73.3%) of the 1,255 total shorebird observations were recorded. The surveys conducted after 14 August when the drawdown was not in effect contributed 334 (26.7%) of the total shorebird observations.
- The primary peak of shorebird observations occurred in late July with a second smaller peak in mid -September even though no drawdown was in effect.
- The 2001 counts for Lesser Yellowlegs(*Tringa flavipes*), Pectoral and Least Sandpipers were reduced after the drawdown ended and water levels increased after 14 August.

2002 Drawdown

During 2002, river flows were more favorable and the drawdown target was maintained for 75 days (03 July to 16 September). Thirteen surveys were conducted from 23 May to 03 September. The results were:

- Observations of 2,250 shorebirds comprising 22 different species were recorded during the 13 surveys. The maximum number of shorebird species observed during any given survey in 2002 was 15.
- The surveys conducted after 19 August to 03 September accounted for 64.9 % of the 2254 total shorebird observations.
- The peak number of shorebird observations occurred on 27 August, with 607 shorebirds observed. No surveys were conducted after 03 September.
- Spotted sandpipers were most frequently observed followed by Least Sandpipers, and Lesser Yellowlegs.

Twenty-four species of shorebirds were observed during 2001 and 2002. The most abundant shorebird species for all counts combined were Spotted Sandpiper (22.3% of total abundance), Least Sandpiper (17.5%), Lesser Yellowlegs (12.68%), Pectoral Sandpiper (12.05%), and Semipalmated Sandpiper (*Calidris pusilla*) (7.06%). Rare sightings included: Ruddy Turnstone (*Arenaria interpres*), American Avocet (*Recurvirostra americana*) Red-necked Phalarope (*Phalaropus lobatus*) Long-billed Dowitcher (*Limnodromus scolopaceus*) and one Whimbrel (*Numenius phaeopus*) .

No data exists for shorebird use of Pool 8 under normal pool operation, but historical data was available for Pool 7 from 1979-1983. Shorebird surveys were conducted in Pool 7 in 2001 and results were similar to

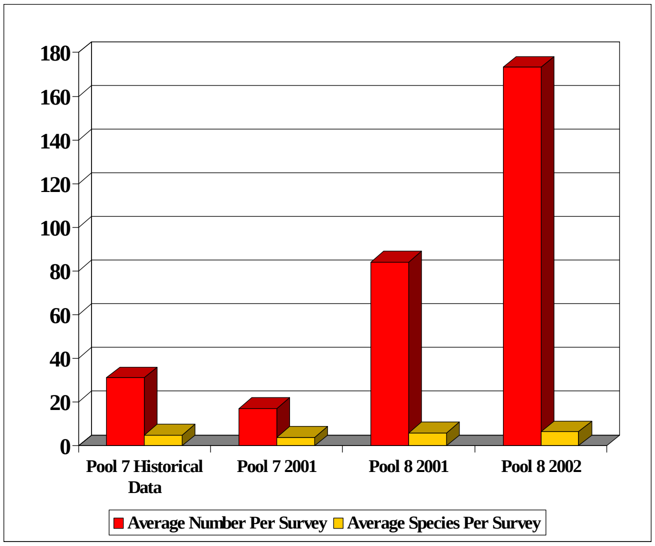


Figure 2.34. Comparison of average shorebird numbers and average species observed between Pool 7 (normal pool operation) and Pool 8 (drawdown conditions).

historical data. A lower average number of shorebirds were observed in Pool 7 for both time periods when compared to Pool 8 results for 2001 and 2002 (Figure 2.34).

The difference in total shorebird numbers between 2001 and 2002 is primarily a result of the large numbers of shorebirds observed from 19 August 2002 survey until the end of the surveys on 03 September 2002, a time frame when there was no drawdown in effect the lower part of the pool in 2001 (Figure 2.35) . During these three surveys more shorebirds were observed than the total number of shorebirds observed in 2001. The difference may have been even greater if surveys in 2002 had extended into mid- September similar to 2001. The extended period of drawdown in 2002 as compared to 2001 resulted in habitat available for later migrating shorebirds.

The relative importance of Pool 8 survey results were examined by comparing the daily count per survey with the average daily count for Prairie Hardwood Transition Bird Conservation Region (BCR23) from International Shorebird Survey (ISS)–Ebird Data using average daily numbers (01 July–30 September, 1995-2010) for Spotted Sandpiper, Least Sandpiper, Pectoral Sandpiper and Lesser Yellowlegs. Overall theses species exceeded Bird Conservation Region 23 regional average counts. Pool 8 high counts for Spotted Sandpiper and Least Sandpiper approached or exceeded the high counts for BCR23.

Conclusion

This study demonstrated the potential of a large scale drawdown on a navigation pool of the Upper Mississippi River to provide resources for migrating shorebirds both in terms of species and numbers.

The results of the 2001 drawdown demonstrated the limitations of depending on a drawdown to provide shorebird migration habitat because of the high probability of complete inundation during a critical time period (mid -August- late September).

Our survey results suggest that maintaining the drawdown whenever possible would be beneficial for the

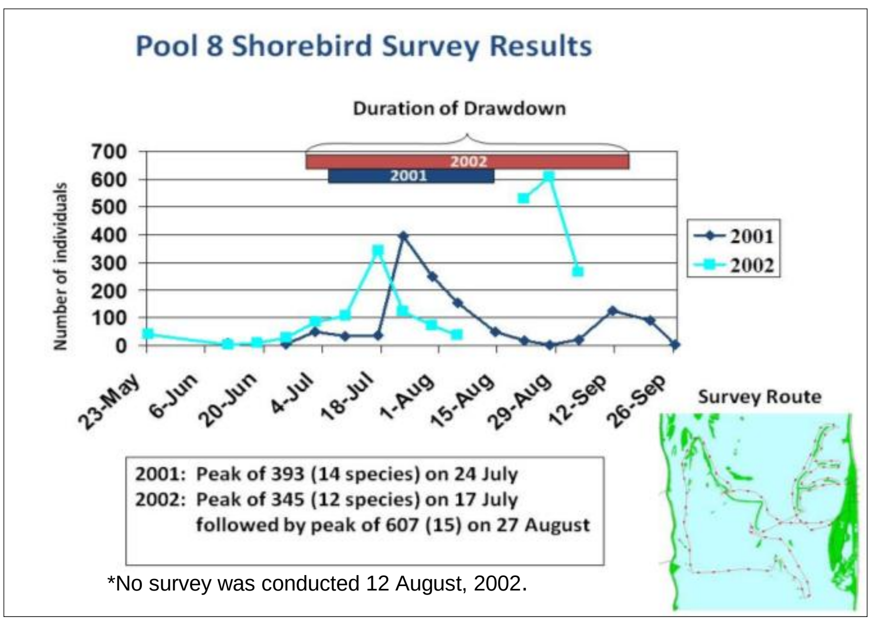


Figure 2.35. The extended period of drawdown in 2002 as compared to 2001 resulted in habitat available for migrating shorebirds as indicated by the number of shorebirds observed in 2002 after mid-August. During the survey of 27 August 2002, 607 shorebirds were observed. In contrast 21 shorebirds were observed during 21 August and 28 August 2001 surveys combined. During the last three surveys in 2002 more shorebirds were tallied than were observed in all of 2001.

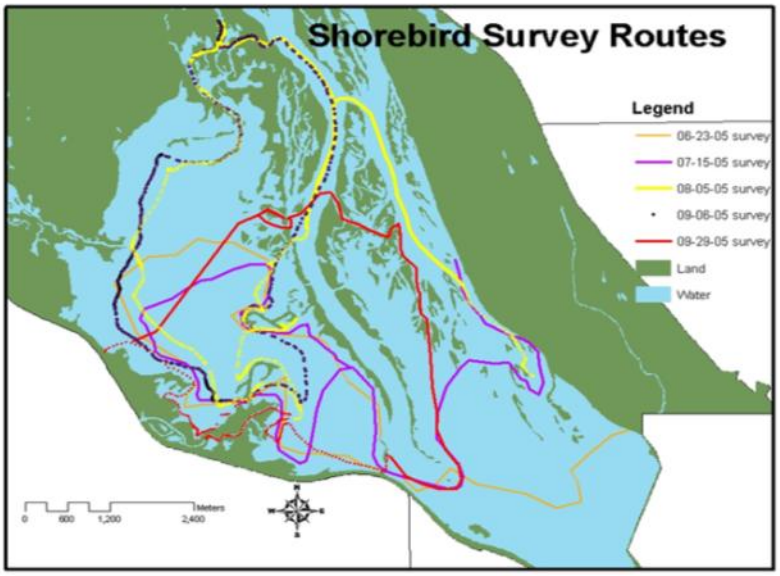


Figure 2.36. The Pool 5 shorebird survey routes were adjusted as the drawdown progressed to focus on accessible areas with exposed substrate. USFWS

late August-late September surge of migrating shorebirds. However data is still lacking to quantify the potential and document the chronology of migrating shorebirds in September while a drawdown is in effect.

Pool 5

Shorebird Monitoring Results-Pool 5 Drawdown

Lisa Reid, *U.S. Fish and Wildlife Service-Upper Mississippi River National Wildlife and Fish Refuge*

Surveys were conducted by the U.S. Fish and Wildlife Service during the Pool 5 drawdowns in 2005 and 2006 to determine shorebird use of the exposed flats and shallow water areas. In 2005, five surveys were conducted (approximately every three weeks) from 23 June to 29 September. Similarly, five surveys were conducted from 28 June to 26 September in 2006. The survey route was adjusted slightly as the drawdown progressed to focus on accessible areas with exposed mud or sand flats (Figure 2.36). Spring Lake was initially included, but the habitat restoration work which included island building and dredging, made it difficult to access that area.

The procedure used to survey shorebirds during the Pool 8 drawdown was followed with two exceptions. The survey was not conducted weekly due to limited staff time. Different boats were used than those used for the Pool 8 surveys.

Pool 5 surveys were conducted with a a shallow draft boat with a surface drive (Go-Devil) and an airboat which was used for two surveys (15 July and 29 September) on an experimental basis due to an inability to get close enough to the exposed flats using the Go-Devil. The airboat method provided a better estimate of the number of shorebirds present even if the species could not be identified. Consequently, an airboat was used for all surveys in 2006 to get a more accurate total of shorebird numbers and survey more of the potential shorebird habitat. Results were:

2005 Drawdown

- A total of 83 shorebirds were observed during five surveys consisting of four identified species and 14 birds of an unknown species.
- The peak occurred during the 05 August survey but was comprised mainly of Killdeer and Spotted Sandpipers, known local breeders. Six Semipalmated Sandpipers were observed on 05 August and 13 yellowlegs (lesser and greater) were observed on 29 September.

From late July through September low river flows caused a shift in pool operation which exposed an additional 1,000 acres in the middle and upper end of Pool 5 for the remainder of the drawdown period but reflooded areas that had been exposed in the lower portion of the pool. This change was beneficial for shorebirds as the vegetation growth on many of the mudflats in the lower portion of the pool prevented use by shorebirds. The newly exposed areas maintained feeding areas for shorebirds in the middle portion of the pool.

While the number of shorebirds observed during the surveys was limited, anecdotal observations obtained during aquatic vegetation and invertebrate sampling in Pool 5 in 2005 using the airboat indicated shorebird use was more extensive than detected through the shorebird surveys. Flocks of 50-100 unidentified shorebirds were observed in the distance as were small flocks of 10-20 yellowlegs after mid July. In addition, approximately 200 shorebirds were observed feeding in some of the last remaining flats in the Whitewater River Delta on 26 September. Observations indicate that in the Weaver Bottoms area and near Buffalo City total numbers of shorebirds may have peaked at between 300 and 1000 birds at any one time during peak migration.

2006 Drawdown
The drawdown scheduled for 2006 began on 12 June, and the target drawdown depth was reached on 26 June. Due to low discharge on the Mississippi River and the inability to maintain adequate depth for commercial navigation the drawdown was discontinued and the pool was back to operation levels by 09 July. The target level was achieved for three days.

A total of 227 shorebirds was observed consisting of seven species, including two American avocets and 55 birds of an unknown species.

The peak (83 birds) occurred during the 28 July survey and was comprised mainly of spotted sandpipers, similar to the 2005 survey. The peak count in 2006 was equal to the total count in 2005 even though the drawdown ended three weeks earlier.

Historical Data
Shorebird surveys were conducted two to three times over the course of the summer in 1986 -1990, both Killdeer (*Charadrius vociferous*) and Spotted Sandpiper were noted. The surveys that did not occur during migration saw 1-6 shorebirds and those taking place during migration noted 3-66 birds. The greatest number, 62 Semipalmated Sandpipers, were recorded 02 June during the spring migration.

Conclusion
Monitoring suggests that temporary feeding areas created by the drawdown were quickly found by locally breeding shorebirds. Although the surveys did not detect a significant increase in migrating shorebirds this is probably due to both the lack of a weekly survey and an inability to get close enough to the exposed flats using the Go- Devil in 2005 and the premature end of the drawdown in 2006 in July. Fall shorebird migration typically occurs between mid July and late September in this area. In the future, shorebird surveys conducted in areas with extensive shallow water should be conducted with an airboat in order to obtain a more accurate count of the shorebirds using the habitat.

