Feasibility Assessment for Rehabilitating the Dowagiac River System in Southwestern Michigan

A Watershed Analysis of Potential Changes to
the Ecology and Community.

By:

George P. Aponte Clarke
Jose R. Batres-Marroquin
Beverly L. Braden
Hiroshi Kato
A. Morris Perot, Jr.

A project submitted in partial fulfillment of requirements for the degree of
Master of Science of Natural Resources and Environment

The University of Michigan
School of Natural Resources and Environment

August 1998

Faculty Advisors:
Associate Professor Gloria Helfand
Adjunct Assistant Professor Paul Seelbach

Abstract

The Dowagiac River is a unique coldwater stream in southern lower Michigan that shares similar characteristics to northern trout streams such as the AuSable River. High groundwater contributions along much of its length provide cold temperatures and steady baseflow throughout the summer season. If the river had not been dredged and straightened in the 1910-1920s to facilitate drainage of agricultural lands in the headwaters region, the river would likely have a higher ecological and recreational potential. The straight course of the present Dowagiac River leads to uniform high velocities without the characteristic pool and riffle sequence found in more natural rivers. Instead, high velocities, homogeneous habitat, and disconnection from the floodplain have degraded the ecological quality of the river. The present study was undertaken to assess the feasibility of river channel rehabilitation within the agricultural context of the watershed by a non-profit group known as Meeting the Ecological and Agricultural Needs within the Dowagiac River System (MEANDRS). The potential rehabilitation area was defined as a variable-width corridor extending from the Pucker Street Dam north to the Cass-Van Buren County line, with re-connection of meanders and the floodplain to the river. Our study had two major components: develop baseline profiles of the present river ecosystem, and conduct a feasibility analysis of the proposed channel rehabilitation project. The biological profile compiled data on aquatic and terrestrial fauna and flora along with natural plant communities. The physical profile examined climate, geology, soils, hydrology, water quality, and channel morphology. Social, recreational, and economic profiles were also developed to gain an understanding of potential stakeholder issues, with an emphasis on agriculture. Since the effects of rehabilitation on drainage was identified as a key concern, the project study area was classified in terms of sensitivity to a rise in the groundwater table using a geographic information system (GIS) and county well records. To examine the feasibility of the proposed rehabilitation, a qualitative matrix was used to provide insight into both short-term and long-term effects of rehabilitation contrasted with the status quo without the project. Major matrix categories reflected the ecological and social aspects of the area, including surface and groundwater drainage, wetlands, water quality, biological integrity, potential for sustainable fishing, recreational potential, agriculture, natural resource/open space conservation, and the community's social well-being. The proposed rehabilitation will largely benefit the general public and recreational users, both within and outside of watershed. These benefits are closely associated with predicted improvements in biological quality of the DRS. Public benefits could come from knowing and appreciating that the ecosystem is healthier, participating in improved recreational opportunities, sharing in the subsequent economic gains, and enjoying the enhanced aesthetic quality of the watershed. Loss of land due to a decrease in drainage capacity could impact activities in areas sensitive to a change in the groundwater table, such as agriculture. Disrespectful behavior associated with increased recreational activity is an important concern. Unavoidable impacts resulting from rehabilitation will affect individuals on a situational basis and may frequently be minimized or mitigated. Adverse effects due to changes in drainage may be mitigated by focusing on areas found to be less sensitive to changes in the groundwater table, specifically the lower to middle sections of the river corridor. Possible conflicts resulting from increased recreational use can be controlled by careful planning of access points and signage indicting respectful use of the river. In general, an adaptive approach soliciting citizen input while considering the physical and ecological qualities of the DRS is recommended. The ultimate decision regarding feasibility falls upon MEANDRS and watershed residents who will need to review this study and determine whether to pursue rehabilitation.

Acknowledgments
The members of this Masters Project would like to sincerely thank the following groups and individuals for their assistance in making this report a reality.

Dr. Gloria Helfand, Associate Professor, School of Natural Resources and Environment (SNRE). Gloria served as our Faculty Advisor. Gloria guided us through the development and implementation of our evaluation matrix, as well as provided invaluable critical review and guidance throughout the entire project.

Dr. Paul Seelbach, Adjunct Assistant Professor, SNRE. Paul also served as our Faculty Advisor. Paul helped us to develop and construct our baseline surveys based on the Michigan DNR Fisheries Division River Assessment report format. He added insight on trout fisheries, water quality, and physical features of the watershed. Paul also provided invaluable critical review and guidance throughout the entire project.

