Terrestrial vegetation of SE Glacial Plains

Historically, vegetation in the Southeast Glacial Plains consisted of a mix of prairie, oak forests and savanna, and maple-basswood forests. Wet-mesic prairies, southern sedge meadows, emergent marshes, and calcareous fens were found in lower portions of the Landscape. End moraines and drumlins supported savannas and forests. Agricultural and urban land use practices have drastically changed the land cover of the Southeast Glacial Plains since Euro-American settlement.

The current vegetation is primarily agricultural cropland. Remaining forests occupy only about 10% of the land area and consist of maple-basswood, lowland hardwoods, and oak. No large mesic forests exist today except on the Kettle Interlobate Moraine, which has topography too rugged for agriculture. Some existing forest patches that were formerly savannas have succeeded to hardwood forest due to fire suppression.

Hydrologic Features

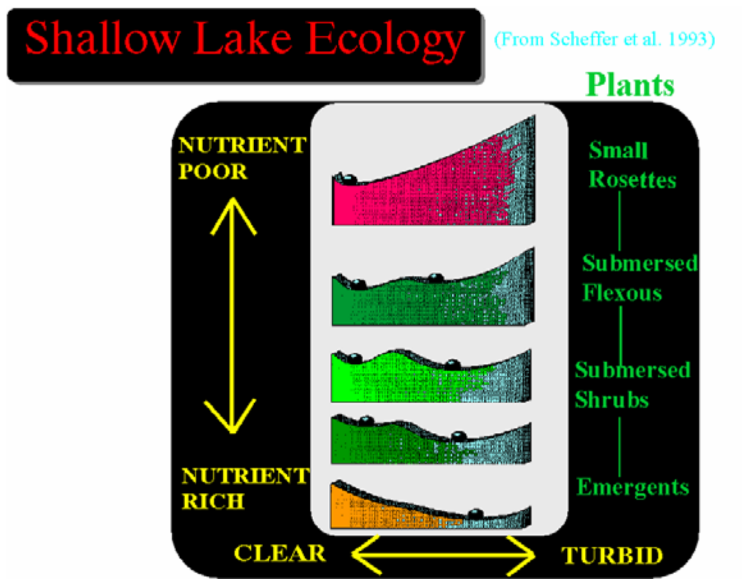
The Southeast Glacial Plains has the highest aquatic productivity for plants, insects, invertebrates, and fish, of any Ecological Landscape in the state. Significant river systems include the Mukwonago, Wolf, Sheboygan, Milwaukee, Rock, Sugar, and Fox. Most riparian zones have been degraded through forest clearing, urban development, and intensive agricultural practices. This Ecological Landscape contains several large lakes, including those in the Madison area and in the Lake Winnebago Pool system. These lakes are important to many aquatic species including the lake sturgeon. Kettle lakes are common on end moraines and in outwash channels. In addition to Horicon Marsh, this Ecological Landscape contains important fens, tamarack swamp, wet prairies, and wet-mesic prairies that contain rare plants and animals. However, most wetlands have experienced widespread ditching, grazing, and infestation by invasive plants. Watershed pollution in the Ecological Landscape is about average according to rankings by Wisconsin DNR, but groundwater pollution is worse than average compared to the rest of the state.

Ecology of Shallow Lakes

Human perturbations, primarily, non-point and point source nutrient loading, introduction of exotic species, and water-level changes have caused changes in the ecosystem function of shallow lakes in the Southeast Glacial Plain. Nature is often assumed to respond to gradual change in a smooth way. However, studies on shallow lakes, and other ecosystems like coral reefs, oceans, forests and arid lands have shown that smooth change can be interrupted by sudden drastic switches to a contrasting state (For review see Scheffer et. al. 2001). Researchers in Europe and North America have been studying shallow lakes intensively and we have gained much understanding from their work. Many formerly clear wetlands and shallow lakes in North America have shifted to an alternative stable state characterized by high turbidity, phytoplankton blooms, loss of submersed macrophytes and encroachment