2.2.6 Waterfowl Response

Drawdowns have been an important tool of wildlife managers for many years to restore marsh vegetation, particularly emergent aquatic plants, and to manage annual moist soil plants to improve food resources for waterfowl. The drawdowns of Pool 8 were therefore expected to have a beneficial effect for waterfowl and other wetland wildlife.

Evaluation of the Waterfowl Response to the Pool 8 Drawdowns 2001 and 2002

Ruth Nissen, *Wisconsin Department of Natural Resources, La Crosse, WI*

The primary objective of the Pool 8 drawdowns, as established by the Water Level Management Task Force was to improve conditions for the growth of aquatic vegetation with special emphasis on perennial emergent species. Management actions that benefit perennial emergent species can provide direct benefits to waterfowl during migration by producing seeds, tubers, and habitat structure for aquatic organisms. Common perennial emergent species found on Pool 8 that produce seeds and tubers include ,broadfruit bur-reed (*Sparganium eurycarpum),* soft-stem bulrush (*Schoenoplectus tabernaemontani*), Eloacharis sp., water plantain (*Alisma subcordatum Raf.*), wild rice (*Zizania aquatica*) and arrowhead (Sagitaria sp.) (Martin and Uhler 1939).

Arrowhead tubers are an important food resource for Tundra Swans and other waterfowl while on the Upper Mississippi River during autumn migration. Common arrowhead (*Sagittaria latifolia*) grows in dense beds in a mean water depth of .43 m (1.4 feet) on Pool 8 (LTRMP data) and one plant can yield 40 tubers. (USDA). An adult swan consumes an estimated 6.2 pounds of tubers per day (Limpert 1974, Faber 1986).

Sessilefruit arrowhead (*Sagitaria rigida*) grows in more open beds in deeper water (mean water depths of .53 m (1.7 feet) in Pool 8 (LTRMP data). The plants are less robust and produce smaller tubers. Arrowhead was expected to benefit from a water level drawdown as the seeds require saturated soils, direct sunlight and tem-

Figure 2.37. Wood duck (*Aix sponsa*) with common arrowhead tuber uprooted by swan cygnet on right in the Raft Channel Area, Pool 8. Photo courtesy of Susan Fletcher.

peratures of 80-90 degrees F. to germinate (USDA)

Arrowhead tubers are consumed by other species of waterfowl even though they cannot reach the tubers buried in the sediment. Feeding swans are often accompanied by various species of waterfowl. In the process of swans loosening the sediment with their feet, tubers rise to the surface where ducks (most frequently mallards in Pool 8) grab the stray tubers (Figure 2.37). The quantity of tubers consumed by ducks and muskrats may be substantial. Limpert found 3670 g loss of tubers per day per swan (6.2 pounds) in arrowhead beds but Faber found 7860 g loss of tubers per day per swan (17.3 pounds) disappeared from Weaver Bottoms (Pool 5) using a similar method. His assessment was this was an over estimate of swan intake because other species steal tubers from swans as they feed (Faber 1986).

Diving ducks generally use the deeper and more open portion of the pools for both feeding and loafing during the fall migration; hence it was anticipated that most species would be less affected by the drawdown. These areas provide food resources and protection from most predators. They also provide some protection from disturbance from hunting activities (including associated boat traffic) due to regulations in Minnesota and Wisconsin which limit open water hunting (Korschgen 1989). Eight species of diving ducks are found on Pools 4- 14 during fall migration; Canvasback ducks (*Aythya valisneria*) comprise the large majority followed by Lesser Scaup (*Aythya affinis*) and Ring-necked ducks (*Aythya collaris*).

Not all diving ducks have the same diet. Lesser Scaup consume primarily animal foods, including crustaceans, insects and mollusks while Ring-necked ducks consume primarily plant foods [(Anderson 1959, Steffeck and Paveglio (unpublished data)]. In the Mississippi flyway Ring-necked ducks favored pondweeds, coon's tail, (*Ceratophyllum demersum*) wild rice, yellow water lily (*Nuphar lutea*), smartweed and sedges, and an assortment of benthic invertebrates (Korschgen 1989). Canvasbacks consume both plant and animal foods, but plant foods are favored during migration. Canvasbacks staging on Pool 7 during fall migration 1979 and 1980, consumed 98.8 % plant foods, fed primarily on wild celery winter buds (*Vallisneria americana*)and tubers of sessilefruit arrowhead. (Korschgen et.al. 1988). Canvasbacks consumed 40% of the standing crop of 380,160 kg of wild celery winter buds in Lake Onalaska.

Both wild celery and sessilefruit arrowhead were preferred foods and have a similar nutritional composition. Birds that arrived first fed on wild celery because these plants senesce and the leaves float to the surface before the birds arrive so they are not feeding in rank vegetation whereas sessilefruit arrowhead does not senesce until after several frosts. Canvasbacks do not feed in these areas until the areas appear as more open water (Korschgen et al. 1988).

A water level reduction could have a negative impact on submersed aquatic species as plants are eliminated from the exposed substrates during a drawdown which possibly may have an effect on diving duck use. Positive effects are a possibility as submersed aquatic plants will often vary in their response to drawdown (Hoyer & Canfield, 1997). Seeds of some species especially sago pondweed, (a food resource for both swans and canvasback) which remain wet produce heavy to excellent seed crops during the period of lowered water levels. A lowering of the water level during a drawdown may not be a detriment to wild celery beyond the drawdown zone. Wild celery plants can respond to changes in depth or light penetration by altering rosette production or leaf length (Owens et al. 2008) and width (LTRMP data). Lowering the water level during a drawdown may benefit wild celery plants growing in deeper water as plants can allocate more resources to localized expansion.

Monitoring waterfowl response, including dabbling ducks, diving ducks, Canada geese and Tundra Swans, was included as part of the evaluation of the effects of the drawdown on biological parameters.

Aerial Surveys

Monitoring the effects of the drawdowns on waterfowl relied primarily on the results of the aerial waterfowl surveys conducted in Pools 4 through 13 of the Upper Mississippi River National Wildlife and Fish Refuge (Refuge) by the U.S. Fish and Wildlife Service, Wisconsin Department of Natural Resources and the Illinois Natural History Survey. Pool 14 was added in 2007. Waterfowl surveyed include Tundra Swans, Canada geese, and 18 species of ducks.

These surveys are conducted weekly from a fixed-wing aircraft at an altitude of 45 m. Birds are counted out from the aircraft to a distance of about .2 km (1/8 mile) on established flight lines, which do not traverse the entire pool, hence these counts do not provide an all inclusive but rather indices to the number of birds present on the Refuge (UMRNWFR Comprehensive Conservation Plan 2006). Weekly flights generally begin during the last week of September and end the week after waterfowl hunting season closes in Minnesota and Wisconsin, usually late November or early December unless the river freezes first. Not all pools may be counted each week due to weather or other flight delays. Birds will also stay on the river well into December if conditions are favorable.

Waterfowl Use Days

The extent of waterfowl occurrence is described in terms of waterfowl use days, a number calculated from aerial survey counts. Use days account for variability issues inherent to these surveys. In general, a use day(s) is defined as: One bird on the river for one day equals one use day. Use days are calculated by averaging the number of birds counted on two consecutive flights and multiplying by the days between flights

Results

Moist Soil Response

The initial plant community which developed during the first year of the drawdown contained a mix of annual (moist soil plants) and perennial emergent and aquatic species. Seed production in 2001 was dominated by annual plants including: rice cut-grass (*Leersia oryzoides*) (51% of total production), chufa flatsedge (*Cyperus esculetnus*) (13%), barnyard grass (*Echinochloa crusgalli*) (13%), and nodding smartweed (*Polygonum lapathifolium*) (11%) (Kenow et al.). These moist soil plants are well known as a food resource for waterfowl (Cottam 1939, Martin and Uhler 1939, Bellrose and Anderson 1943, Weller 1978, Fredrickson and Reid 1988).

Monitoring this aspect of the drawdown was not included in the initial planning process, therefore no formal waterfowl ground surveys were conducted during August and early September prior to the start of waterfowl aerial surveys in late September.

Waterfowl observations recorded during the weekly shorebird surveys of lower Pool 8 in 2001 indicate shorebird use decreased and waterfowl use increased as the habitat changed from open mudflats in July to flooded annual moist soil plants by mid September (Hill et al.) (Figure 2.38). Large flocks of 1000+ waterfowl were observed in September during the surveys. Large flocks consisting of 1000-2000 Blue-winged Teal, in addition to Canada geese and coots

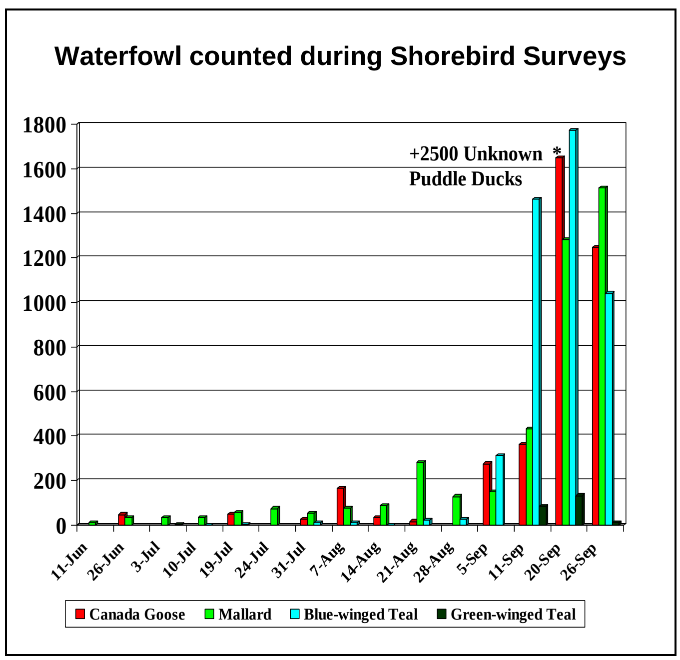


Figure 2.38 The number of waterfowl counted during the shorebird surveys in lower Pool 8 increased in late August and through September 2001. Note: the count on 20 September does not include 2500 unidentified dabbling ducks. USFWS

Figure 2.39. Exposed substrates below Boomerang Island. Exposed substrates in 2001 supported abundant moist soil plants as a result of the drawdown which attracted large flocks of Blue Winged Teal, Canada geese and coots in late August and September. Robert Hurt photo.

were documented using the flooded vegetated flats below Boomerang Island (Figure 2.39) and in the Wisconsin Islands Closed Area in early September 2001 (J. Nissen, unpublished data).

Waterfowl counted in Pool 8 during the late September survey in 2001 and 2002 increased two to four fold from the waterfowl numbers in 2000. The results suggests waterfowl were responding to the availability of food resources in Pool 8 in 2001 and 2002 in late September as well (Figure 2.40).

Waterfowl Aerial Surveys

Waterfowl use days for dabbling ducks, Canada Geese, Tundra Swans and diving ducks were compared between Pool 7, 8 and 9. In years prior to the Pool 8 drawdowns, these three pools and Pool 13 provided the main waterfowl use areas on the Refuge. The use days for Pool 8 closed and open areas were also examined to detect potential changes in use within the pool.

Dabbling Ducks

With two exceptions, year-to-year increases and declines in use days followed similar patterns in Pools 7, 8, and 9 between 1997 and 2009 (Figure 2.41). The change in dabbling duck use days in 2001 (use days in Pool 8 and 9 were very close to that of Pool 7) and 2002 (use in Pool 8 exceeded Pool 7) suggests dabbling duck use shifted from Pool 7 to Pool 8 and 9, possibly due to improving habitat conditions. After 2003 the drawdowns may have had a positive impact on dabbling duck habitat in Pool 8, but conditions improved in Pool 7 and 9 as well.

Dabbling duck use days for closed areas within Pool 8 were examined to detect changes in use that may reveal a response to the change in vegetation which resulted from the drawdowns. The Goose Island No Hunting Zone, which covers 354.5 hectares (876 acres) in the mid pool area of Pool 8, historically provided the majority of dabbling duck use days in Pool 8 and was the only closed area on Pools 4-14 to meet a Refuge goal of 200 duck use-day per acre goal ((UMRNWFR Comprehensive Conservation Plan 2006).

After 2001, there was a shift of dabbling duck use within Pool 8 to the Wisconsin Islands Closed Area (2614 ha. or 6461 acres) as reflected by the steady increase in the percentage of use days in Wisconsin Islands Closed Area (WICA) located in lower Pool 8, and corresponding decrease in use days in the Goose Island No Hunting Zone as a percentage of the total pool (Figure 2.42). By 2004, the number of dabbling duck use days recorded in WICA exceeded those in the Goose Island No Hunting Zone.