Thomas McClain, Adjunct Lecturer, SNRE. Tom served as our Faculty Consultant. Tom helped significantly with the application of methodologies developed by the Groundwater Education in Michigan (GEM) Center at the University of Michigan – Flint to develop the groundwater elevation map.

Geographic Information System (GIS) Laboratory, SNRE – especially, Drs. Andrew Brenner and Paul Richards, for providing significant time, effort, and resources that made our GIS analysis possible.

Meeting Ecological and Agricultural Needs within the Dowagiac River System (MEANDRS), our client, for providing an incredible learning opportunity that let us work with many talented and dedicated people, as well as offering realistic advice and feedback.

Jay Wesley, MDNR Fisheries Biologist. Jay assisted with the definition of the original project scope, helped to secure project funding, provided invaluable knowledge of the project area, and provided guidance throughout the project process.

Kalamazoo chapter of Trout Unlimited, MDNR Natural Heritage Small Grants Program, and **the Great Lakes Aquatic Habitat Fund**, for their financial support. **Sauk Trails** provided financial management of these grant monies.

Lauren Hughes of the GEM Center at Western Michigan University, for local information as well as "The Hydrology and Hydrogeology of the Dowagiac River Watershed" report prepared by her students.

Donna Erickson, Associate Professor of Landscape Architecture, SNRE. Donna assisted with the agricultural tools appendix by answering numerous questions and provided several helpful references.

Dr. Richard Brewer, Professor of Biology, Western Michigan University, for his review of riparian associated birds for the biological profile.

Dr. Burton Barnes, Professor, SNRE, University of Michigan, for his review of plants and plant communities for the biological profile.

Bill Westrate, Jr. and **Dorothy Blanchard**, both amateur naturalists, for their review of the amphibian and reptile sections for the biological profile.

Last and most importantly, we would like to thank our friends and loved ones for their encouragement and patience during the last 18 months, whose support has truly made this project possible.

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Executive Summary

Setting and Client

The Dowagiac River, located in southwestern Michigan, was channelized in its headwaters region in the early 1900s and the 1920s, deepening and straightening the channel. These changes resulted in a lower water table and increased drainage, which opened up agriculture land in the headwaters previously characterized as swamp. Changing the river from a natural to a managed system enhanced agricultural opportunities, but also had significant detrimental impacts on the ecological, recreational, and aesthetic potentials of the watershed.

Recognizing the rehabilitation potential of the Dowagiac River system, a group of local citizens formed a non-profit group known as Meeting the Ecological and Agricultural Needs of the Dowagiac River System (MEANDRS). Through rehabilitation, MEANDRS sees an opportunity to stimulate economic opportunities by enhancing the ecological and recreational potential of the Dowagiac River System (DRS). At the same time, MEANDRS is interested in preserving the agricultural character of the watershed.

MEANDRS' vision for rehabilitating the river focuses on creating a natural corridor within the agricultural landscape using the river as a connecting theme. MEANDRS' goal is to improve the biological quality of the instream and riparian habitat, along with the aesthetic and recreational qualities associated with the river, while minimizing any impacts on riparian landowners and agricultural interests.

Baseline Data (Appendices 1-4)

One of the more important influences on the Dowagiac River is its geology. The coarse-textured deposits of the Kalamazoo moraine and associated outwash drive the hydrology of the area. The coarse textured soils aid infiltration so that a large aquifer has developed which provides a high degree of groundwater contribution to the Dowagiac River system. When the watershed's groundwater table intersects the river or its tributaries, these high yields flow directly into the river, constituting a stable baseflow with cold water temperatures.

The large amount of groundwater contribution to the river helps maintain good surface water quality. The pH is slightly alkaline and the amount of suspended sediments is relatively low. The contribution by point sources such as industries is relatively little in the watershed. However, the high water table makes groundwater resources vulnerable to leaching of contamination on or near the land surface by fertilizers, pesticides, and animal waste.

The channel morphology of the Dowagiac River was dramatically changed by channelization. The stream was straightened, making the gradient steeper. The vertical connection between the main channel, and the floodplain with its associated wetlands was severed. High flows in a channelized system can have significant biological impacts, mainly due to uniform high velocities that cannot be tolerated by most aquatic organisms. Trout, in particular, need a pool-riffle sequence in order to feed, breed, and rest.

