Muskegon Futures:

Riparian Management

Muskegon Watershed Research Partnership Bulletin 8

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Introduction

Figure 1. Trees and shrubs line the riparian corridor of this Midwestern stream.

Riparian lands are the attractive and often exceptionally valuable edge where landscapes end and waterscapes begin. Rivers, lakes, even wetlands have a *riparian zone* that marks the sometimes abrupt, sometimes gradual ecological transition from a wet to a drier upland landscape. The riparian edge attracts people; both for its inherent beauty, and also for its access to water resources and recreation. Ecologically this transition zone is important because it regulates much of exchange of water, sediment, and pollutants that occurs between the land and receiving aquatic ecosystems. Watershed managers often focus attention on the need to protect riparian zones from excessive development. Nevertheless, it is the case that there remains much technical controversy over the details of exactly how riparian zones interact with adjacent waters And, it continues to be especially difficult to evaluate the relative merits of specific riparian management practices. Likewise there is much debate about what exactly constitutes the riparian zone we need to protect. Historically Michigan and many states use the normal high water mark, or the 100-year flood event elevation, to identify riparian zones requiring protection. Flood related definitions are based primarily on potential risks to human life and property, not really on measured risks to adjacent aquatic ecosystems. Many communities today are considering or have already adopted stricter "set-back" regulations with the intention of protecting water resources. These typically vary in size from 10 to several hundred ft. What do we know about the efficacy and appropriate scale of riparian buffer management practices? How valuable might this kind of regulation be on the Muskegon river and its tributaries?

In 2002, representatives of 13 watershed and environmental organizations met at GVSU's Annis Water Resources Center in Muskegon with MWRP scientists from five universities to identify key questions that would be addressed by the watershed multi-model which at that time was under development. Stakeholders proposed evaluating a number of land management options which potentially might protect of ecological future of the Muskegon River system. These included the evaluation of a series of progressively stricter riparian buffer (set-back regulation) scenarios (see Muskegon Futures: Bulletin 2).

In this bulletin we report on MWRP research results relevant to the issue of riparian zone management. This includes studies using state-wide datasets to explore the impacts of riparian development (agricultural and urban) on the transport of phosphorus in Michigan rivers, and on the biological integrity of stream fish and insect communities. Taken together with the results of the MREMS scenario modeling of set-back buffers, we now have a much clearer scientific basis to guide our use and protection of the Muskegon Watershed's riparian lands.

Riparian land use and it's impact on phosphorus transport by rivers

Most Michigan rivers and lakes have relatively low levels of dissolved phosphorus (P) available to them. As a result, phosphorus pollution (addition by people) is widely associated with rapidly increasing aquatic plant productivity including algal blooms; a syndrome referred to as *eutrophication*. This in turn often leads to a series of consequences, including declining oxygen levels, which ultimately harm both fishes and the invertebrate community they depend on as food. Controlling phosphorus-containing effluent discharges and river and groundwater contamination from diffuse (non-point) sources on the landscape is one of the most important things we can do to maintain the ecological quality of our rivers and lakes.

As a part of the model building for the MWRP Mega-Modeling project researchers analyzed the relationship between land cover conditions and observed nutrient loading and transport in Michigan's rivers. Building on government, university, and MWRP data sets for the Lower peninsula of Michigan we developed loading equations that accurately described patterns of daily P transport occurring across a wide variety of watershed conditions. Detailed statistical analysis provided strong empirical support the idea that riparian buffers can protect the ecological integrity of our surface waters with respect to P pollution. And by incorporating effects of land use change on land cover composition we also learned some important lessons about how land management can help control phosphorus transport through our river systems.

Results of these analyses showed that, all else being equal (river size , water flow, geology, season), four land cover variables had statistically important effects on P transport loads (Table 1 below): % of the riparian zone within 40 m of the waters edge in forest cover; % of the riparian zone in agricultural land use; % of the entire watershed in agricultural land cover; and the %the entire basin in urban land cover. Of these land use categories, only forested riparian buffers improved water quality by reducing P transport in the river. Agricultural land cover in the riparian zone, and both agricultural and urban land cover in the basin reduced water quality by significantly increasing observed P loads. Urbanization of the upstream watershed had the strongest direct (isolated) effect on phosphorus loading; and this effect occurred whether or not there was urban land cover actually in the adjacent riparian zone. Agricultural land cover in the upstream watershed had a slightly weaker impact, and agricultural land use in the riparian zone itself had an even weaker (although still significant) negative impact.