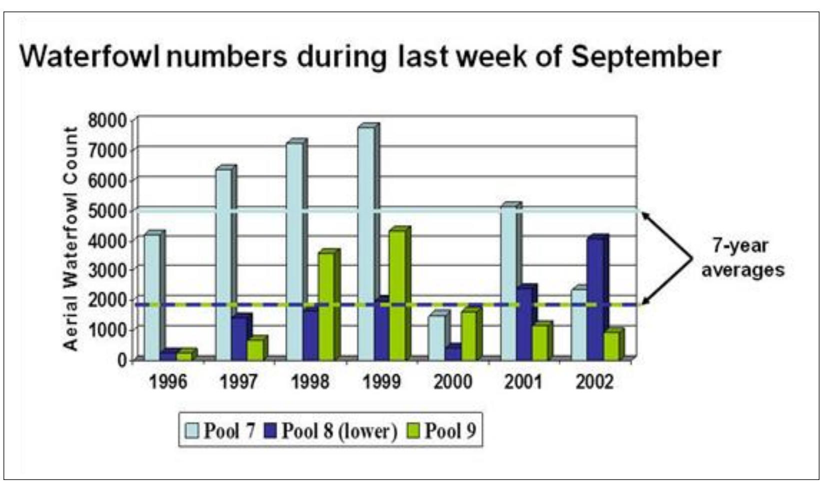


Figure 2.40. late September waterfowl aerial survey for Pools 7, 8 and 9 Pool 8 numbers in 2001 and 2002 exceeded the 7 year average for Pools 8 and 9. USGS

Canada Geese

Prior to 2003 use days varied widely between the three pools. Year-to-year increases and declines for Canada geese use days in Pools 7, 8 and 9 were similar from 2003 to 2009 (Figure 2.43).

Tundra Swans

Because Pool 8 has provided the most tundra swan use days on the Refuge each year from 1997-2009 with the exception of 2005, it is difficult to detect changes due to the effects of the drawdown in Pool 8 as compared to other pools (Figure 2.44). Pool 8 use days as a proportion of Refuge use days increased from 1997 to 2009; 1997–2001 the mean percentage was 35.4%; 2002-2007 the mean percentage was 39.3%. The 4% difference is within the range of annual variability.

Tundra Swan use days for areas within Pool 8 were examined to detect changes in use that may reveal a response to the change in vegetation which resulted from the drawdowns. Prior to the drawdowns of 2001 and 2002 swans congregated in several places within Pool 8 including WICA, Goose Island No Hunting Zone, and the mid pool area of Pool 8 open to hunting. After 2001 there was a shift in swan use within Pool 8 as a larger percentage of swans congregated in WICA (Figure 2.45). In 2006, the peak count in WICA was 31,560 swans, Pool 8 Open was 175 and Goose Island No Hunting Zone was 2285 swans.

When Pool 8 use days are separated from the Refuge total, and examined over a longer period of time, it appears a change in swan use patterns began in 2006 which has continued through 2012. Construction of Environmental Management Program- Habitat Restoration and Enhancement Program (EMP-HREP) Phase III Islands, 2007 -2009, affected swan use by providing thermal protection and loafing sites from 2008 –2012. However that offers no explanation for the 2006 peak when Pool 8 use days exceeded the rest of the Refuge (Figure 2.46).

In 2006 Pool 8 provided 53.4 % of the total Refuge use days. In comparison the mean percentage for 1997-2009 is 38.4%. The difference is primarily due to the increase in use days in WICA, which produced 93.7% of the Pool 8 Tundra Swan use days in 2006. In addition, WICA provided more swan use days than any other pool. The 2006 peak in Pool 8 swan use days can be primarily attributed to the development of arrowhead beds and restoration of other emergent aquatic plants in WICA which provided attractive habitat for swans and other waterfowl. Other factors also contributed, such as an above average Eastern Population of Tundra Swans. Weather was not a contributing factor

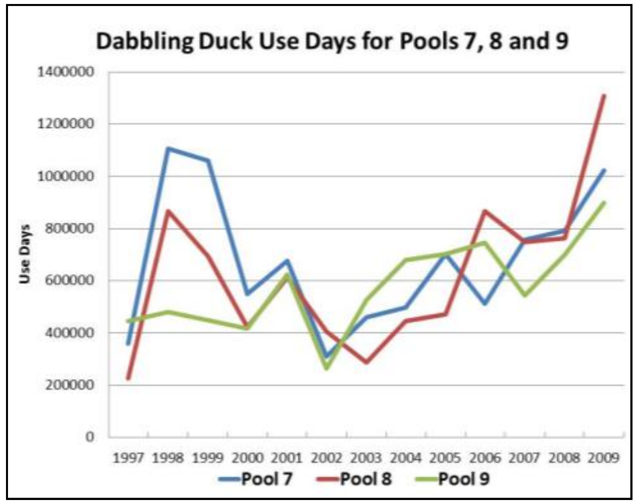


Figure 2.41. Dabbling duck use days followed similar patterns in Pools 7, 8 and 9 between 1997 and 2009. WDNR

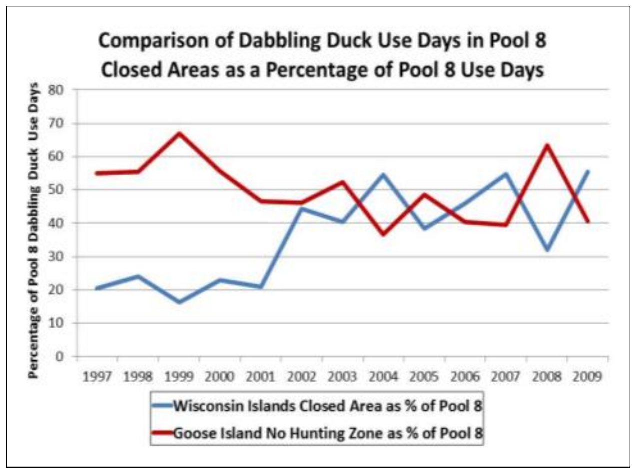


Figure 2.42. By 2004 the number of puddle duck use days recorded in WICA exceeded those in the Goose Island No Hunting Zone. WDNR

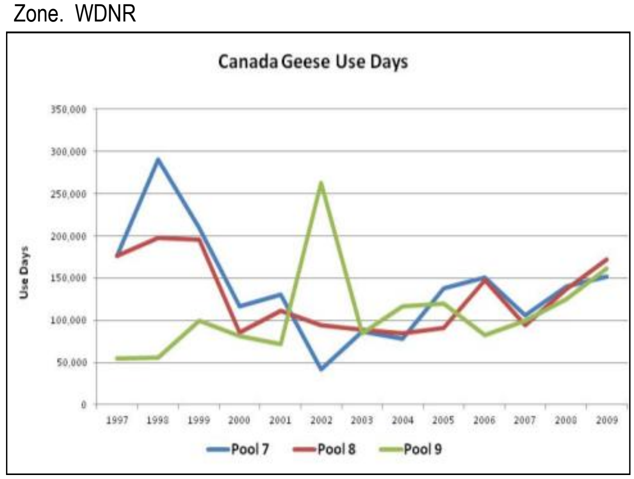


Figure 2.43.. There was no discernible effect from the drawdowns in Pool 8 on Canada geese use days as compared to Pools 7 and 9. By 2008 the HREP island construction project in lower Pool 8 most likely had an impact on use patterns. WDNR

as most of Pool 8 was frozen over the first week of December.

Swan use of WICA was maintained from 2002 to 2007, which suggests the drawdown effect on the expansion and development of arrowhead beds and other emergent aquatic plants in the WICA was sustainable for at least six years post drawdown. The effect of the Phase III Islands after 2007 on swan use cannot be separated from the effect of the drawdowns. As Figure 2.46 shows, the Phase III islands have provided habitat components that have helped to maintain swan use of lower Pool 8, from 2008-2012 at a high level.

Upper Mississippi River, Pools 4-9, is the second most important fall migration staging area for Eastern Population of Tundra Swans (EP) (Wilkins et al. 2010). Research results of 43 satellite-tracked adult female Tundra Swans banded on the wintering area indicated 43% of the marked birds used the Upper Mississippi River Pools 4-9 for 33.6 days during fall migration 2001-2002 (Wilkins et al. 2010). Research conducted in 1998 and 1999 (pre drawdown) suggests 52% of cygnets used the Upper Mississippi River during fall migration (Thorson et al.2002). Therefore changes in swan use days on Pools 4-9 may have implications for the EP distribution during fall migration.

An analysis of Wilkins satellite data, obtained from Wilkins in 2013, indicated few swans were documented on Pools 10-13 and all were recorded in Pools 4-9 previously, therefore Pools 4-9 can be expanded to include Pools 10-13 (Refuge). The Refuge mean peak for 2001-2002 represented

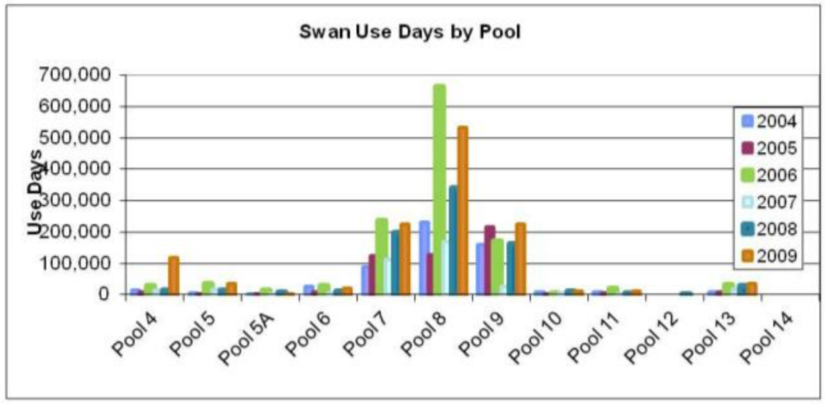


Figure 2.44 . Pools 7, 8 and 9 have provided the majority of Refuge Tundra Swan use days. WDNR

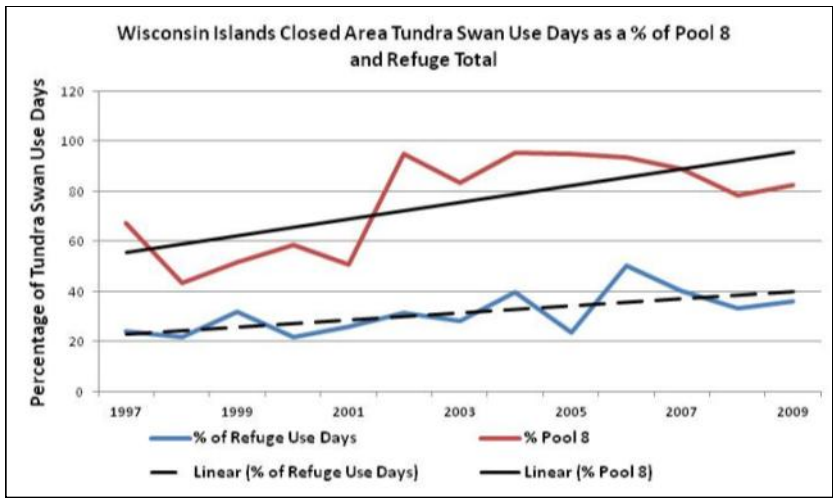


Figure 2.45. From 1997-2001 WICA produced an average of 54.3 % of Pool 8 use days, after 2001 the average increased to 89%. WDNR

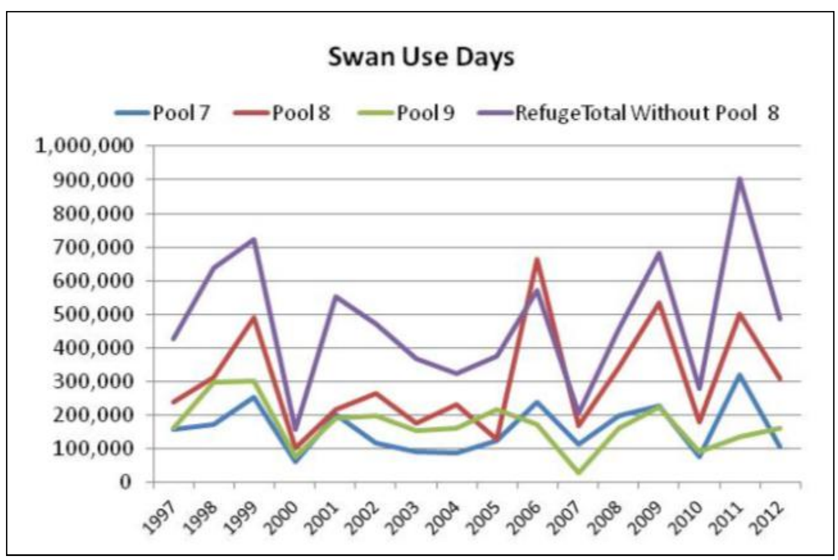


Figure 2.46 . After 2005 there was a change in swan use of Pool 8 as compared to Pools 7 and 9. WDNR