Due to channelization, which resulted in swifter flow velocities, the current predominant fish species are warmwater fishes rather than the coldwater species that would be expected due to the river's high groundwater contribution. Current warmwater fish species include the blackside darter, white sucker, common shiner, and hornyhead chub. Coldwater species, primarily brown trout that have been stocked, are able to live but not reproduce in the channelized portions of the Dowagiac River because of the degraded habitat. In contrast, brown trout are able to reproduce and maintain their population in Dowagiac Creek, a more natural tributary of the Dowagiac River. The Dowagiac River has suitable coldwater qualities, but lacks physical habitat diversity; therefore, the Dowagiac River is a good candidate for rehabilitation.

The floodplain along the Dowagiac River is presently disconnected from the river because of channel incision and the high spoil bank along one or both sides of the river which have created a levee. Reconnection would improve stormflow and sediment regulation, and allow woody debris to be transported into the river, providing cover for fish and food for other organisms. A more natural river would have less bank erosion and clearer waters. A functioning floodplain would serve as a buffer for non-point source pollutants entering the stream. These changes will not only improve the environmental quality of the system, but also improve the recreational potential and aesthetic appeal as well.

Periodic flooding is a natural disturbance along riparian corridors. Vegetation in a natural river floodplain generally develops according to a zonation pattern based on frequency of flooding. The high banks of the levee (dredge spoils) and the downcutting of the river have meant that the natural flooding of the Dowagiac River has been impaired since the dredging operations in the early 1910s to mid-1920s. The levee has become the site for both bottomland and more upland species and the natural pattern of zonation of first and second bottoms has become less distinctive along the Dowagiac River. A rehabilitation effort, including reestablishment of some of the connections to the floodplain, would result in a more natural plant zonation pattern, leading to greater diversity of plant species and associated animal diversity because of increased shelter and available food plants.

The Dowagiac River corridor is characteristic of southern bottomland forests which are dominated by silver maple, red ash, and American elm (MNFI 1996). Black willow, cottonwood, and sycamore are also found. Other plant associates include black walnut, black maple, and box elder. Shrub species common to the Dowagiac River System include gray dogwood, nannyberry, bladdernut, prickly ash, American hazelnut, and clones of paw paw.

Cass County has the highest hog production of any county in the state of Michigan. Sales of hogs account for 61% of the agricultural revenues of the county. Corn and soybeans are the primary row crops grown in the county. This area is at the edge of the fruit belt; apple, cherry, and peach orchards are located in the northwestern township (Silver Creek Township). In the headwaters region located in Van Buren County, specialty crops such as asparagus and cucumbers are grown.

Agricultural trends in Cass County follow statewide agricultural trends. The size of farms has almost doubled since 1959, while the number of farms has decreased to nearly half. The average farm operator is 52 years of age, indicating that few young farmers are continuing in farming. More than half of the farms in Cass County reported losses in 1992. However, the contribution of several large hog farms raised countywide revenues from farming so the average revenue for Cass County was reported as positive.

There is some light industry in the area. Both Dowagiac and Cassopolis have industrial parks. Southwestern Michigan relies heavily on blue-collar occupations as sources of employment for its labor force. Wages in southwestern Michigan are on average 25% lower than the rest of the state. Blue-collar industrial jobs are complemented by a small segment of county employees located in Cassopolis, the county seat. Niles, at the southern-most edge of the watershed, is the largest city in the area and also has some light industry.

Feasibility Study

MEANDRS defined the area of rehabilitation as “a variable width river corridor sufficient to preserve biological integrity without interfering with the agricultural nature of the watershed.” This area could tentatively extend from the Pucker Street Dam (north of the city of Niles) north to the Cass/Van Buren County line.

Groundwater contours from the groundwater mapping portion of this research project (interpolated from well depth records plotted onto United States Geological Survey [USGS] topographic maps) were digitized and analyzed using Geographical Information System (GIS) software. The major purpose of this analysis was to determine sensitivity of areas to flooding from a higher groundwater level. This analysis was completed to help MEANDRS chose suitable areas for rehabilitation, and to estimate the worst case scenario, in terms of potential land loss, if rehabilitation were to occur across the entire length of Cass County.

To choose the main issues to evaluate for the feasibility analysis, we reviewed a survey of riparian landowners along the Dowagiac River (MSU Extension 1997). This survey provided us with an understanding of the concerns and interests of riparian owners. As a result of this review, we developed nine broad categories for assessing the success or failure of a rehabilitation effort within the DRS.