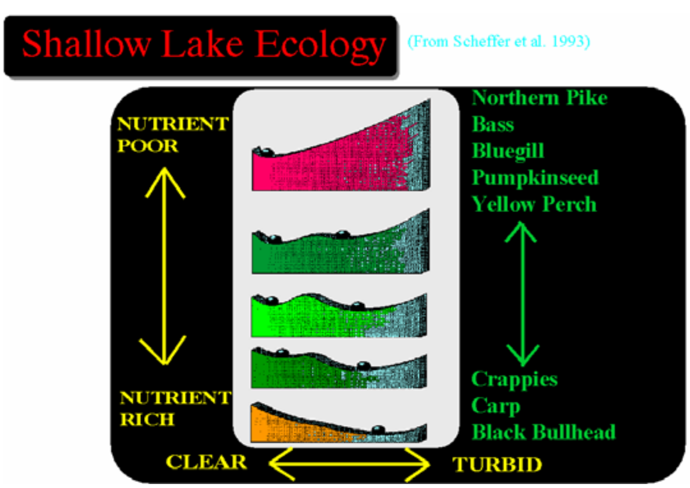
by emergent plants, low waterfowl use, and altered fish communities (benthivores/planktivores dominate). These patterns of ecological changes are detrimental to water quality, and to the biodiversity of wildlife and fisheries. The turbidity state of a lake immediately affects its economic and recreational value for humans. From most perspectives, the clearwater state is to be preferred to the turbid state. The production of drinking water, for example, can seriously be impeded by the formation of algal blooms that may lead to clogging of filters or that may result in a bad taste or odor of the water. These problems are even worse in the case of blooms of cyanobacteria, of which several genera (e.g. *Microcystis, Anabaena,* and *Aphanizomenon*) are known to produce substances that are toxic to cattle or humans. Also with respect to fisheries, the clearwater state is preferred. Fish kills through acute anoxia are much more common in phytoplankton infested eutrophied lakes than in transparent water lakes. Furthermore, fish species quality (species composition, e.g. the presence of pike) as well as fish meat quality (for consumption) is generally higher valued in clearwater lakes. Finally, the amenity value of clearwater lakes with a well-developed macrophyte vegetation is much higher than of lakes in the turbid state, increasing their value for recreation.

Figure 16



Martin Scheffer (Scheffer 1989) developed an ecological minimal model that describes bi-stability in the ecological properties of shallow lakes (Figure 16). Scientists now recognize that shallow lakes may have two alternative stable conditions, a clear or turbid state. The valleys in the landscape diagram correspond to stable ecological conditions. Each picture shows the stability properties at different nutrient conditions. In the oligotrophic situation a clear state is the only stable condition, and likewise in the hypereutrophic condition the turbid state is the only stable conditions. Continued enrichment gradually causes the stability of the clear state to shrink to nil, where the lake is more vulnerable to perturbations that would shift the equilibrium to the turbid state.

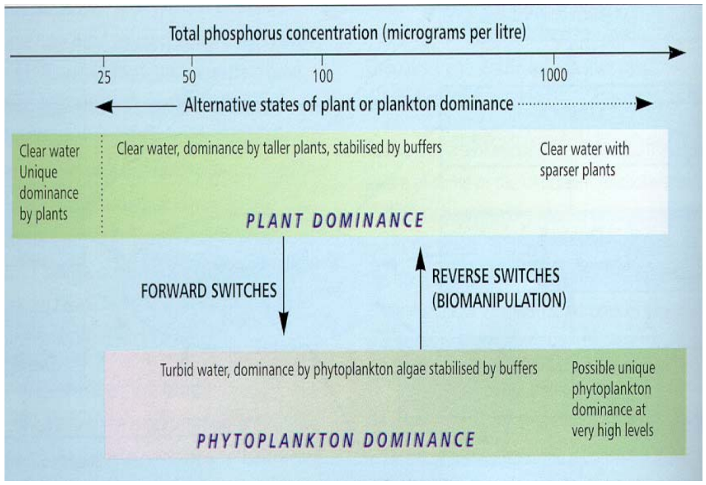
Figure 17



Fish communities also respond to these changes in habitat and water quality (Figure17). Lakes with dense macrophytes support northern pike and bass as the top piscivores with bluegill, pumpkineseed and yellow perch as the primary benthivore/ planktivores. In turbid open water lakes species like carp, black bullhead, and white crappie tend to dominate. The biomass of the piscivore populations like northern pike is often very low in these ecosystems. The health of Littoral zone habitat in terms of aquatic plants is dependent on the nutrient status of the waterbody and shallow water habitat of lakes undergoing cultural eutrophication are much more dynamic, variable, and it's difficult to sustain their resource quality of their shallow water habitat.