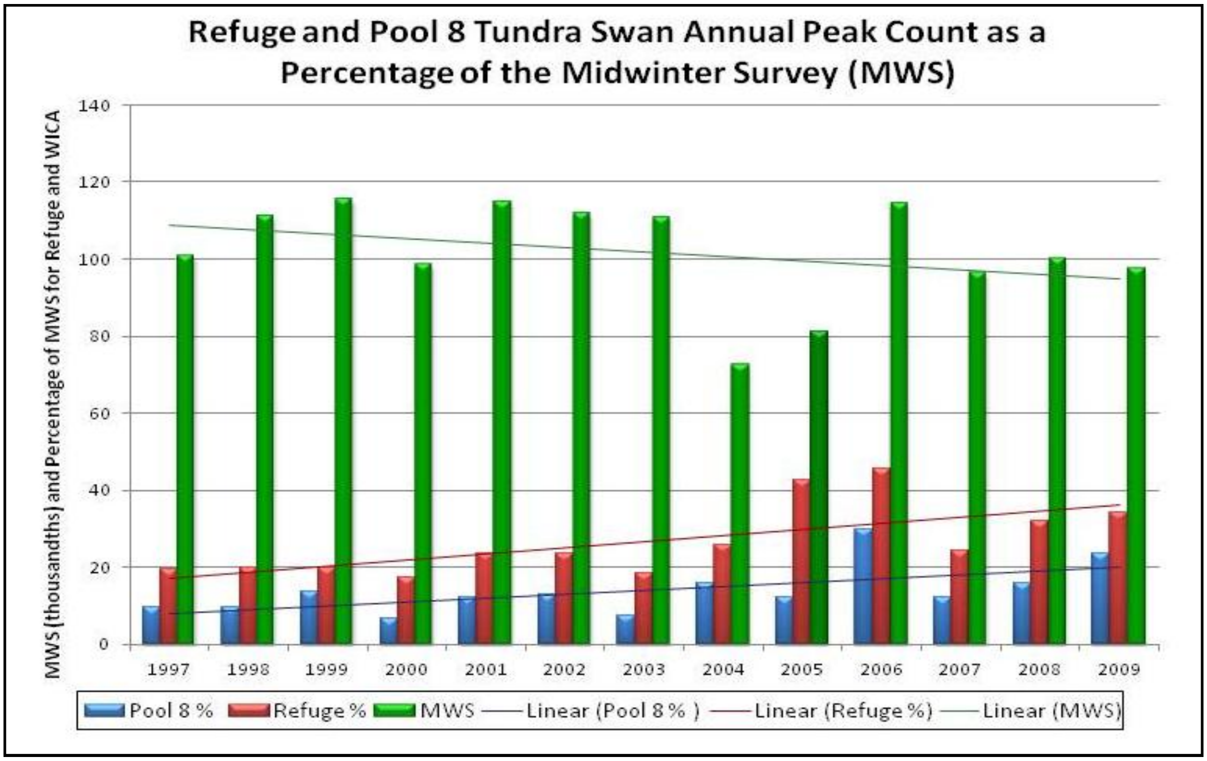


Figure 2.47. Tundra Swan Peak Count for Pools 4– 13 and Pool 8 (separate) as a percentage of the Midwinter Survey of the Eastern Population (EP). The peak count in 2006 was 52,070, which represents 45.51% of the EP. Pool 8 represented 29.8% of the EP and WICA peak count alone was equivalent to 27.6%. The positive changes in habitat from the drawdown may have influenced EP swan distribution in 2006. Please note the MWS is conducted in January, consequently the MWS for 2008 was compared to the use days for fall 2007. WSDNR

23.6% of the EP swans (which provides a minimum estimate of swan use) of Pools 4-13. In contrast Wilkins found 43% of marked swans used the Refuge in 2001 and 2002 during autumn migration, which may provide some indication as to a maximum number of EP swans using the Refuge. The average annual Refuge swan peak fall count increased from representing 19.1% of the EP in 1997-2000 to 30.0% from 2001-2009, an increase of 50% (Figure 2.47).

The average peak fall count in Pool 8 increased from representing 9.8% of the EP for the years 1997-2000 to 12.5% for 2001 and 2002 (satellite data indicated 18% of the marked birds used Pool 8), and 29.8 % for 2006. The WICA peak count was 27.6%. The increase from 9.8% to 29.8%, almost a three fold increase, suggests that the positive effects of the drawdown on habitat had more than just an effect on Refuge use days. The restored emergent vegetation and improved habitat conditions by 2006 in Pool 8 appear to have influenced EP distribution during fall migration, although the magnitude of the peak fall count was influenced by the higher than normal Eastern Population of Tundra Swans. The results indicate the continuing importance of maintaining this fall migration staging area (Pools 4-13 and particularly Pools7-9) to the continued health of the Eastern Population of Tundra Swans.

Diving Ducks

Diving duck use days on Pools 7, 8 and 9 decreased in 2000. In 2001 Pools 7 and 9 rebounded but Pool 8 continued the downward trend (Figure 2.48). In 2002 numbers decreased on all three pools. Pool 8 use days increased after 2002 until 2008, whereas use days were more variable in Pool 7 and 9.

The submersed aquatic vegetation (SAV) standing crop biomass in Pool 8 dropped in 2000 from 1999 levels and then tended to increase through 2004 (Kenow-Pool 8 Vegetation Monitoring Data). LTRMP data indicates SAV frequency in 2000 was comparable to 1998. After 2000 the frequency steadily increased. Pool 8 wild celery abundance increased in a consistent pattern from 2001 to 2004 (LTRMP Data) (Figure 2.49). The positive change in wild celery and SAV from 2001 through 2002, the second year of the drawdown, while diving duck use days decreased indicate use days were affected by other variables than abundance of SAV. In 2002, the breeding population estimate for canvasbacks reached a 10-year low (USFWS Waterfowl Population Status 2006). This may have had an effect, as use days also declined on Pools 7 and 9 in 2002. Likewise the increase in diving duck use days on Pool 8 since 2002 is the result of several variables including the increase in SAV.

Pool 5

Waterfowl Response to the Pool 5 Drawdowns

Lisa Reid, *U.S. Fish and Wildlife Service-Upper Mississippi River National Wildlife and Fish Refuge*

Waterfowl use days for Tundra Swans, Canada Geese, dabbling and diving ducks were compared between Pool 5, the drawdown pool, and Pool 5A and lower Pool 4, non-drawdown pools.

Dabbling Ducks
Dabbling duck use days increased two fold from 2004 to 2005 and again by 2006. Use days have been maintained in the range of a 321,000 to 390,000 from 2006-2009, suggesting that habitat conditions improved after the drawdown (Figure 2.50).

Canada Geese
Canada geese use days increased in Pool 5 from 2005 to 2011 suggesting there was possibly a benefit from the drawdown. However, Pool 4 had a much more dramatic increase over the same time period indicating improved habitat conditions or other variables were contributing to the increase in Canada geese use days on that pool also. Of note: after 2005, Pool 5 produced similar numbers of use days as Pool 6, in contrast to the years prior to 2005. During years 1997 to 2004, Pool 5 generally produced less than half as many use days (Figure 2.51).

Tundra Swans
Tundra swan use days in Pool 5 increased after the drawdowns. In 2006 and 2008 use days were comparable with that of lower Pool 4 and use days in 2009 were similar to 2006 (Figure 2.52). No dra-

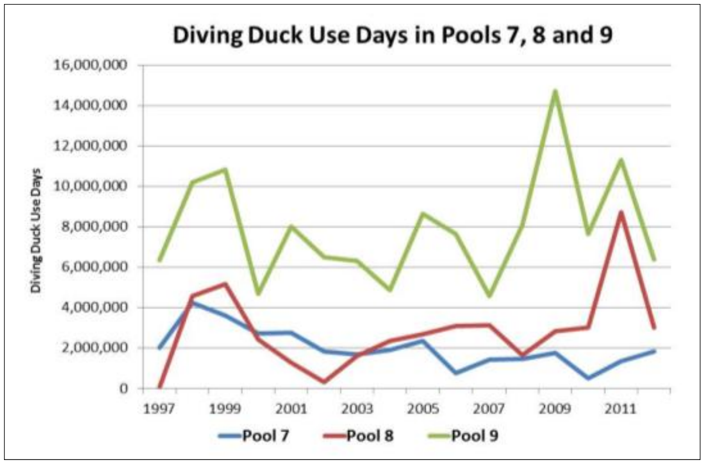


Figure 2.48. Diving duck use days on Pools 7, 8 and 9 of the Upper Mississippi River. The breeding population estimate for canvasback ducks reached a 10-year low in 2002. WDNR

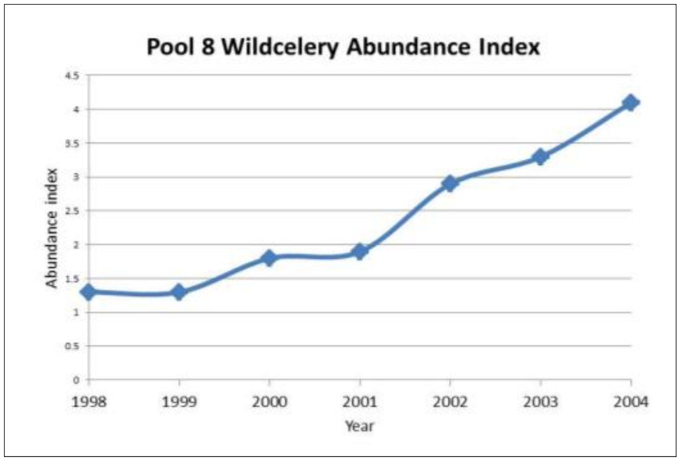


Figure 2.49. Wild celery abundance in Pool 8 increased in a consistent pattern with the exception of 2001, the first year of the drawdown. LTRMP data

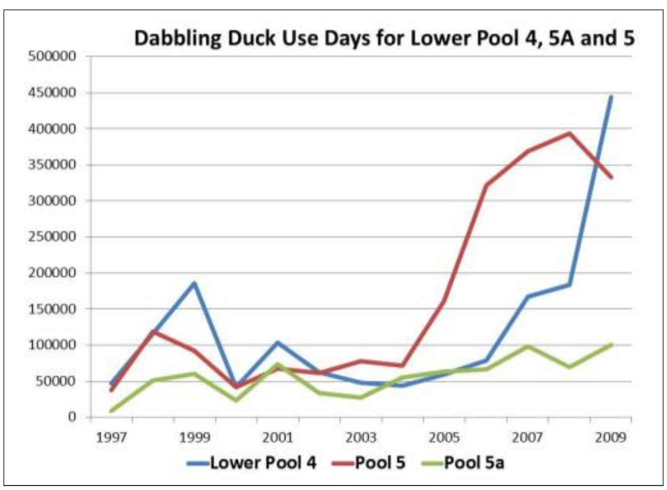


Figure 2.50. Dabbling duck use days increased two fold from 2004 to 2005 and doubled again by 2006. USFWS

matic change in use patterns occurred primarily because one area that benefited from the drawdown- Weaver Bottoms- has always been the primary Tundra Swan use area on Pool 5. Swan use days in 2005 were low because Tundra Swans spent far less time than normal on the river due to an early freeze-up.

Diving Ducks

Diving duck use days increased from 58,145 in 2005 to 240,800 in 2006. Use days from 2006-2009 varied from 223,500 to 320,000 (Figure 2.53). The increase in use days on Pool 5 since 2005 is probably the result of several variables including the increase in the abundance of submersed aquatic vegetation, especially wild celery.

Conclusion

It is difficult to assign changes in waterfowl distribution on an individual pool or Refuge basis to one event or variable such as a drawdown because distribution is influenced by many factors, including: the effects of hunting and other forms of human disturbance on waterfowl, the amount of available food, the longitudinal distribution of food resources on the river and the distances waterfowl are known to fly from roosting to feeding sites, and other biological needs (UMRNWFR Comprehensive Conservation Plan 2006). Waterfowl use days are also affected by flyway waterfowl populations and timing of freeze-up in the fall. Hence, any trends in waterfowl use on a single pool or Refuge basis need to be evaluated with caution. With these caveats in mind the results of the surveys suggest:

Pool 8

Waterfowl responded to the food resources offered by flooded moist soil plants during the first year of the drawdown in 2001.