The categories are as follows:

- Surface and Groundwater Drainage
- Wetlands
- Water Quality
- Biological Integrity
- Potential for Sustainable Fishing
- Recreational Potential
- Agriculture
- Natural Resources/Open Space Conservation
- Community's Social Well-being
    - General Public
    - Farmers within the Rehabilitation Area
    - Riparian Landowners
    - Recreational Users

With the understanding developed from baseline studies, we predicted anticipated changes in the system if rehabilitation of the Dowagiac River were to be implemented. We were also able to anticipate continuing trends without the project. The two scenarios, with rehabilitation and without rehabilitation, were examined and a summary of these results is presented Table 1. The "without project" scenario was evaluated to serve as a point of comparison for evaluating project feasibility. Both the short and long-term effects were considered. Short-term was defined as the period immediately following the completion of construction activities. Long-term was defined as the time period after system stabilization had been achieved.

Results

If the river is reconnected to its floodplain and several meanders are restored, substantial improvement to the ecological function and quality of the DRS is expected. With the connection of the floodplain, ecological functions such as nutrient cycling and sediment deposition will create higher quality habitat for breeding and rearing of both invertebrates and fishes. The stream will provide more heterogeneous velocities and diverse habitats due to the restoration of riffle-pool sequences.

Currently the Dowagiac River has a high groundwater contribution and a steady baseflow. It lacks an alternating pool-riffle sequence since the river is a fast-flowing channel. With suitable feeding, breeding, and resting locations, trout could thrive and naturally reproduce in the Dowagiac River. With rehabilitation, the Dowagiac River trout population could rival northern coldwater streams like the AuSable and Manistee rivers.

Improvement to aesthetic qualities of the floodplain will make hiking and bird watching more pleasurable activities. A more meandering course, a diversity of channel velocities, and more natural scenery along the river would, likewise, make activities such as canoeing more pleasant.

The local economy could receive a substantial boost from anticipated ecological and recreational improvements. Outdoor recreation, especially trout fishing, has significant economic value. It is likely, there will be an increased demand for services such as angler shops, canoe liveries, guide services, restaurants, and gas stations brought about by visiting recreational users.

The main possible adverse effect of the project could be a change in drainage. Rehabilitation is expected to decrease the enhanced drainage function of the channelized river somewhat, and result in an increase in the number and size of riparian wetlands. In general, lengthening the Dowagiac River by adding meanders will slow the movement of water though the system causing the water table to rise in some areas of the watershed. While the ecological functioning of riparian wetlands is expected to improve, the consequences of decreased drainage may mean that some individual farmers may find their lands less tillable because of the higher watertable. Some residential properties in the high sensitivity area may also be affected, possibly experiencing difficulties with basement flooding. These problems can be avoided by choosing locations for the rehabilitation from areas with low sensitivity to flooding the lower reaches of the river.

Another possible negative effect is that increased recreational demand could lead to increased conflicts over the use of the river corridor. Conflicts could be between recreational users such as canoeists and fishermen, or between recreational users and riparian owners who might be troubled by increased trespass. Planning for public access points and providing restrooms could lessen conflicts with riparian owners. Educational materials on respectful use of the river could help lessen conflicts between recreational users.

Synthesis

As large, landscape-scale ecosystems that cut across political boundaries and yet must be managed holistically, river ecosystems pose special challenges to natural resource decision-makers. Therefore, it is necessary to consider management decisions both within the natural environment, and within the context of the social and economic conditions of their respective watershed and region. Often, competing interests result in conflicts between users, making management decisions difficult.

In the case of the DRS, there is some evidence of a desire to shift management strategies from one that focuses on the utility of the river as a drainage system, to one that balances the ecological and recreational potential with the agricultural needs. The DRS needs to be rehabilitated if its highest ecological potential is to be realized. Since the DRS is not in an obvious stage of crisis, watershed residents might lean in favor of maintaining the status quo or managing for drainage. The benefits of rehabilitation need to be clearly communicated, stakeholder interests heard, and adverse impacts addressed if rehabilitation is to proceed.