Switches
Water-level dynamics, nutrient loading regimes, biotic interactions, and severe weather events are often cited as the causal mechanisms for this drastic shift in ecological condition. The events or manipulations to a shallow lake system that cause a change between plant-dominated and algae-dominated states are known as a switch (Moss, 1998b). A change from plant dominance to algal dominance is referred to as a forward switch (Figure 18). Reverse switches cause a change from algal dominance to a plant-dominated system and are often associated with intentional human efforts to restore a shallow water system.

Figure 18



Forward Switches
Two types of forward switches occur in shallow lakes: those that directly destroy the plant structure, and those that indirectly affect the plant structure by preventing buffer mechanisms from operating. The direct type includes mechanical harvesting of plants, the application of herbicides, or damage done by boating. It can also include natural damage from wind, storms, ducks, and geese (Moss 1998b, Sondergaard et al 1996). Examples of indirect forward switches include the leakage of pesticides and other toxins that kill zooplankton, higher water levels, the addition of nutrients from surface run-off, and introduction of common carp. There is a strong correlation between the presence of pesticides in sediment and zooplankton mortality (Stansfield et al 1989). With populations of zooplankton reduced, lakes become susceptible to algal domination.

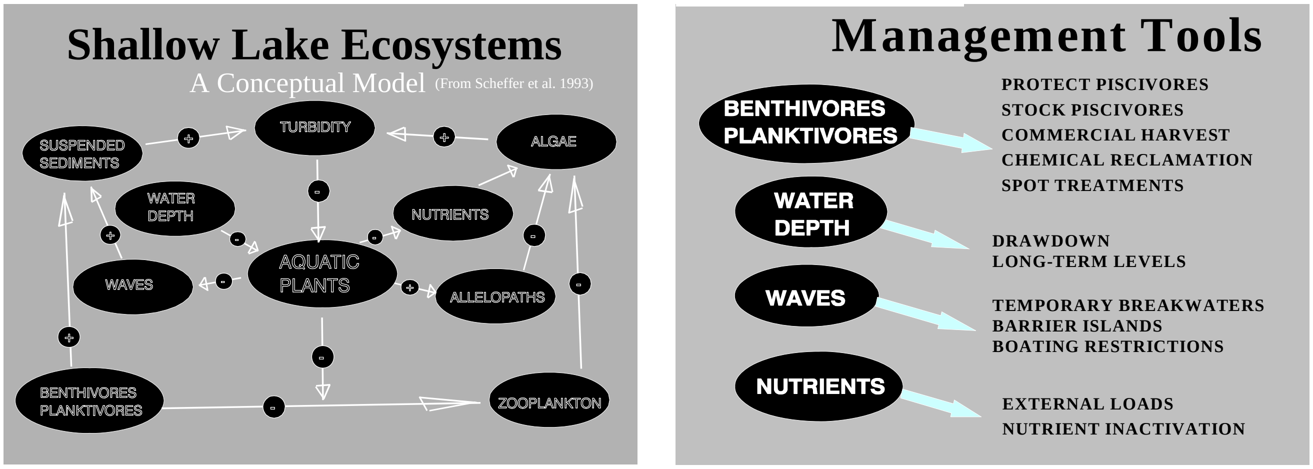
Water-level fluctuations are among the major driving forces for shallow lake ecosystems (Coops and Hosper 2002; see (Attachment 6). Water level in a lake is an important control variable with respect to aquatic macrophyte dominance. Vegetation can withstand turbid water more easily if a lake is shallower. High water levels are identified as a cause that induces a shift from macrophyte dominance to turbid algal dominance conditions in shallow lakes. A small shift in critical turbidity resulting from a higher water level can cause a loss of macrophyte coverage and a forward switch to the algal-dominated state (Scheffer 1998). This phenomenon for shallow lakes (raising water levels—decline in vegetation; lowering water levels—increase vegetation) is widespread. Numerous examples are found in North America and worldwide; Lake Tamnaren, (Wallsten and Forsgren, 1989; Bengtsson and Hellstrom, 1992), Rice Lake (Engel and Nichols, 1994), Upper Winnebago System, Lake Okechobee (Steinman et al. 2002), Lake Krankesjon (Blindow 1992; Blindow et al. 1993), Lagoon of the Islands (Sanger 1994).