The restoration of emergent plant beds in lower Pool 8 as a result of the drawdowns affected dabbling duck and swan distribution within Pool 8. Swan use has been maintained from 2002 – 2007 possibly longer, which suggests the drawdown effect on the expansion and development of arrowhead beds and other emergent aquatic plants has been sustainable for

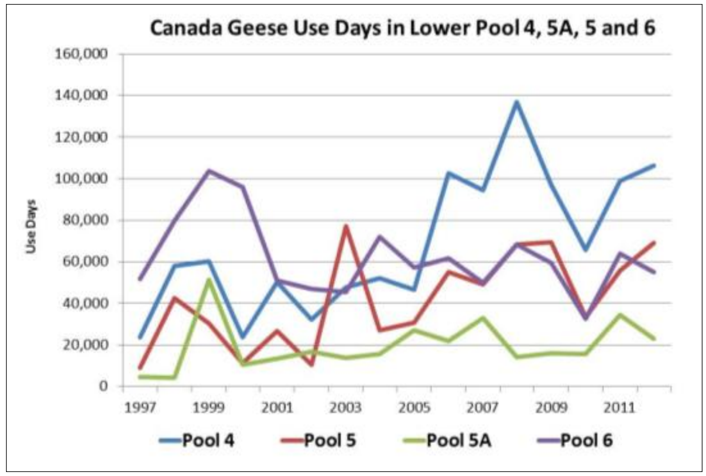


Figure 2.51. Canada geese use days. USFWS

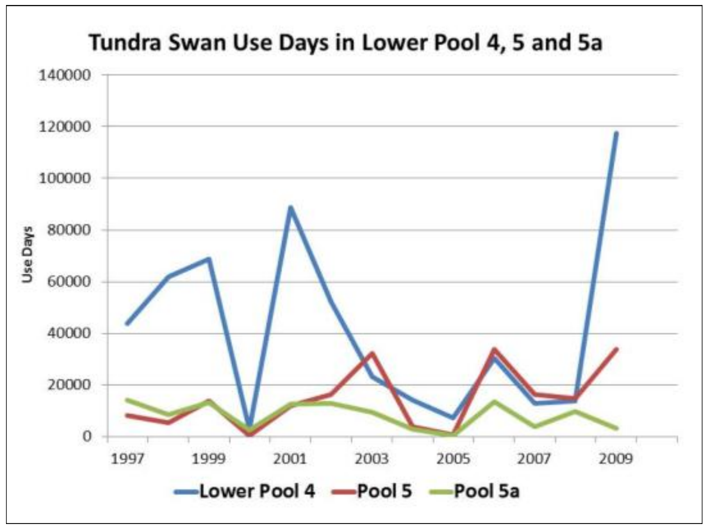


Figure 2.52. Tundra swan use of Pool 5 increased the year after the drawdown, but no dramatic changes in use patterns occurred after 2006. USFWS

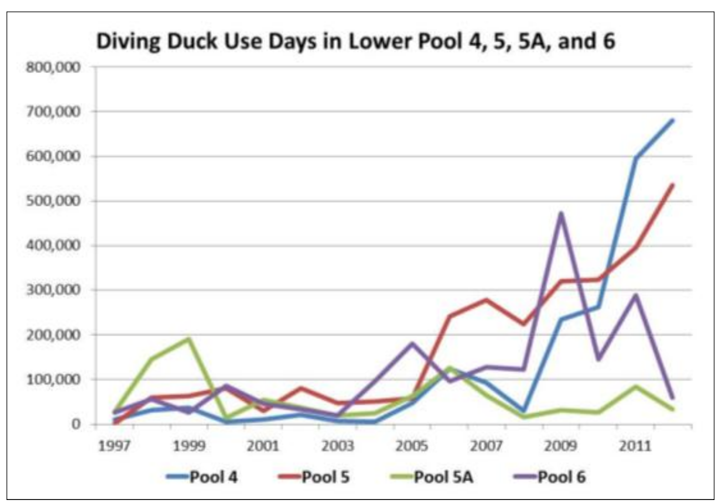


Figure 2.53. Diving Duck Use Days 1997– 2011 for Pools lower Pool 4, 5, 5a and 6. USFWS

at least six years post-drawdown.

The decline in diving duck use days during the drawdowns were the result of a variety of variables.

The positive effects of the drawdown on habitat in Pool 8 influenced Refuge swan distribution and probably EP distribution. The results indicate the continuing importance of maintaining this important fall migration staging area to the continued health of the Eastern Population of Tundra Swans.

Pool 5

The response by waterfowl including dabbling ducks, diving ducks and tundra swans to the Pool 5 drawdown was evident. Use days for puddle ducks, divers, and swans were the highest recorded in 10 years. And although adjacent pools also saw an increase, the increases in Pool 5 were much more dramatic particularly for dabblers and diving ducks.

Waterfowl Hunter Surveys

Lara Hill-*U.S. Fish and Wildlife Service-Upper Mississippi River National Wildlife and Fish Refuge*

In 2001, personnel from the U.S. Fish and Wildlife Service and U.S. Geological Survey conducted interviews with 924 waterfowl hunting parties at access sites around Pool 8. These interviews or "bag checks" occurred on 25 randomly selected days throughout the 60-day duck hunting season, 29 September through 27 November. Hunting parties may have been interviewed on multiple occasions during the season. During each bag check, hunters were asked a number of questions related to their day's hunting experience in addition to two questions specific to the Pool 8 drawdown:

- Were you aware of the water level reduction in Pool 8?
- If yes, do you feel the water level reduction had a positive or negative effect on river habitat?

Results indicated 94% (of the parties) were aware of the drawdown, and 62% of those felt it produced positive results, while 14% thought the results were negative .

In 2002, interviews were conducted with 344 waterfowl hunting parties at access sites around Pools 7 and 8. These interviews occurred on 12 randomly selected days (five surveys days on Pool 7 and seven days on Pool 8) throughout the 60-day duck hunting season. Hunters on both pools were contacted because hunters hunt waterfowl in both pools.

In Pool 8, 79.4 % of hunters said they were aware of the drawdown, and 66.9% of those felt it produced positive results. This was a slight decrease in awareness of the drawdown but an increase in a positive viewpoint. Survey results indicated Pool 7 hunters were only slightly less aware of the drawdown in Pool 8 but were inclined to be less positive about the results of the drawdown.

The results suggest that the waterfowl hunters using the drawdown pool were not negatively impacted and viewed the results of the drawdown as positive.

Avian Botulism Monitoring Results

William Thrune- (retired) *U.S. Fish and Wildlife Service*

Avian botulism is an often fatal disease of birds resulting from ingestion of toxin produced by the bacterium *Clostridium botulinum.* Important environmental factors that contribute to initiation of avian botulism outbreaks include: water depth, water level fluctuations, water quality; the presence of carcasses; rotting vegetation; and high temperatures.

Because many of these factors may be present during a drawdown, monitoring this aspect of the drawdowns was conducted during other drawdown monitoring activities. Minimal waterbird mortality on lower Pool 8 during 2001 or 2002 was observed.

Avian botulism was detected on a stretch of the Black River in upper Pool 8. (Botulism has occurred on this stretch in the past.) During 2001 nearly 50 sick/dead mallards and one herring gull were removed from the area. Additional mortality may have occurred but was not reported or observed. Avian botulism was confirmed by the National Wildlife Health Center in a mallard carcass collected 08 August 2001.

In general there was no effect from the drawdowns on the occurrence of avian botulism in Pool 8.

2.3 Effects on Physical and Chemical Parameters

2.3.1 Water Quality

Background

Prior to the experimental drawdown it was suspected that drawdown would promote increased sediment re-suspension due to wind stress over shallower water.

Pool 8 Drawdown

Water Quality and Meteorological Monitoring Used in the Assessment of Water Level Drawdown of Navigation Pool 8 of Upper Mississippi River in 2001

John Sullivan - *Wisconsin Department of Natural Resources*

Continuous monitoring of dissolved oxygen, water temperature, light penetration and wind speed and direction was conducted in lower Crosby Slough off Stoddard, Wisconsin during June to September 1999 (pre-drawdown) and 2001 (during drawdown). In addition, daily composite samples of turbidity and total suspended solids were collected with a automatic water sampler and measurements of gross sedimentation were estimated using sediment traps. The purpose of this monitoring was to assess potential changes in water quality associated with the drawdown.

River flows were greater during the drawdown in 2001 than pre-drawdown measurements made in 1999 which presented difficulty in evaluating drawdown-induced water quality changes. It was suspected that drawdown would promote increased sediment resuspension due to wind stress over shallower water. However, wind-induced effects on sediment resuspension (increased total suspended solids or turbidity) were generally low at the monitoring site and were easily over shadowed by changes in river flow. Other results were:

- Mid-day light penetration was less in 2001 yielding a confounding response compared to measurements of total suspended solids.
- Diurnal dissolved oxygen fluctuation (maximum-minimum) increased noticeably in 2001 as compared to 1999 and was likely a drawdown-related. These changes in dissolved oxygen were attributed to increased submersed aquatic plant growth and attached algae in the vicinity of the monitoring platform in 2001 rather than increases in phytoplankton concentrations. Although dissolved concentrations showed large daily fluctuations in 2001, levels rarely fell below the 5 mg/L water quality standard.

In general total suspended solids and turbidity were not significantly greater during the summer of 2001 when the pool was drawn down 1.5 feet as compared to 1999 when accounting for changes in river flow between the monitoring periods. Wind induced effects on sediment resuspension explained less of the variation in total suspended solids, turbidity or light penetration than river flow. As a result, it can not be concluded that wind-induced effects on sediment resuspension were greater during the drawdown based on these data.

Long Term Resource Monitoring Water Quality Trends 1988-2005

Jim Fischer- *Wisconsin Department of Natural Resources –Long Term Resource Monitoring Program*

A number of factors affecting water quality have been monitored in Pool 8 since 1988 through the Long Term Resources Monitoring program and these same factors were monitored during the 2001 drawdown. Notable trends include:

- Suspended solids concentrations during summer stratified random sampling (SRS) events continued on a decreasing trend. Median concentrations in the backwater and impounded strata (7.4 and 6.8 mg/L, respectively) of Pool 8 during 2005 were the lowest recorded since SRS began in 1993.
- A record-low dissolved oxygen concentration (DO) was observed at a lower pool fixed-site in July 2001, but it followed a trend that had started before the drawdown. The median DO concentration (8.9 mg/L) during summer SRS was similar to other years in the impounded stratum, suggesting that the drawdown had no detectable effect on DO concentrations in that stratum.
- Nutrient and chlorophyll a concentrations and patterns were generally similar to those observed in Pools 4 and 13 during the summer SRS period. For example, median nitrate-nitrite concentrations in the backwater stratum of the three pools ranged from 1.1 to 1.6 mg/L during 2001 and from 1.5 to 1.7 mg/L in 2002.

- The highest median nitrate-nitrite nitrogen concentration during 12 years of summer SRS was recorded for Pool 8 backwaters in 2004, however backwater concentrations were similarly high in Pool 4. Higher concentrations were also recorded in the main channel and were likely a result of increased watershed inputs.

In general, there were no obvious changes in water quality parameters that could be directly attributed to the drawdowns; most parameters were within the normal range of variability and followed the same patterns or trends as previous years.

Pool 5 Drawdown

Analysis of Water Quality Following a Drawdown in Navigation Pool 5, Upper Mississippi River System

Rob Burdis- *Minnesota Department of Natural Resources,* Long Term Resource Monitoring Program

Water quality monitoring was conducted at fixed sites in Pools 4 and 5 as part of the Upper Mississippi River Restoration - Environmental Management Program's Long Term Resource Monitoring component. Sampling in Pool 5 was discontinued in 2004 due to program cuts; however, special funds were obtained to continue monitoring historical fixed sites to evaluate the effects of the Pool 5 drawdown on water quality.

A BACI (before-after-control-impact) design was used to detect any effects of the drawdown on water quality. Utilizing fixed sites in Pool 4 as controls, the mean differences in water quality parameters between paired sites in Pool 4 and 5 pre-drawdown were compared statistically to the mean differences post-drawdown to determine if the drawdown had any effect on water quality.

River discharge in the UMR was very low in the two years following the drawdown, particularly in July and August due to minimal rainfall. Discharge can have a major influence on water quality and should be taken into consideration when examining the data over this period. In addition, submersed aquatic vegetation (SAV) in lower Pool 4 was at the highest percent frequency measured there since the current method of sampling SAV was initiated in 1998.

Results

Turbidity and total suspended solids were not statistically different pre- and post-drawdown at either backwater or main channel sites when analyzed using the BACI design. However, turbidity was noticeably lower at the control backwater site in Pool 4 and the Pool 5 backwater site in the two years following the drawdown, indicating a reach wide reduction in turbidity unrelated to the drawdown.

Total phosphorus and chlorophyll-a concentrations pre- and post-drawdown were significantly different between the backwater sites but not the main channel sites. Prior to the drawdown, concentrations of both of these water quality parameters were consistently higher at the Pool 5 backwater site than the Pool 4 site, but were more similar post- drawdown resulting in a statistical difference.

The difference pre- and post-drawdown for dissolved silica and conductivity were significant at the main channel sites. Concentrations of dissolved silica at Lock and Dam 5 were lower at times compared to Lock and Dam 4 in the two years following the drawdown. Similarly conductivity was lower at Lock and Dam 5 on several dates resulting in a statistical difference.

No statistical differences were found at the backwater or main channel sites for water temperature, dissolved oxygen, pH, volatile suspended sediments, soluble reactive phosphorus, total nitrogen, nitrate-nitrite nitrogen, and ammonia.

There was no response in Pool 5 water quality that could be directly attributed to the drawdown in the two years following at either backwater or main channel sites. There were statistically significant differences pre - and post-drawdown in total phosphorous and chlorophyll-a between the backwater sites and in silica and conductivity between the main channel sites. However, the differences are most likely not drawdown related. Although summer turbidity levels at the Pool 5 backwater site were at record lows following the drawdown, similar results were observed in lower Pool 4 over the same time period. The low turbidity in 2006 and 2007 is likely the result of increased aquatic vegetation in these backwaters and the low discharge that occurred during this period.

All LTRMP data are a product of the U.S. Army Corps of Engineers' Upper Mississippi River Restoration-Environmental Management Program, Long Term Resource Monitoring Program (LTRMP) element, as distributed by the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin.

