Muskegon Futures: Managing the Land

Introduction

It is hard to imagine that the Muskegon River Watershed could experience a more dramatic transformation than the massive harvesting of its forests between the 1850s and the turn of the 20th century. Yet, the Muskegon Watershed Research Partnership’s (MWRP) Mega Model projections suggest that the next 50 years might bring even more ecological change to the region than did the last 50 or even 150 years. Land management decisions we are making today will affect the future of both the Muskegon River and coastal Lake Michigan. Are we making decisions wisely?

Scenario Modeling

In 2002, 37 representatives from 13 watershed organizations and government agencies met with MRWP scientists to decide what management issues should be explored with the developing Muskegon River Ecological Modeling System (MREMS or Mega Model). Together the group decided to evaluate a number of future land management options ranging from reducing rates of urbanization to forest expansion. Ten different future landscape scenarios (for the period 2010-2100) and 10 historical (1830-1970) landscapes have been evaluated using Mega Model estimates of hydrology, temperature, main stem hydraulics, sediment transport, chemistry, and the condition of fish and aquatic insect populations for each of the landscapes generated. Climate conditions for each scenario were kept the same, so differences in ecological outcome are due only to the particular landscape management option being tested. Assumptions and results for four key land management scenarios are described briefly below.

Business As Usual (BAU) Scenario

In this scenario the Land Transformation Model (LTM2) constructed future landscapes assuming that the average rate of urban and forest growth observed from 1978 to 1998 will continue into the future. These expansions occur at the expense of agriculture, and so farming in this version of the future also continues to steadily decline across the watershed.

The future of the Muskegon River under this scenario is troubling. During most of the 20th century the effects of expanding urbanization have been partially masked by the even faster re-growth of the watershed’s forested lands from extensive timber harvests of the 19th century. It has been only since the that forest recovery began to substantially slow while urbanization continued to increase (see FIG. 1 on page 2).

In the Business As Usual Scenario this relatively new trend of increasing urbanization and declining forest cover continues through the year 2100. This in turn leads to increasing river flows and faster pollutant transport as we approach the 22nd century.

While larger river flows might seem like a good thing, the practical implication is that for the next 100 years, both storm flows and summer base flows would be getting larger and larger, leading to increasing rates of sediment erosion and transport, and increasing flooding along riparian margins as the river channels...
Business As Usual (BAU) Scenario (continued)

adjust to their new loads. MREMS suggests that many river segment channels will need to grow 10-30% larger (in terms of conveyance capacities) and will move towards that goal by either extensive lateral erosion or by cutting-off existing meanders to increase channel slopes (see FIG. 2 on page 3). Hand-in-hand with systemic erosion comes downstream channel filling with sand in some areas. The overall result will be a 20-30% increase in the annual rate of sediment delivery to the main stem impoundment system and to the lower river delta and Muskegon Lake. Along with sediment, the MWRP models predict increases in rates of carbon, nitrogen, and phosphorus loading to river channels, to Muskegon Lake, and eventually Lake Michigan. Increased nutrients in turn accelerate rates of eutrophication (increases in algal growth and related decreases in water quality). On a brighter note: land use change alone will bring slightly cooler water temperatures as a larger fraction of the rainfall is diverted from evapo-transpiration to recharge of groundwater aquifers.

The implications of the BAU Scenario for river fishes and related organisms are also quite negative (see FIG 3 on page 3). The overall ecological condition of fish and aquatic insect communities would decline over time. Based on MWRP studies the Muskegon River today is among the best examples of an ecologically healthy river system in Michigan’s Lower Peninsula (only about 10% of river miles are ecologically degraded). The BAU scenario more than doubles the miles of river habitat ecologically degraded by 2070 (>21%). This implies a drop in fish and insect diversity, and shifts in species composition towards more pollution tolerant organisms and smaller populations of rare and sensitive organisms.

Not all species will be negatively affected, nor will all places. Detailed models of main stem steelhead reproduction suggest that higher flows and marginally lower temperatures will lead to larger populations, but smaller sized steelhead juveniles each year. The overall effect on adult steelhead production is unclear but scientists are working on more sophisticated models to evaluate this. Larger, somewhat cooler flows may also favor other salmon in the main stem river, but significant losses of these populations are predicted in many important tributary systems.

Reduced Sprawl (RUS) Scenario

In the Reduced Urban Sprawl (RUS) Scenario, future landscapes are modeled with the constraint that urban land use in the watershed grows at half the average 1978-1998 rate. In the real world this could be achieved either by halving the population growth rate (by county), or reducing the so-called “sprawl rate” by 50% (sprawl rate is the ratio of increase in developed land surface to increase in human population size). Alternately, the same effect could be achieved by simultaneously reducing both population growth and sprawl rate (e.g. a 25% reduction in growth and a 25% reduction in sprawl rate yields a 50% reduction in urban land cover). Typically, sprawl rate is reduced by zoning restrictions. Population growth is driven by combinations of economic and aesthetic incentives, disincentives, and the state of the general economy. In our scenario, urban expansion is reduced but forest recovery continues at 1978-1998 rates. The result is a landscape with less urban cover and much more forest land cover. Because urbanization and reforestation occur at the expense of farmland, agricultural land use is much reduced (compare in FIG. 2 to BAU Scenario on page 3).