Reverse Switches- Shallow lakes suffering from turbid water and algal blooms tend to be resistant to recovery and reducing external nutrient loading alone has been often shown to be insufficient to restoring clear water conditions and aquatic habitat (Hosper 1998, Scheffer 2001, Moss 1996). Major fish-kills and reductions in water-levels are the most frequent natural causes cited for reverse switches in shallow lakes.

Restoration projects aim to induce a reverse switch in Wisconsin's shallow lake management often involve; 1) water level drawdowns; 2) reductions in benthivorous (carp, black bullhead) and planktivorous fish (white crappie, shad, young-of-year carp) by mechanical removal or chemical treatment; 3) Stocking of piscivorous fish (northern pike, largemouth bass, walleye); 4) Protective sportfishing regulations to maintain high biomass of piscivorous fish and by piscivory a comensurate lower biomass of planktivorous and benthivorous fish; 4) Reductions in external loading to a range where bi-stability is anticipated (see figure 19); and 5) reducing the impacts of motorboats on aquatic plants (Kahl 1991).

Fish play an important role in maintaining the stable condition, whether it is turbid or clear. In the turbid condition, fish can either recycle nutrients within the pelagic habitat or transport nutrients between habitats. The transport of nutrients from benthic to pelagic habitats provides a source of "new" nutrients that are fundamentally different from

Figure 19



recycled nutrients because nutrients released by benthic-feeding fishes can increase the total nutrient content of pelagic waters. Thus, they are best compared with external nutrient loading or other net sources of nutrients (anoxic sediment transport-phosphorus from sediments). Common carp can often be a big part of the problem because they root out aquatic plants when feeding, causing turbidity that prevents the regrowth of plants. Wetlands with high carp populations have noticeably less diverse and abundant aquatic plants, invertebrates, fish, and wildlife populations than those without carp.

Figure 20

Cladocerans, or water fleas "vacuum" the algae from lake water. When they are abundant, the water is more clear. If conditions are unfavorable, i.e. zooplanktivorous fish abundant, refuge absent, the lake water remains turbid from algae.

Biomanipulation- is an ecological management approach that manipulates the biomass of a particular level of the food web to have an effect on the biomass of another. The term originally encompassed a range of techniques applied to terrestrial and aquatic ecosystems. In aquatic systems it typically refers to top-down manipulation of fish communities, i.e. enhancement of piscivorous (fish-eating) fish populations and reduction of zooplanktivores and/or benthivores (Perrow et al, 1997). In one of the earliest published reports, Caird (1945) hypothesized that stocking of Largemouth Bass was responsible for reductions in phytoplankton through food chain interactions. Several researchers (Hrbacek et al, 1961; Brooks and Dodson, 1965; Hurlbert et al, 1971) found that planktivorous (plankton-eating) fish can severely reduce or eliminate *Daphnia*, the largest, most efficient grazers of phytoplankton (Figure 20). These results suggested that lowered planktivorous fish densities would maintain greater densities of *Daphnia*, and thus control algal biomass. A reverse switch involves biomanipulating the fish community to reinstate the plant buffers and destroy the buffers of algal-dominance. An abundance of small, zooplanktivorous fish can quickly reduce the population of *Daphnia* that efficiently graze algae. Biomanipulation seeks to replenish the zooplankton population by reducing the population of their predators. To decrease populations of small zooplanktivorous fish, top predators, such as pike, are added to the system. Biomanipulation to attain a plant-dominated state can also involve eliminating Common Carp from the system, not just because of their zooplanktivorous habits, but more importantly, their behavior of stirring sediments and the resultant turbidity that inhibits plant growth. Carp impact both water clarity and aquatic vegetation growth through their benthic, or bottom feeding activities. Studies have demonstrated a positive relationship between benthivore biomass and re-suspension of solids (Breukelaar, et. al., 1994) and phosphorus concentrations (Personn and Hamrin, 1994). Carp obtain their diet of insects, small clams, and worms by grazing along the lake bottom. Food and bottom sediments are sucked into the mouth cavity where the gill rakers pass the food organism and separate out the larger non-food items, which are then forced out of the gills, causing re-suspension of sediments. The suspended sediments then impede the ability of sunlight to penetrate through the water, and lack of light reaching the bottom of the marsh leads to no growth of aquatic plants. Because it is often impractical to selectively remove carp while maintaining desirable fish species, total fish eradication is often performed for a biomanipulation project. The lake is then restocked with healthier balance of fish including more "top predator" piscivorous fish. These fish keep the population of zooplanktivorous fish under control by preying on eggs and juvenile fish so that large zooplankton such as *Daphnia* are allowed to flourish and consume phytoplankton (algae). As a result, the water becomes clearer, allowing sunlight penetration and the proliferation of the submergent aquatic plant community. The established aquatic plant community utilizes the nutrients (i.e. nitrogen and phosphorus) that were the main food source of the algae, and the algae diminish.