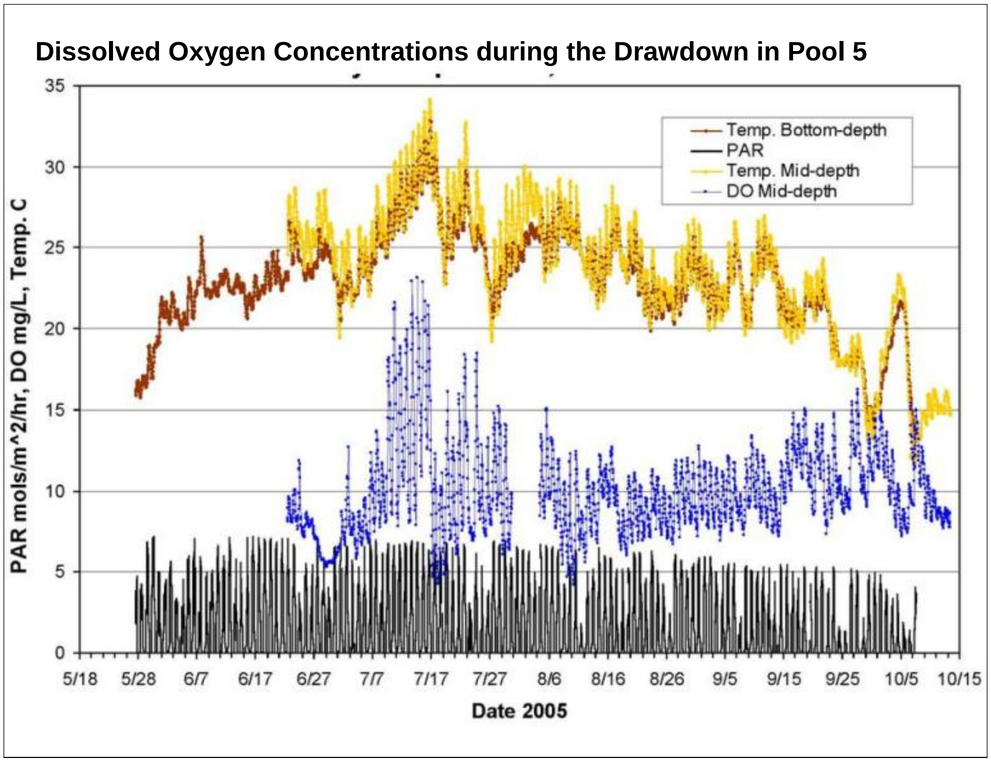


Figure 2.54. Very high dissolved oxygen concentrations and large diurnal fluctuations in dissolved oxygen were noted during the period of maximum drawdown. WDNR

Continuous Water Quality Monitoring of Weaver Bottoms

John Sullivan, *Wisconsin Department of Natural Resources*

Continuous monitoring data of dissolved oxygen, water temperature, light penetration, surface photo synthetically active radiation (PAR), wind speed and wind direction were collected in upper Weaver Bottoms during May to September, 2005. An automated water sampler was used to collect daily composites samples for total and volatile suspended solids. Monitoring equipment was installed on a small platform located in open water in the northern portion of Weaver Bottoms. Gross sedimentation was measured with cylindrical sediment traps deployed near the monitoring platform.

Results

Very high dissolved oxygen concentrations (> 20 mg/L) and large diurnal fluctuations in dissolved oxygen were noted during early July during the period of maximum drawdown (Figure 2.54). This response occurred during the period of maximum water temperatures (greater than 86°F) which likely contributed to increased photosynthetic activity. Wind speeds were also lower during this period which may have contributed to reduced mixing and increased algal concentrations.

Highest total suspended solid (TSS) concentrations generally occurred during periods of highest wind speed although the actual correlation between TSS and wind speed was low. Daily average wind speeds were usually less than 10 mph with only one day exceeding 15 mph. Correlation between average daily wind speed and total suspended solid concentrations were hampered by inconsistent and variable sampling intervals.

A marked increased in light penetration was noted in September and occurred during a period of very low TSS concentrations, some less than the report limit (<3 mg/L). Gross sedimentation rates declined during August and very low rates were measured during September, consistent with the low TSS levels. Sedimentation rates in September were 50-90% lower than similar measurements made in upper Weaver

Bottoms in September 1993 and 1994. The mechanism for this response was not specifically determined but was likely influenced by increased aquatic plant growth (reduced sediment resuspension) in the vicinity of the monitoring site and low phytoplankton concentrations.

2.3.2 Contaminant Monitoring

Numerous investigations have documented environmental contaminants and their effects in the Upper Mississippi River ecosystem. These investigations indicated that while environmental contaminants occur within the Pool 8 ecosystem with the possible exception of localized "hotspots", significant threats to fish and wildlife resources were not expected under normal circumstances. However the degree to which these contaminants could become available to the food chain and result in adverse effects due to water level management practices in Pool 8 was unknown.

Contaminants in Tree Swallows in Relation to Water Level Management

Dr. Thomas Custer and Dr. Christine Custer,
U.S.Geological Survey-Upper Midwest Environmental Sciences Center

The purpose of this study was to determine the degree to which the bioavailability of environmental contaminants in Pool 8 was affected by the drawdown. Contaminants were a concern as sediments would be exposed in the lower part of Pool 8 for the first time in 60 years during the drawdown. Also flooding of previously dried out wetlands, such as a year following a drawdown, could have increased the rate of mercury methylation and in turn made mercury more available to terrestrial vertebrates that feed in aquatic environments. Tree swallows were a useful species for contaminant assessment of sediments. They feed on emergent aquatic insects and therefore their eggs and tissues reflect sediment contamination. Tree swallows were also used to identify contaminant pathways and to determine if these contaminants may affect reproductive success. Samples of swallow eggs and nestlings were collected and analyzed for mercury and other contaminants in 2000, 2001 and 2002.

Results

Mercury concentrations in tree swallow eggs and nestlings did not significantly increase after the Pool 8 drawdown. Mercury concentrations in eggs were intermediate to levels reported in tree swallows from other North American locations.

Metals and other elements, PCB's, and organochlorine insecticides did not increase following the 2001 drawdown and were not elevated compared to other samples collected from other North American locations.

Hatching success of eggs did not differ among years or locations and was comparable to a nation wide average.

In conclusion, the bioavailability of contaminants did not appear to increase as a result of the drawdown.

2.3.3 Sediment Consolidation

Sediment characteristics identified as being potentially affected by the drawdown included chemistry of pore water, organic matter content, and concentration of nitrogen compounds.

Prior to the drawdown it was known that sediment organic content in the drawdown zone would decrease depending on the sediment type, initial water content of the sediment, position in the drawdown zone, length of the drawdown period, rainfall during the drawdown, air temperature, wind, humidity, groundwater seepage, and reflooding. Limited consolidation of sediments was expected because most of the drawdown zone was silty sand with low organic content (Pool 8 Definite Project Report). However more information was needed regarding impacts of changes in sediment characteristics as a result of the desiccation and rewetting process.

Experimental Determination of the Impacts of Sediment Desiccation and Rewetting on Sediment Physical and Chemical Characteristics in Lawrence Lake, Pool 8

William F. James, John W. Barko and Harry L. Eakin-
U. S. Army Corps of Engineers

In June 2000, over fifty intact sediment cores were

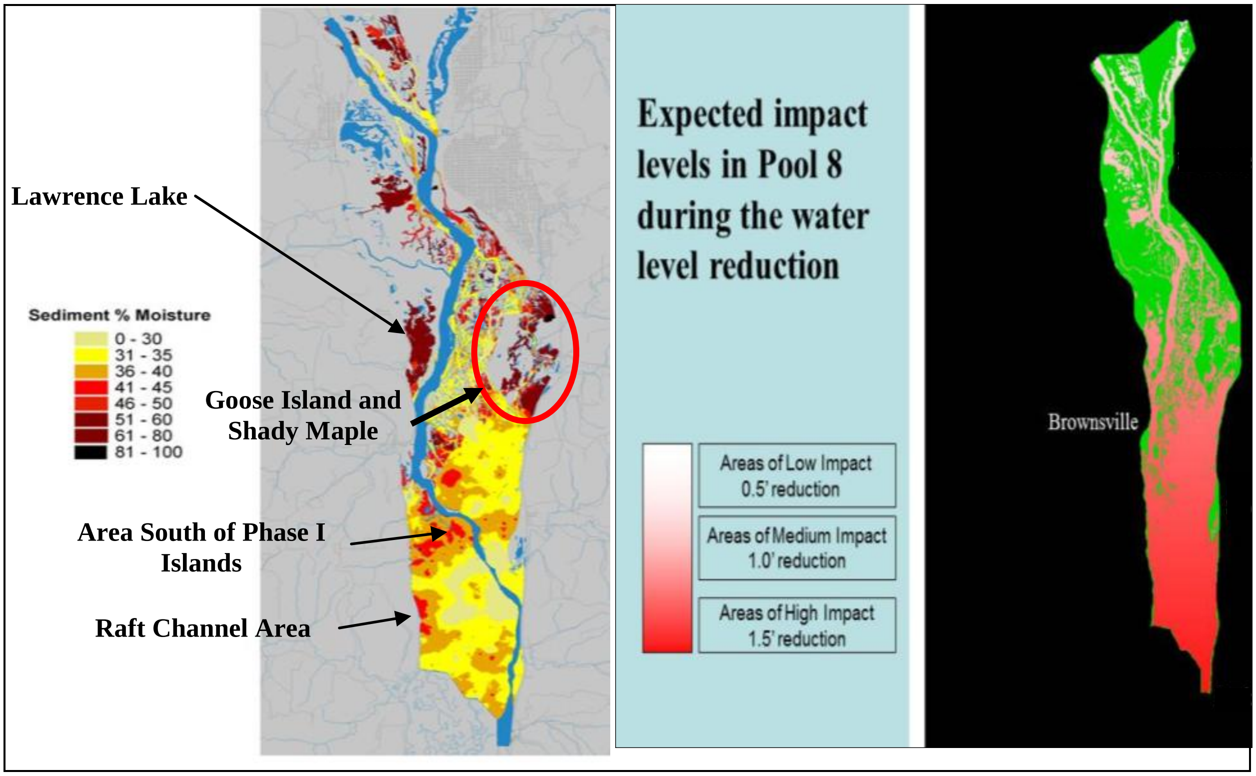


Figure 2.55. Sediment Moisture Content in Pool 8 and Zone of Impact from a 1.5-ft. Water Level Reduction. Areas with low moisture content (yellows) have corresponding low sediment carbon content, and high moisture sediments (black areas) such as Lawrence Lake have high organic carbon content. Areas with higher organic content would have a greater probability of sediment consolidation. Other areas with a higher organic carbon content include Goose Island and Shady Maple, Raft Channel Area and the area south of the Phase I Islands. The 2001 drawdown affected the mid portion of the pool June-September, the lower portion had a drawdown in effect only until mid August. The 2002 drawdown affected the lower portion (Raft Channel Area) the entire drawdown period., with little effect in the mid portion of the pool. USGS and WDNR

collected at a station (depth = 0.7m) located near the entrance to Lawrence Lake. The surface sediments at this site exhibited high moisture content and low sediment density (Figure 2.55).

The sediments were dried under laboratory conditions and subjected to treatments to determine loss of moisture from sediment cores over time, chemistry of pore water, organic matter content, and concentrations of nitrogen and phosphorus compounds.

Results

The desiccation process resulted in substantial sediment consolidation as the percent moisture and organic matter content declined while sediment density increased after the rewetting process.

Sediment desiccation and rewetting resulted in marked changes in sediment P (phosphorus) characteristics including, pore water P mass, and mean mass of aluminum bound P and calcium bound P. However the mean mass of sediment organic P appeared to remain approximately constant.

There was an overall net loss of organic N as a result of the desiccation and rewetting process that could not be accounted for by increases in other N fractions. This pattern suggested that N was being lost to the atmosphere via denitrification.

Increases in available nitrogen, coupled with consolidation of loose organic sediments suggested that desiccation of sediment in Lawrence Lake would likely result in improved conditions for submersed aquatic plant growth including: reduction in sediment resuspension potential, improvement of rooting medium (i.e. nutrients and sediment texture) for submersed aquatic plant growth, conversion of soluble nutrients to particulate forms and reductions in organic matter concentrations.

2.3.4 Nitrogen Cycling in Backwater Sediment

Dr. William Richardson, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

Nitrogen enrichment of the Mississippi River may be the cause of two important environmental issues in the Midwest—high levels of toxic ammonia in river sediments and wide spread hypoxia (low oxygen concentrations) in the Gulf of Mexico at the mouth of the Mississippi River. Little is known about how nitrogen in the Mississippi River is processed, stored or biologically removed by the River ecosystem.

Water level management has the potential to affect significant changes in nitrogen cycling and reduce the accumulation of potential harmful ammonia in highly organic backwater sediments. Ideally, a drawdown will dry and oxygenate organic sediments, increasing the oxidation of accumulated ammonia to nitrate. Upon rewetting, sediments again become anaerobic, and nitrate is removed through the natural process of bacterial denitrification (converted to inert nitrogen gas and released to the atmosphere). This process requires anaerobic conditions, highly organic sediments, and nitrate - all conditions provided by drying and rewetting of backwater areas (Figure 2.54).