Since the future is still substantially dominated by urbanization in the southwestern part of the watershed, river flows are still predicted to rise and nutrient levels to increase. But the extent of this change is reduced relative to the BAU Scenario. The RUS Scenario is a “greener” vision of the future by far, with not only the most forest cover across the watershed but also with the lowest projected rates of eutrophication in receiving waters, and the least impact on fish and other biological communities inhabiting the river system (see FIG. 3 on page 3).
Farmland Preservation (FLP) Scenarios

Urban sprawl gobbles up farmland and economically marginal farmland is abandoned to forest. Increasing speculation about the potential for an agricultural revival in Michigan associated with bio-fuel development requires a vision of the future in which the Muskegon River Watershed’s farmland is more actively preserved in the face of urban sprawl. In the FLP Scenarios, conversion of existing farmland to shrubs and then forest is not allowed. Furthermore, urbanization continues at the expense of agricultural lands, either at a reduced rate (FLP1 uses the RUS sprawl rate), or the observed historical rate (FLP2 uses the BAU sprawl rate). FLP1 preserves the most farmland and FLP2 preserves the next most farmland of our major future scenarios.

Not surprisingly, the results of the farmland preservation simulations depend upon the accompanying urban sprawl assumption. When sprawl rates are low (FLP1) ecological responses lie roughly in between the results of the highly urbanized BAU and the greener RUS scenarios (see FIGS. 2 & 3). Increases in flow and erosion are still substantial. Nitrogen loads are quite a bit higher, but phosphorus loadings are lower than in the BAU Scenario. The overall impact on the ecological health of the river lies likewise between the BAU and RUS Scenarios. But if the urban sprawl rate is high (FLP2), then the ecological impacts are even more extreme than in the BAU Scenario. Ecologically, this is clearly the least preferable vision of the future Muskegon River.

FIGURE 2. Summary comparison of BAU, RUS, and FLP scenario outcomes for model year 2070 on the lower reaches of the Muskegon River. Note that climate is held constant for all scenarios and that scenarios are ordered in the figure by decreasing impact on physical channel variables. tp = average annual total phosphorus load; tin = average annual total dissolved inorganic nitrogen load; flow is the average annual discharge rate; DD = channel dominant discharge. Changes in dominant discharge imply a long-term trajectory of erosion (DD increasing) or deposition and meander formation (DD decreasing relative to 1998).

FIGURE 3. Biological responses in MREMS to landscape scenarios. Presented relative to present day, where 0 on the vertical axis represents values in 1998.
Where Can Land Cover Management be Most Effective?

Scenario modeling provides a powerful tool for exploring potential consequences of our land use decisions. While it is often useful to talk about the Muskegon River as a whole, the MWRP Mega Model actually operates at much finer geographic scales in order to incorporate and represent the highly variable landscapes of the Muskegon River Watershed. Model output can be examined at tributary sub-basin or even channel segment scales to address local impacts and responses. For example, MREMS analysis suggests decreased sprawl rates and increased rates of forest recovery (as in the RUS scenario) will protect biological integrity and water quality in the future. But, where in the watershed is management action most critical? Most land use decisions are made locally and with respect to relatively small parcels, zoning, and setback regulations are controlled by county, townships, and municipal government. Land use choices are more critical in some sub-basins of the Muskegon River than in others. Muskegon River tributaries that are the most sensitive to development may, or may not, be actually facing future development pressure. And because areas facing rapid land use change vary in terms of geology and climate, they also vary in their responses to changing forest cover and urban sprawl. Examining model output by sub-basin can give us a better sense of where careful land management decisions are likely to be most helpful to local river and stream environments, and where they are not (FIGS. 4 & 5).

For example, identifying sub-basins where both future threats are high and land cover-based mitigation is likely to be effective, can help us prioritize and focus watershed protection activities. MWRP modeling can provide relevant information by sub-basin for many different ecologically important variables. Figure 5 is an example of prioritization based on the joint risk of nutrient pollution, channel erosion, and declining biological integrity. Sub-basins are ranked by a combined score reflecting both degree of threat and potential effectiveness of land cover-based mitigation. Highly ranked sub-basins are the most logical places to focus land management activities. Many other criteria, for example basin size or recreational value, could be included in this type of prioritization.

A Climate-Change Caveat

In the MWRP modeling studies, rain and temperature patterns are held constant at 1985-2005 levels to allow us to isolate the effects of land use change alone. However, precipitation rates on the Muskegon River have in fact been slowly climbing since the 1890s; and today’s best climate projections call for both increasing rain and temperatures into the next century. Since MREMS already predicts a future of increasing river flows with constant climate, increasing precipitation will likely produce even higher flows. Our own development of the watershed’s future landscape will largely determine how much higher.

For more on potential effects of climate change on the Muskegon River see the Muskegon Futures: Volume 7.

The Bottom Line...

How we decide to use our landscape will largely determine the future of the Muskegon River. MWRP Mega Modeling studies suggest that: (1) Controlling the rate of urban sprawl is the single most potent tool available to protect the future of the river, its fishery, and its receiving waters, including Lake Michigan. (2) Maximizing forest cover in the future will (as it has in the past) provide substantial mitigation of the effects of urban and agricultural development. (3) Maximizing farmland preservation in an ecologically sound manner requires a simultaneous reduction in rates of urban sprawl. (4) The prospect of climate change makes rational land-use planning all the more imperative.