Improvements to the DRS will largely benefit the general public and recreational users both within and outside of the watershed. These benefits will come from knowing and appreciating that the ecosystem is healthier, participating in improved recreational opportunities, sharing in economic gains, and enjoying the enhanced aesthetic quality of the watershed. Economic gains associated with improving environmental amenities, increasing recreational potential, and maintaining the agricultural viability of the region could be substantial. Less tangible, but equally important, benefits come from an increased connection to the watershed such as increases in community pride and identity.

Some people may feel, however, that the potential loss of farmland associated with rehabilitation is a more critical issue than the rehabilitation benefits. MEANDRS can avoid or minimize the impact of the loss of agricultural lands by focusing on areas most favorable to rehabilitation, namely the low to moderate-sensitivity areas. Using our GIS analysis as a guide, MEANDRS can identify areas where hydrologic conditions are less likely to cause a significant change in drainage, or where land uses are more compatible with wetter conditions (e.g., forested areas). Plate 1 shows a large area of moderate to low-sensitivity stretching upstream approximately five miles from the Pucker Street Dam to the area where Peavine Creek joins the Dowagiac River. We recommend that MEANDRS focus their efforts on the lower portion of the river and work upstream, monitoring as they proceed for changes in the drainage function.

Our study was an attempt to narrow the focus of consideration for MEANDRS. We feel that the ultimate decision regarding feasibility falls on MEANDRS and the residents of the watershed. MEANDRS and the watershed's residents will need to review this study and determine for themselves whether rehabilitation makes sense. The group must consider the anticipated benefits and potential adverse effects within the agricultural context of the watershed, and in terms of the stakeholders involved.

Section 1 – Introduction

1.1 Setting

The Dowagiac River is located in the southwestern Michigan counties of Cass, Van Buren, and Berrien. This region is, and historically has been, a predominately agricultural area. Major population centers are Decatur (a village), Dowagiac (a small city), and Niles (a somewhat larger city). The original character of the Dowagiac River is unusual for southern Lower Michigan. Whereas most southern Michigan rivers are fed mostly by surface water runoff, this fair-sized river is highly connected to groundwater sources that supply substantial summer baseflows. High baseflows result in a stable flow regime for the river, cold water temperatures, and good water quality. With many of the river's original characteristics still intact the Dowagiac River is a strong candidate for rehabilitation. Although a coldwater system has less biological diversity than a warmwater system, it enables some specialized organisms such as trout to thrive. Thus rehabilitation would highlight the unique potential of this stream in southern Michigan.

Despite being a coldwater river, the Dowagiac River has not been able to support a thriving coldwater community. In particular, high velocities and homogeneous channel habitat impede the maintenance of a self-sustaining trout population such as found in the nearby Dowagiac Creek. In the 1920s, the Dowagiac River was channelized (deepened, widened, and straightened) in order to lower the water table, increase drainage, and open up agricultural land in the headwaters. While changing the river from a natural to a managed system enhanced agricultural opportunities, it had significant detrimental impacts on the ecological, recreational, and aesthetic potentials of the watershed. The floodplain along the Dowagiac River has a great potential for biological diversity but is presently disconnected due to high spoil banks along the levee. Floodplains also serve to moderate flows, function in sediment and organic storage and transport. Channelization has caused physical and ecological changes in the river that have lessened its overall value to the surrounding communities, especially its scenic quality and recreational potential. The Dowagiac River has the possibilities of providing multiple recreational uses, including hiking, fishing, canoeing, and swimming.

1.2 Client

Recognizing the rehabilitation potential of the Dowagiac River system, a group of local citizens formed a group called Meeting Ecological and Agricultural Needs within the Dowagiac River System (MEANDRS). Through rehabilitation, MEANDRS sees an opportunity to stimulate economic opportunities by enhancing the ecological and recreational potentials of the Dowagiac River System (DRS). At the same time, MEANDRS is interested in preserving the agricultural character of the watershed. MEANDRS is working together with local and state organizations to achieve their goals, and the group is interested in reviewing a variety of system-wide options for rehabilitation within the watershed.

MEANDRS' vision for rehabilitating the river focuses on creating a natural corridor within the agricultural landscape with the river as the central theme. Rehabilitation would improve the diversity and quality of fish and wildlife habitats, as well as aesthetic and recreational qualities associated with the river; while minimizing any adverse impacts on riparian landowners and agricultural interests. At the same time, natural resource improvements would enhance the quality of life in this region. MEANDRS anticipates that community involvement will foster a vision that balances ecological enhancement with socioeconomic sustainability (including agriculture) along with raising the local citizen's awareness of the river as a special resource.