Sediment Nitrogen Cycling- Pool 8

As part of a larger research program on nitrogen cycling in the Upper Mississippi River Basin, Dr. A suite of sediment characteristics and bacterial processes were measured before, during and after the summer drawdowns of Pool 8 in 2001 and 2002.

In 2002 the effects of sediment drying and rewetting resulting from the water level drawdown on patterns of sediment nitrification and denitrification and concentrations of sediment and surface water total nitrogen, nitrate and ammonium were determined. In 2001 only sediment ammonium and total nitrogen were examined. The results were:

- Sediment ammonium (NH4) decreased significantly during periods of drying although there were no consistent trends in nitrification and denitrification or a reduction in total sediment nitrogen.
- The reduction of sediment ammonium (NH4) was likely a result of increased plant growth and nitrogen assimilation, which was then redeposited back to the sediment surface upon plant senescence.
- Water level drawdowns likely reduce denitrification due to reduced delivery of nitrate-rich river water, water retention time, and river floodplain connectivity, while promoting significant accumulation of organic nitrogen.

These results indicate that water level drawdowns are probably not an effective means of removing nitrogen from the Upper Mississippi River.

Sediment Nitrogen Cycling (for Pool 5- 2005 drawdown)

Our previous work in the drawdown of Pool 8 suggested rooted emergent and submerged aquatic plants may be important in removing large amounts of N from river sediments.

During the 2005 Pool 5 drawdown we manipulated plant densities in areas impacted (dry sediments) and unaffected (wet) by the drawdown in attempt to clarify the effect of plants on N removal processes. We measured sediment nitrogen in areas with or without plants and plant tissue nitrogen before, during, and after the drawdown. We found that sites affected by the drawdown exhibited greater plant growth and removal of ammonium from sediments than unaffected sites. Surprisingly, total sediment nitrogen levels did not change during the drawdown (wet versus dry areas), nor did we detect a reductions in sediment N related to plant densities. Areas with significant plant growth actually contained higher levels of sediment nitrogen near the sediment surface in the fall compared to areas without plants. In addition, exposing sediments to the atmosphere during a drawdown inhibited the natural process of bacterial denitrification (natural nitrogen removal process). The nitrogen content of rooted submersed aquatic plants throughout the Pool was also measured, and this information will be used to quantify the amount of N stored in sediments relative to the amount removed either by bacterial denitrification or plants during growth.

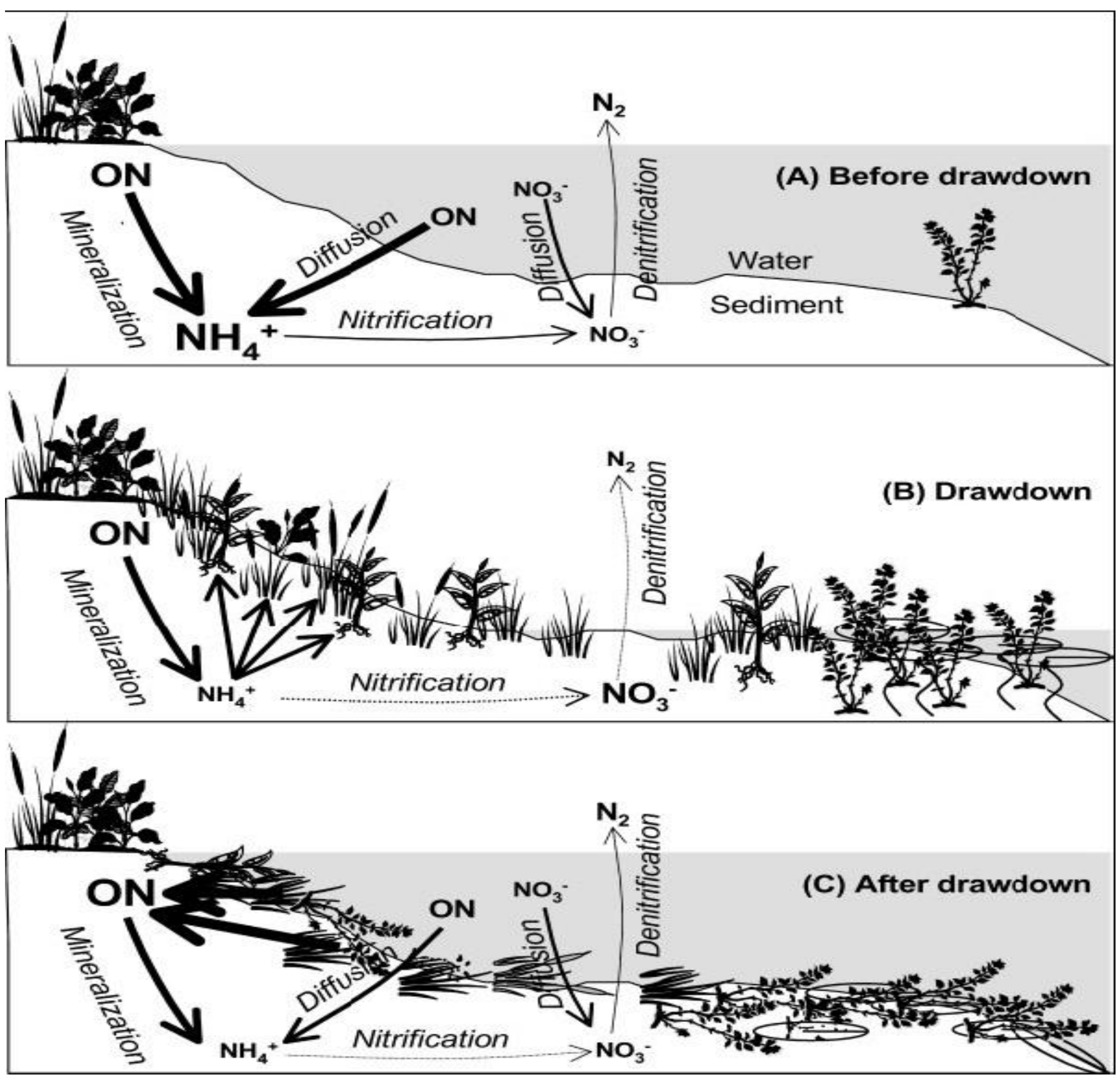
This study, and that of the Pool 8 drawdown, suggests that rooted aquatic plants move large amounts of nitrogen into their tissues from deeper sediments during summer growth, but the amount of N in the sediments is so large that it is difficult to detect a plant effect on

Figure 2.56.. Conceptual model of nitrogen (N) cycling in Upper Mississippi River Pool 8 in 2002:

Under normal pool management (A), there is a significant pool of sediment ammonium (NH4+), primarily generated from mineralization of organic nitrogen (ON); nitrification and denitrification are coupled resulting in very low levels of sediment nitrate (NO3-).

During drawdown conditions (B), plant assimilation, initial increases in nitrification, and potentially a slowing of mineralization significantly reduces the sediment NH4+ pool, whereas nitrification and denitrification are uncoupled resulting in a build up of sediment NO3-.

Upon rewetting (C), plant senescence and decomposition increase the organic N pool, but the anaerobic conditions and low NH4+ in the sediment continues to inhibit nitrification. Anaerobic conditions also stimulate denitrification and subsequent reduction in sediment NO3-.USGS-UMESC



total sediment N. During the fall, these N-rich plants decompose and deposit organic N on the sediment surfaces – essential acting a N-pumps bringing N from N-rich deeper sediment up to the sediment surface. Once on the sediment surface, the N-rich plant tissues will either be flushed downstream during floods or recycled back into sediments through uptake by algae and bacteria (Figure 2.56).

2.4 River Use Monitoring

2.4.1 Commercial Tow Operator Survey

Paul Machajewski, *U.S. Army Corps of Engineers St. Paul District*

The potential navigation impacts of the drawdown were coordinated extensively with the navigation industry through the River Resources Forum, the Water Level Management Task Force, the River Industry Action Committee, and the U.S. Coast Guard. Pilot surveys were conducted in pools 8,5 and 6 to get user input on the condition of the main channel. Similar survey methods were used for each drawdown (Table 2.7).

Pool 8

Towboat operators were provided survey forms at L/D 8 (upbound) and L/D 7 (downbound) and asked to turn the forms in at the next lock and dam after they traversed Pool 8. Between 4 July and 15 August (dates of the earliest and latest returned forms) roughly 100 towboats passed through Pool 8. Of the 100 towboats, 10% turned in survey forms.

Pool 5

Between 17 June and 8 September, 2005 (first and last completed survey received) roughly 100 towboats passed through Pool 5. Of the 100 towboats, roughly 10% completed an informal survey asking the pilots their opinion on the drawdown impacts to navigating Pool 5.

Pool 6

Between 1 June & 1 September, 2010, roughly 325 towboats passed through Pool 6. Of the 325 towboats, approximately 10% completed an informal survey asking the pilots their opinion on the drawdown.

Results

Pool 8 is generally described as a pool that is already tough to navigate. During the drawdown, navigating the pool was a bit tougher, however it was still navigable.

Pool 5 is generally described as a pool that is already tough to navigate. During the drawdown, navigating the pool was tougher especially in certain reaches of the pool (i.e. Lower Zumro and Mt. Vernon.) The ability to navigate safely during the Pool 5 drawdown was questioned. However, it is important to note that during the drawdown, there were six groundings reported, but none of the groundings were directly correlated as being caused by the drawdown. The grounding reasons were similar to reasons for groundings during normal operations. The majority of the groundings were caused by tows out of the main channel. None of the groundings caused significant delays.

Tow pilots describe Pool 6 as a shallow pool especially immediately downstream of Winona (below Winona Railroad Bridge, Homer, & Blacksmith Slough). The drawdown makes the conditions more pronounced and tougher to navigate. During the drawdown navigating the pool was more difficult, as compared to a non-drawdown year, and had a more swift current. The pilots reported the drawdown having an effect on their flanking ability and the outdraft condition at Lock & Dam 6.

2.4.2 Recreation and Commercial Uses

Although the long term environmental and ecological improvements expected from a summer drawdown would benefit boating and fishing enthusiasts, the potential short term negative effects on these activities were recognized by the Water Level Management Task Force. These effects were primarily associated with reduced access to launch ramps, docks, harbors, marinas, boat houses, and some reduced backwater access and potential safety concerns due to submerged hazards such as wing dams. As a result an effort was made to minimize those effects prior to the drawdowns in Pool 5, 6 and 8.

Impacts on recreation during the drawdown were monitored in several ways. Pool 8 impacts were evaluated using the Recreational Boating Study. Pool 5 impacts were evaluated using this same study but also used recreational lockages data, public access use surveys, and a windshield interview survey. No surveys or evaluations were conducted for the Pool 6 drawdown

Table 2.7. Questions and Response of Tow operators regarding the drawdown.

1. Compared to previous years was navigating the pool ….

	Pool 8 N~10	Pool 5 N~10	Pool 6 N~ 32
About the same	6 60%	20% 2	40%
More difficult	4 40%	50% 5	60%
Less difficult	0	10% 1	Not asked

2. How have the main channel current velocities affected you during the drawdown?

	Pool 8	Pool 5	Pool 6
Same	70%	30%	30%
Less	0	10%	Not asked
More	30%	20%	70%

How has the outdraft at the L & D affected you during the drawdown?

	Pool 8	Pool 5	Pool6
Same	20%	10%	60%
Less	20%	0	Not asked
More	40%	10%	40%
No effect	20%	30%	Not asked

4. How has the drawdown affected your flanking ability/ maneuverability throughout the pool during the drawdown?

	Pool 8	Pool 5	Pool 6
Same	40%	0	30%
Less	0	10%	Not asked
More	40%	30%	70%
No effect	2 20%	10%	Not asked

Comments received from tow operators:

Pool 8 drawdown (1.5 ft drawdown)
Sub par channel conditions, too shallow and narrow (6)
Great idea for habitat improvement (2)
Barges pulled towards shallow water (1)

Pool 5 (1.5 foot drawdown)
Sub-par channel conditions: too shallow and narrow; more dredging needed (12)
Navigation safety has been compromised (1)

Pool 6 (1 foot drawdown)
Very swift current in Pool 6 this year.
Shallow conditions throughout Pool 6; more dredging needed.
Drawdowns have a negative effect on commercial navigation

Table 2.8. Quantity of material dredged at sites in Pool 8 funded through Section 1135. Dredging in four sites was financially supported by local government units. In two locations local property owners banded together. The remaining three sites were dredged to mitigate the effects on commercial enterprises. The two commercial enterprises affected provided the non-federal financial support.

Dredge Cuts	Planning Estimate (cy)	Estimated Material removed (cy)
French Slough 1	275	325
French Slough 2	555	650
Goose Island 1	No data available	1100
Lower bluff slough (2 sites)	805	No data available
West channel (2 sites)	1840	No data available
Harbor lights harbor	700	No data available
Engh' Fishery	300	No data available

which was a minor drawdown of 1-foot at the lock and dam.