Water-level- Lowering of water level simulates a natural disturbance event, drought, and can buffer the plant-dominated state or even induce a reverse switch from algal-dominance to a plant-dominated state (Scheffer, 1998). Drawdown can consolidate sediments, reduce internal nutrient loading, and provide opportunities to conduct habitat and shoreline improvement projects (Figures 21 and 22). Coops and Hosper (2002) suggest that shallow lake managers consider a combined strategy of restoring natural water level fluctuations and managed manipulations designed for a specific process to occur. For further discussion on the influence of water levels on the ecology of shallow lakes see Attachment 6.

Figure 21

July 12, 2001

Figure 22

August 27, 2001

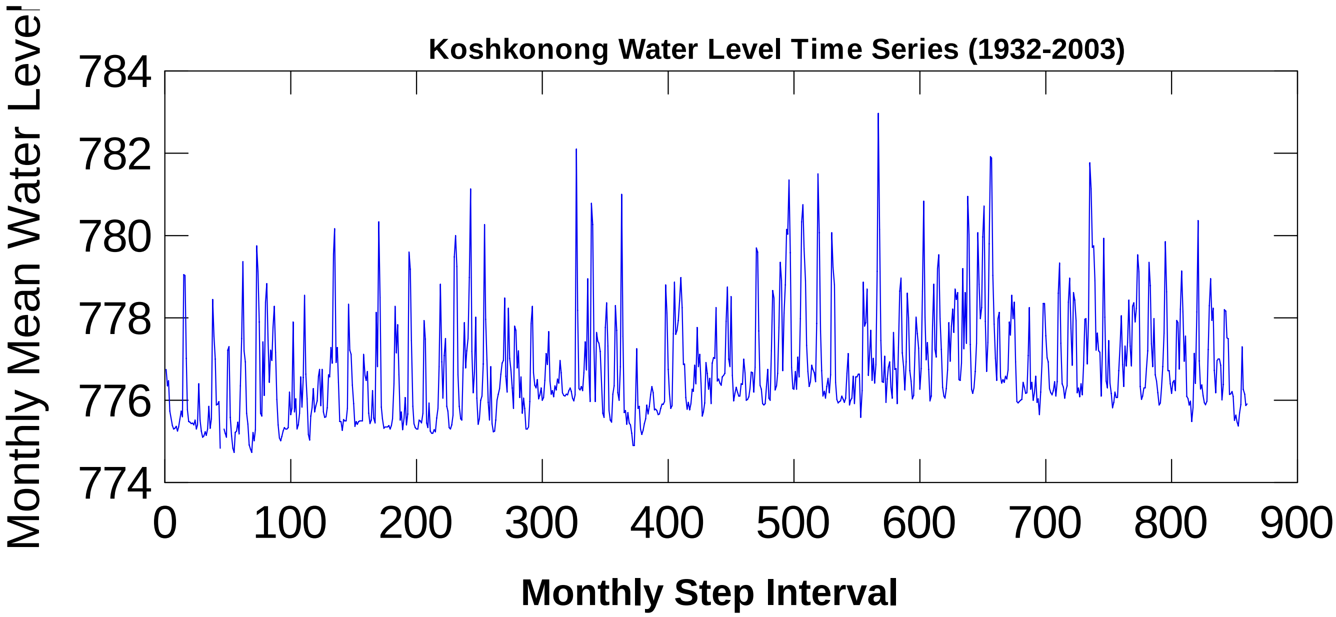
<u>Example of vegetation response to drawdown on Pool 8 of the Upper Mississippi River Pool 8.</u> Substrates were exposed between 6-10 July. Plant response dominated by flatsedges, teal lovegrass, rice cut-grass, common arrowhead, and nodding smartweed.