Because different types of land use replace each other on a limited landscape, we also wanted to consider the indirect effects of land cover change. For example we are all aware that in Michigan urban land use often displaces agricultural land use. Likewise, agricultural land use often displaces forest land cover. Correcting for these and other interactions with a path analysis, we can estimate the likely overall impact of a change from one type of land cover to another. Looking at P loading this way, we found that change to forested riparian zones again had a strong positive effect on water quality. But the "net" impact of urbanization is reduced a little and that of agricultural land use increased a little. This result reflects the fact that riparian tree cover tends to be less affected than riparian farming by urban sprawl.

We concluded that set-back regulations specifically aimed at replacing riparian agriculture with forest buffers should significantly reduce phosphorus loading to the Muskegon ecosystem. Urban setbacks appear to have little effect, unless they are large enough to significantly reduce total upstream urban land cover. Both of these results are echoed in the more mechanistic MREMS scenario experiments described on the opposite page.

Table 1. Standardized relative effects of land cover categories on observed Total Phosphorus load transport in Michigan Rivers. (a) direct effect only of a unit land cover change on river reach TP export (kg/day). (b) overall effect when corrected for land use interactions. Colors give a visual interpretation to the relative impacts of each land cover type on water quality; ranging from green (improves quality) through red (degrads quality).

Land Cover Type	*direct effect on Total Phosphorus export* (a)	*"total" effect on Total Phosphorus export* [CORRECTED FOR INDIRECT EFFECTS] (b)
Riparian forest	-.12	-.12
Riparian Agriculture	+.03	+.05
Basin Agriculture	+.09	+.12
Basin Urban	+.13	+.07

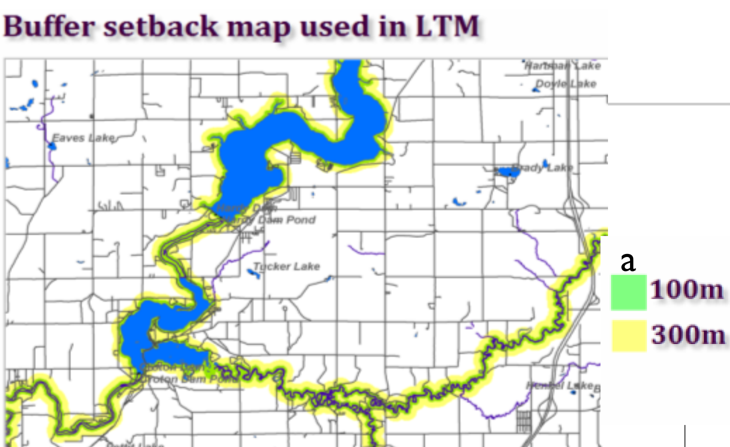
Riparian Set-backs: a modeling experiment

The 2002 Stakeholders conference requested a series of "set-back" modeling experiments using the MREMS Mega-Model. The resulting scenarios examined the potential effects of a 100m and 300m urban development set-back regulation for the main stem Muskegon, all in-line lakes and reservoirs, and the main stems of all major tributary streams. These scenarios were developed by the same Land Transformation Model (LTM2, at Purdue University) used in all the MREMS land Management scenarios. In this experiment all development in the set-back zone occurring after model year 2000 was re-directed by the LTM2 to regions outside the buffered zone. (For an example see Fig.1a)

A third, more extreme set-back "buffer" scenario was also run. It excluded all future development from lands adjacent to the riparian edge which a had travel time for groundwater to the river channel of one year or less . Effectively this excluded development from all sites with strong hydrologic connectivity to the river system (Fig. 1b). Travel times were based on estimates from the ILHM Hydrologic model running MODFLOW codes at MSU.

Results of the model simulations suggested a modest impact of set-backs on total phosphorus concentrations and loads, but relatively small effects on nitrogen, sediment, and water yields. The effects varied considerable from river reach to river reach. With a 100m set-back buffer, annual phosphorus loads declined on average 2%, but as much as 80% in one reach, and increased as much as 22% in another. With a 300m setback the average reach P load fell by 3% (range: -40% to +7%). The one year travel time buffer excluded urban development from a large area, and had the greatest impact on P loading. On average the decline in annual loading was 15%, with the greatest decline observed was 90%. But, again a number of river reaches responded with increased loads as well; the highest of these showing a 47% increase. Still, the confidence band around the average response was relatively small and most parts of the river saw at least a 10% reduction in P loading.