Pool 8

Monitoring Results of Efforts to Reduce Impacts on Recreation Use in Pool 8

Ruth Nissen, *Wisconsin Department of Natural Resources*

Extensive information was gathered about boating access sites, beaches, popular backwater areas, wing dams, and commercial recreational facilities on Pool 8. On this basis, as well as public input received at public meetings and results from questionnaire surveys provided to commercial and recreational interests, a minimum elevation at the La Crosse gage of 4.2 was selected, to minimize adverse effects in the La Crosse area on commercial and recreational interests. Please note that the official La Crosse gage at Isle la Plume hit a low of approximately 3.8 -4.0 during the weekend of August 11-12. Sand from the high floodwaters during spring filled the gage causing inaccurate readings. The gage was repaired and the water level was remedied as quickly as possible.

The effect on commercial and public recreational facilities in lower Pool 8 also entered into the selection of a target drawdown level at Lock and Dam 8.

Recreation Access Dredging

Provisions were made for dredging to provide adequate access at some recreational boat landings and access channels through the federal Continuing Authority Program – Section 1135 which provided a 75 percent cost share to local governments or residents. The Minnesota-Wisconsin Boundary Area Commission served as the non-Federal sponsor for the project. The commission did not provide funds, but collected funds from local entities to support the dredging in various locations..

Nine sites were dredged as part of this project (Table 2.8). Dredging was conducted under two contracts. Eight sites were dredged under one contract by L&S Industrial and Marine. Inc. at a coast of $199,860, which was completed in June. The ninth site required use of land based excavation equipment, completed by Strupp Trucking, Inc. in July at a cost of $14,585.

The estimated cost of the 1135 dredging from planning to implementation was $245,000. The non-federal share was approximately $61,200. However, federal contract regulations increased the cost of dredging substantially for the 25 percent local cost share.

Recreation Use Assessment

The impacts on recreational use during the drawdown were evaluated using the biennial Recreational Boating Study of the Upper Mississippi River which began in 1989 and is repeated in odd numbered years. This aerial survey includes a study area from lower Pool 4 to the U.S. Army Corps of Engineers -St. Paul District line in Pool 11, near Guttenburg, Iowa.

Aerial surveys confined to the main channel capture about 60% of total boating use based on the results of a mail in survey conducted in 2003. The other 40% is off the main channel in side channels and backwater areas. However the results of the aerial survey provide perspectives of trends in boating use over the 1989-2003 period and enable comparisons between Pools 7, 8, and 9 to determine effects from the drawdown. While the techniques have remained consistent, the number of survey flights was reduced to five in 2003 due to a reduction in funding. The years 1999 and 2001 were more comparable with 11 flights in 1999 and 12 in 2001.

In general, recreational boating activity within the study area (Pools 4-11) during 2001 appeared to be slightly lower than the levels documented between 1989 and 1999. In contrast the average peak day watercraft counts for 2003 greatly exceeded all of the other years in the study period. This is most likely a result of the 2003 survey consisted of only five flights, four of which were on peak days and one of which took place on Saturday, 05 July, a day when an exceptional amount of recreational boating activity occurred.

The data suggest that watercraft were distributed widely within the study area from 1989 to 2003. Some geographic trends related to the drawdown in Pool 8 as well as Pools 7 and 9 include:

Pools 4, 8 and 10 had the most boating activity during the study period.

The total numbers of boats observed during the 2001 surveys decreased for all pools in 2001 from 1999 levels. However the proportion of boating activity actually increased in Pool 8 during 2001 and was slightly higher than the 1989-2003 average (not including the Black River zone, which was discontinued after 1997).

In terms of boat distribution on Pools 7, 8 and 9, the 2001 drawdown of Pool 8 does not appear to have had a significant positive or negative impact on recreational boating activity.

In summary, there does not appear to have been any major fluctuation in recreational boat activity in Pools 7, 8 or 9 other than the general decrease in boating activity during 2001 which occurred in all pools in the study area.

Pool 5

Monitoring Results of Efforts to Reduce Impacts to Recreation Use in Pool 5

Ruth Nissen, *Wisconsin Department of Natural Resources*

The Pool 5 Recreational Boat Access Survey was conducted by the Minnesota Department of Natural Resources and included in the **Pool 5 Drawdown Initial Report**. This survey, which included an assessment of public boat access sites, private docks, and other access areas, provided baseline information for planning for the drawdown.

Recreation Access Dredging

The public generally supported a Pool 5 drawdown as long as some "reasonable" level of public access could be provided. A Citizens Advisory Committee provided a map to the Water Level Management Task Force highlighting priority access sites. Three sites were identified as needing dredging, and alternative solutions to dredging (moving temporary docks or developing a new access) were identified for two additional sites. All areas identified were channels typically used to access the main river channel from a public boat ramp. Sites needing to be dredged were near Murphy's Cut by Half-moon Landing on the Minnesota side, and at two locations in Belvidere Slough on the Wisconsin side. Dredging was completed to mitigate for impacts as a result of the drawdown not to improve recreational access (Table 2.9). After the dredging was completed the access routes were buoyed to help identify the channel.

Funding recreational access dredging is a challenge and relies on a variety of sources. Possible sources identified prior to the drawdown included Section 1135. Projects under Section 1135 must be cost shared on a 75 percent federal and 25 percent non-federal basis. The drawdown project would also have to be approved as a Section 1135 project. The Wisconsin Department of Natural Resources has a state funded program (Recreational Boating Fund) that could cost share 50% of the recreational boat access dredging if it is in association with a public access site such as a boat landing.

For the Pool 5 drawdown the USFWS provided $50,000 (sufficient funds to accommodate a 2.0 foot drawdown estimated at $49,000) to cover the upfront

Table 2.9. Pool 5 Drawdown - Recreation Access Dredging for 1.5- foot Drawdown. All sites dredged were channels typically used to access the main river channel from a public boat ramp. Dredging was completed to mitigate for impacts as a result of the drawdown not to improve long term recreational access.

Dredge cuts	Planning Estimate (cy)	Pre dredge Est. (cy)	Total Removed (cy)
Halfmoon Landing (Murphy's Cut)	8	183	395
Belvidere Slough	197	374	1,396
Buffalo City	556	951	1,908
Total	761	1508	3,699

costs of the recreational access dredging. The necessary funds were transferred to the U.S. Army Corps of Engineers (COE). The states reimbursed the USFWS for their agreed share. (WI – ½ total cost for all sites in WI waters, MN - $15,000). There was also a 6% transfer fee for the USFWS to provide funds to the COE. Izaak Walton League provided $2500 to purchase channel marker buoys.

Recreation Boating Study

A recreational boating survey, including aerial photography from a series of 10 flights, was conducted for Pools 4, 5, and 5A during the summer of 2005. Data from 2005 was compared to recreational usage data collected during the period of 1989-2003. This survey involves aerial counts of boats throughout the summer season and is repeated in odd numbered years. Results from the recreational boating study indicate no major fluctuation in boating activity in the immediate or adjacent pools as a result of the drawdown.

Recreation Boat Lockages

Recreational boat lockages through lock and dams 3, 4, 5, and 5A were examined for trends for the years 1989-2005. No significant trends were detected for the 15 year time period. Approximately 13% of recreational boats use the locks according to surveys conducted in 2003 and 2006.

Results from 2005 and 2006 Mississippi River Pool 5 Drawdown Study of Public Access Use

Minnesota Department of Natural Resources

To monitor the effects of the drawdown on public access use, public access locations in pools 5,5A, and 4 were monitored in 2005 and 2006 from mid- June to early October. Because of low flows the drawdown was cancelled in mid- summer but the monitoring of public access continued. The results were compared to a similar study completed in 2003. In 2006 a windshield survey was distributed at public access in pools 5, 5a and 4.

Results - Public Use Access Levels for Pools 4, 5 and 5A in 2003, 2005, and 2006

Both 2005 and 2006 had more boating use than 2003 during the summer period. Although 2006 had less boating use than 2005, most of the boating use differences between 2006 and 2003 are statistically significant.

The boating use differences between 2003 and 2005 were mostly due to the much larger contribution of three accesses in 2005 (Ike's Park- lower Pool 4, Alma landing (Pool 5), and West Newton- Pool 5, which was new in 2005) while the remaining 24 accesses generated about the same amount of boating use in both 2003 and 2005.

Windshield Survey Results

During the 2006 boating season, 998 surveys were randomly distributed on windshields at designated public boat landings in Pool 5, with 431 returned. The survey showed:

- 94% of boaters in Pool 5 were satisfied or very satisfied with their boating experience.
- 91% of boaters in Pool 5 had some knowledge of the drawdown.
- 76% of the boaters in Pool 5 observed an in-

crease in aquatic vegetation.

- 51% of the boaters in Pool 5 rated the drawdown as very effective or mildly effective for improving fish and wildlife habitat.

In summary, the drawdown had little effect on public use of Pool 5.

Pool 6

Recreation Access

Ruth Nissen, *Wisconsin Department of Natural Resources*

The Pool 6 drawdown was a minor drawdown with a target water level reduction of 1-foot at the lock and dam. Concerns regarding the effects of the drawdown were expressed by several marina owners, one near Winona and two marinas located in the lower end of the pool. The Water Level Management Task Force agreed to provide as much assistance as possible to marina owners such as educate boaters, provide signs, dredging permit assistance, etc. The goal was to communicate frequently with the owners to work on solving problems as they occurred.

Recreational Access Dredging
Sunflower Enterprises/Newt dredged 500 cubic yards of material from behind the lock wall in 2010. USFWS paid $23,800 for mobilization, dredging the channel, and disposal of material for access to the Sunset Marina, with the understanding the marina would be open to the public with no charge. The channel was marked by buoys.

Sand Hump at end of Boat Ramp
Sunset Marina had problems with a hump located about 55 feet, from the end of the boat ramp, most likely caused by power loading. COE marked the hump for boaters.

A hump at the end of the boat ramp for Pla-moor Campground was leveled off and later concrete blocks and a log were removed from the ramp area. In addition the channel from the marina was marked to keep boats out of the shallow water

Figure 2.57. Marina, located in the SE corner of Pool 6 next to the locks. Dredging along the lock wall removed 500 cubic yards to improve access. In mid August floating mats of submersed aquatic plants were trapped in the marina as it is located in a dead end bay next to the lock chamber. A weed harvester removed over 200 tons (wet weight). WDNR

Drawdown Depths and Staff Gage
Maps showing the drawdowns depths were provided to every marina and every boat landing in Pool 6. Winona Marina received a staff gage to help boaters navigate past the last dock slips.

Buoys to mark channel
Buoys were placed at Straight Slough.

The issues appeared to have been alleviated with no alteration to the planned water level reduction until mid August when the submersed plants in Pools 4-10 were uprooted due to a substantial rise in water levels due to heavy rains. The plants moved downstream in the current and accumulated in the lower end of the pools. The effect was system wide and unrelated to the drawdown.

Problems due to this event were resolved at one marina by moving the boats out of the slips and helping the vegetation mass to move down-stream. The other marina located in the SE corner of the pool) had continuing difficulties with the mass of uprooted plants and debris (Figure 2.57).

Due to this situation, combined with the onset of decreased flow on 25 August, the drawdown was ended and the pool was at normal levels by 03 September.

2.5 Cultural Resources Monitoring

2.5.1 Cultural Resources Investigation - Associated with the Drawdown of Pool 8 and Pool 5

Bradley Perkl, *U.S. Army Corps of Engineers- St. Paul District*

There are approximately 240 known cultural resource sites recorded within the floodplain and along the terraces and uplands in Wisconsin and Minnesota in Pool 8, and 63 sites in Pool 5.

Many pre-contact sites in floodplains are important because they have never been plowed, and in fact were covered by flood sediments soon after they were used. In some places, this sedimentation has created "stratified" sites which can be studied by excavating one layer after another, going back further in time with each successive layer. Up to 30 m of bankline retreat is documented for sites in Pool 8, destroying significant portions of these sites.

Shoreline erosion can be caused by flood events, fluctuating water levels of the pool, and wave action from wind and commercial and recreational boat traffic (Figure 2.58). The susceptibility of each archeological site to erosion has many factors. In addition to site destruction, indirect impacts from erosion potentially include site vandalism and artifact looting. Thus, the effects of a pool drawdown to individual cultural resources are difficult to predict and the Pool 5 and 8 drawdowns had the potential to impact numerous cultural resources.

In an effort to understand the impacts that a drawdown would have on cultural resources, a cultural resources monitoring study was conducted which focused on known archeological sites located on the shoreline portion of Pool 8. and later Pool 5. In addition to examining the known sites, previously unrecorded sites exposed during the drawdown were identified.

Results

Thirty -three archeological sites were monitored during the 2001 Pool 8 drawdown. Fifteen of these sites had a high probability of impact from shoreline erosion or looting.

Five archaeological sites were monitored during the 2005 Pool 5 drawdown. Two of these sites had a high probability of impact from erosion and looting.

The differences in known sites between the pools appears to be factor of geomorphic masking of sites in Pool 5. Locations susceptible to damage by vandals are being monitored by law enforcement personnel.

Figure 2.58. Archeological site erosion USACE

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