The Role of Wetlands

Several processes in wetlands are important for shallow lakes: transport and settling of suspended solids, denitrification, nutrient uptake by marsh vegetation (increasing nutrient retention), and providing critical habitat conditions for predatory fish. Within limits, the presence of a wetland zone around lakes may thus increase the ability of lakes to cope with nutrients and enhance restoration. Model calculations have revealed that nutrient concentrations are lowered by the presence of a marsh area, and that the critical loading level for a shift to clear water is increased (Janse et. al 2001).

Fluctuating water levels play a key role in the dynamic process of marsh rejuvenation, promoting and maintaining high levels of species richness and habitat diversity (van der Valk 1981). Many of the emergent macrophyte beds that dominate the marsh are killed during sustained periods of high water (Coops and Vander Velde 1996; Rea 1996; Clevering and Lissner 1999). Once water levels fall again, the exposed mudflats are initially colonized by ruderal, opportunistic plants, and later by emergent species. Water Levels for Lake Koshkonong exhibit distinct seasonal variation (due to being a floodplain flowage). But water level regulation has further inter-annual variation in summer levels. This water level management eliminates water levels that typically occur during drought conditions (Figure 23). Note that in figure 23 the annual differences in the summer lows (lowest points in the time series plot) are minimal throughout the whole period of record. Stabilization in this context generally refers to a reduction in the magnitude of water level fluctuations. A number of researchers have noted that prolonged stabilization of water levels has highly detrimental effects on shallow marshes (Harris and Marshall 1963; Van der Valk 1981)

Figure 23. Monthly mean water levels reported at the Fort Atkinson Water Plant from 1932-2003 .



A case study in water level management – Delta Marsh, Manitoba, Canada
An excellent case history of water level management and coastal wetland habitat changes can be found for Delta Marsh (Gordon Goldsborough, Personal Communication; Dale Wrubleski Personal Communication; Kenkel 1995). The Delta Marsh is at the south end of Lake Manitoba, 90 km north-west of Winnipeg. It is one of the largest and traditionally most important marshes in the prairies. It consists of shallow bays of water interconnected by winding channels. It covers more than 15,000 ha (37,065 acres), but it's size varies somewhat depending on water levels. The area is particularly important as a staging marsh for waterfowl now averaging over 50,000 ducks during the fall. In the past, peak staging populations have exceeded two million ducks and geese.

Delta Marsh is one of only two Wetlands of International Importance identified as Ramsar Sites in Manitoba. The Convention on Wetlands of International Importance (Ramsar Convention) was adopted in Ramsar, Iran, in 1971, and came into force in 1975. The Convention's mission is the conservation and wise use of wetlands by national action and international cooperation as a means to achieving sustainable development throughout the world.