Impacts of the set-back zones on biological portions of the MREMS modeling were subtle, with 3-5% declines in total impaired miles being seen with the 300m set-back in particular. In the biological assessment models the one year travel-time buffer tended to make impairments rates a bit worse. Because urban exclusion from such a large a zone tended to (1) maintain riparian agriculture in place along the river; and (2) caused a more dense are more sensitive to urbanization than the large main stem and lower main tributaries being protected by the set-back. A similar tendency for the travel time set-back scenario to cause more channel destabilization is also related to these indirect consequences of the regulation.



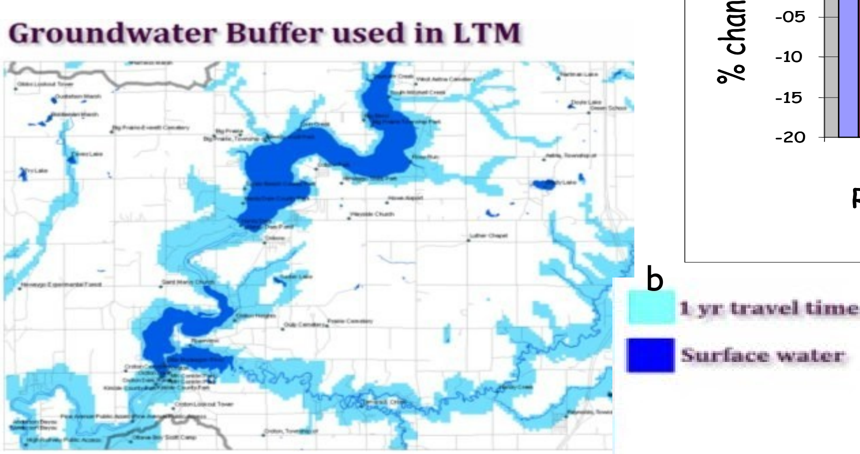
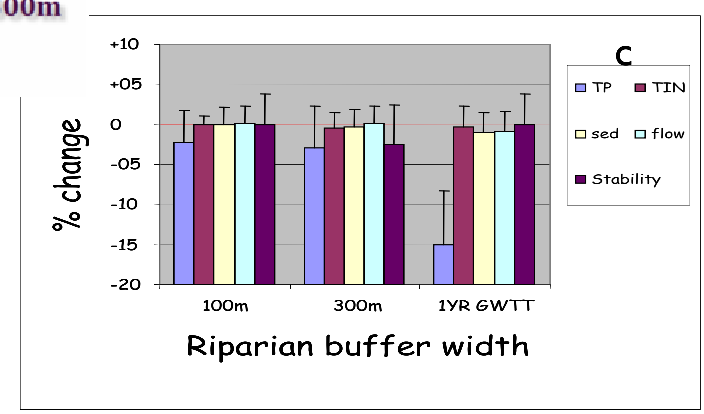


FIGURE 1. Riparian set-back experiments run with the Business-As-Usual scenario (see bulletin 2) .
a) 100m and 300m set-back zones.
b) 1 year groundwater travel time set-back zone.
c) Average reach results for the three different set-back buffer experiments: annual average nutrient loading, sediment load, volume water discharge, channel stability. Brackets reflect 95% confidence limits around the reach average value.