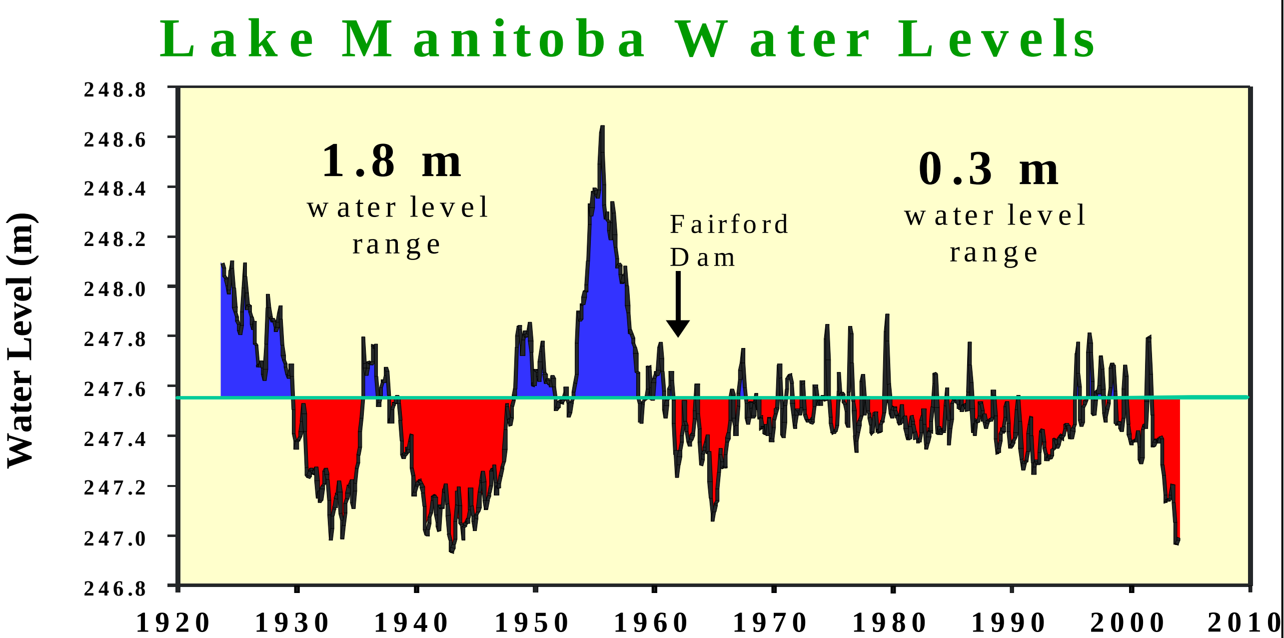
The nutrient-rich, shallow water of Delta Marsh supports a luxuriant growth of algae and submerged aquatic plants, as well as bulrushes (e.g. hardstem bulrush) which border the open water and also form small islands. Common throughout the marsh is the cattail and on slightly higher ground the giant reed forms dense stands. Whitetop grass and sedges characterize the wet meadows that usually dry out at some point during the growing season. Better drained, more upland sites are colonized by sand bar willow, Manitoba maples, green ash and cotton wood. Invariably, as water depth decreases there is a change in species from pondweeds to emergent macrophytes such as bulrushes, cattails and reeds, then wet meadow species such as sedges and whitetop grass, followed by willow and other upland species

In order to avoid the low water levels of the 1930's and 1940's a dam was built at the Clandeboye channel in 1944 at elevation 247.8 m. This allowed water to enter the marsh when lake levels exceeded 247.8 m but water could not drain out when lake levels fell. Several other connections between the lake and marsh were blocked.

High water levels in Lake Manitoba in the mid-1950's overtopped the Clandeboye dam, killed marsh vegetation, and rejuvenated the marsh but it flooded marginal haylands. Agricultural lobbying resulted in the construction of a dam at Fairford to regulate Lake Manitoba with a target of 247.5 m (reducing it's fluctuations from 2 m to 60 cm).

For example, since 1924 there have been four periods of 3 to 15 year-duration when water levels in Lake Manitoba were higher than the long-term average. These have alternated with conditions as in the drought of the 1930's and 1940's (Figure 24). The high water in the 1950's resulted in the death of more than 20% of the reeds and cattails in the marsh. When the water levels fell, seeds buried in the mud that had lain dormant for years were able to germinate and the mudflats were colonized by damp ground annuals soon to be replaced by whitetop grass or cattails and a rejuvenated marsh came into being. It is this type of dieback and recolonization that has allowed the marsh to survive. To remain viable, marshes need high water levels of long enough duration to kill emergent vegetation and drawdowns to allow revegetation.

Figure 24



Since regulation of the Fairford Dam in 1960, drought and flood conditions have been largely removed and the following changes for Delta Marsh have occurred; erosion of emergent macrophyte "islands"; higher water column turbidity; abundant cyanobacterial blooms; fewer submersed plants; fewer wildlife; and encroachment of hybrid cattails (*Typha x glauca*) into shallow areas (Figure 25).

Figure 25. Green shaded area represents aerial coverage of hybrid cattails in Delta Marsh in 1965, 1979, and 1997.