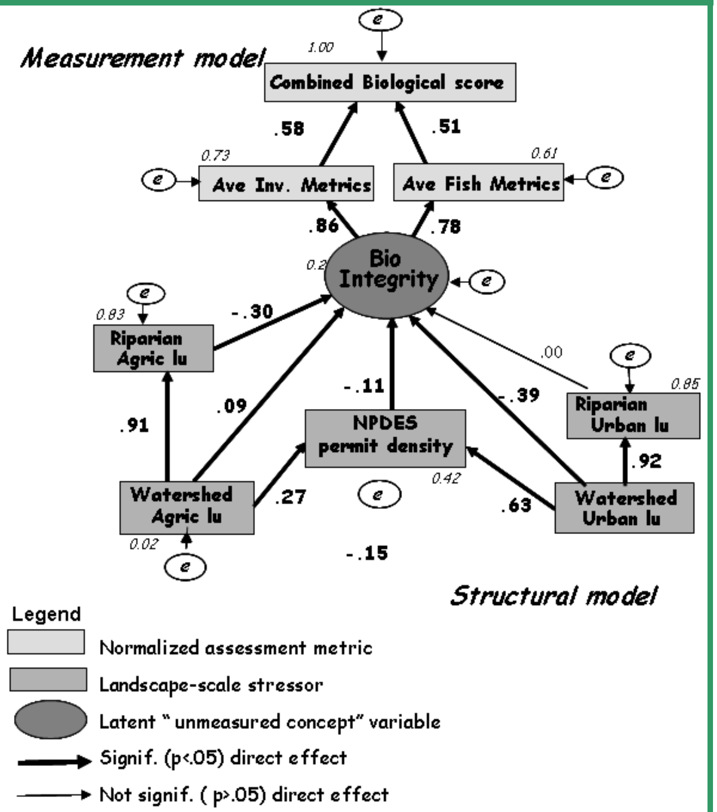


Riparian land use and it's impact on Biological Integrity

As a part of the development of an ecological assessment model for the Muskegon River, MWRP researchers analyzed thousands of samples of fish and insect communities from around the Sate of Michigan. One product of that analysis was a state-wide causal model (Fig. 2) examining the relative impacts of basin and riparian land cover characteristics on rates of ecological impairment in Michigan's Rivers and streams. The diagram illustrates the network of causes and effects which link land use, known point sources of effluents, and biological integrity using a technique called Structural Equation Modeling (SEM).

An important result from this analysis was that for biological impacts, the negative effects of agricultural land use seem to come primarily from the riparian zone. This suggests that riparian set-back buffers in agricultural areas would be a particularly effective way to restore insect and fish communities, as well as to reduce phosphorus loading (see page 2). In contrast, an independent effect of urban development on riparian land was not detectable, so the impact of urbanization appears to come from development across the watershed in general. This again means we have little evidence that urban set-back rules would be effective in mitigating the impacts of urban sprawl when it already dominates the upstream catchment.

This analysis ultimately gives us a ranking of the causes of observed ecological impairment of rivers in Michigan. Overall, urbanization of the watershed has had the largest impact. Agricultural development of the riparian zone is the next most serious cause of impairment. Agricultural land use in the watershed is the third most important cause, and point-source effluents the fourth.



Landscape stressors	"causal" strength Direct	Total
Watershed %urban	**-0.394**	**-0.43**
Watershed %ag	0.092	**-0.212**
Riparian buffer %ag	**-0.301**	**-0.301**
NPDES permit density	**-0.108**	**-0.108**

The Bottom Line...

Riparian zones are critically important components of watershed ecosystems. MWRP studies provide ample direct evidence that land use practices in the riparian zone affect the quality of downstream river and lake communities. Our studies clearly show the need for riparian buffer requirements in agricultural settings, and likewise the value of the restoration of floodplain forest cover. Benefits of promoting riparian zone protection and restoration would be (1) increased biological integrity for the river, (2) reduced eutrophication in receiving lakes downstream (3) reduced oxygen depletion (4) increased channel stability and (5) decreased sediment transport. The efficacy of set-back regulations in urban settings is less clear. This is not because urban environments are less problematic. Instead, it reflects the overwhelming efficiency of water and material transfer in urban drainage systems which seems to overwhelm potential riparian buffer benefits. The solution to urban impacts on the river seem to require a basin-wide reduction in sprawl and impervious cover.

The MREMS set-back modeling experiments were designed, in part, to provide information about the relationship between buffer size (set-back distance) and ecological benefits. Based on our analysis we see that the benefits generally increase with set-back distance although indirect effects of land use allocation can complicate outcomes. We found that the 300m buffer scenario provided the widest and most consistent ecological benefits. Notice that all of our set-back distances were large relative to the scale typically envisioned in township ordinances. Notice also that the scale of beneficial change obtainable through set-back regulation is relatively modest for most parameters we examined. The exception was phosphorus loading. While this may be in part reflect scale limitations in our process models, we believe it is an important result that for our scenario modeling as a whole, proportional changes in land cover at the watershed scale had much larger effects than changes riparian buffer land use composition. The "take home" message from this should be clear: while riparian management can contribute to the overall health of the Muskegon watershed, it cannot compensate for (nor "fix") problems arising from the impacts of large-scale changes in basin land cover and climate.

For more detailed information visit our website at www.mwrp.net/