1.3 Problem Statement

A watershed-level feasibility assessment is an essential step towards developing and selecting rehabilitation options that meet the long-term concerns and goals of the watershed community. MEANDRS sought a technical assessment of whether its objective of rehabilitating the watershed would be a feasible and practical approach for achieving their goals. Therefore, we conducted a preliminary study to explore the historical and current characteristics of the Dowagiac River System, and to predict potential changes that could result from proposed rehabilitation actions. This information is provided to MEANDRS in the form of a feasibility assessment.

Our study is an attempt to narrow the focus of consideration for MEANDRS. The people of the three county area, especially those living within the DRS, will need to review the highlights of this study as presented by MEANDRS and determine, for themselves, whether rehabilitation makes sense. We feel that the ultimate decision regarding the desirability of rehabilitation falls on MEANDRS and the residents of the watershed. The overall feasibility will be affected by whether MEANDRS can find outside financial support for this demonstration project. The group must consider the anticipated benefits and potential adverse effects within the agricultural context of the watershed, and in terms of the stakeholders involved.

This project report does not entail an engineering feasibility analysis or an assessment of rehabilitation costs. The engineering effort needed to restore meanders and establish some reconnections to the floodplain is not insignificant, and costs are likely to be sizable. Not only does the present study team not have the expertise to advise MEANDRS on engineering and cost issues, but these issues are very site specific. Information from other rehabilitation projects on engineering feasibility and costs cannot be easily extrapolated to the DRS. Cost estimates from other projects tend to be highly unreliable as indicators since there is considerable variation among hydrology, flow rates, soils, geology, land costs, and climate. MEANDRS needs to assess the interest in the community, narrow their potential site selection, and then invite potential contractors to submit estimates once the proposed task has been defined more precisely.

1.4 Objectives

The goal of our study was to determine the feasibility of rehabilitating the ecological potential of the DRS while maintaining the agricultural character of the watershed. To achieve this goal we addressed the following 6 objectives.

- To describe current and historical characteristics of the river system in order to establish a baseline for analysis.

- To create a criteria matrix showing which factors will be affected and to what extent by the proposed rehabilitation actions.

- To forecast what changes could occur, with and without rehabilitation, and to what extent they might occur in both the short and long term, based on our matrix criteria.

- To identify and predict the effects of changes to existing conditions, and evaluate the effects qualitatively using the matrix criteria.

- To discuss the implication of changes, and identify advantages and disadvantages resulting from rehabilitation.

- To synthesize our findings into an overall feasibility assessment; recommend ways to avoid, minimize, or mitigate any potential adverse impacts from rehabilitation.

1.5 Document Organization

The remainder of this report is organized in the following manner:

In Section 2, we provide background information for river rehabilitation projects in general, then apply this knowledge to this research project. Implications of channelization and rehabilitation (its counterpart) for river systems are presented with a review of the current scientific literature. Next the focus is narrowed to apply general principles to the specific case of the DRS. Our findings regarding baseline conditions in the watershed are then summarized from the detailed profiles (Appendices 1-4). We also discuss how the river system and region used to look and function, what are the present qualities of the watershed, and trends for the future of the watershed area, even if a rehabilitation project is not implemented.

In Section 3, we discuss our research approach and the specific methods used to predict, evaluate, and synthesize our findings. We attempted to predict what are the implications of undertaking a rehabilitation project in the DRS. The development of the matrix criteria and their evaluation made up the major focus of our feasibility study. The matrix evaluation answered what changes might be anticipated. Groundwater mapping and GIS analysis supplemented the matrix analysis; it was used to determine which areas within the watershed are the most suitable for rehabilitation.

In Section 4, we present and discuss our predictions of the potential effects of a rehabilitation project in the DRS and the implications of those effects by examining nine evaluation categories. We use our ratings of these categories to assess the probable success or failure of the rehabilitation project. We present our results in an evaluation matrix containing a detailed account of how each individual category might be affected by a rehabilitation project in the DRS. We then integrate the findings for each individual category into an overall picture of the watershed, and present a general summary of feasibility issues.

Finally in Section 5, we present MEANDRS with recommendations regarding ways to avoid, minimize, or mitigate possible negative effects of rehabilitation that were identified during the course of our study. We also present ideas for including and establishing a working relationship with various stakeholder groups. We conclude with some thoughts on funding issues for MEANDRS to consider before they proceed further.

Section 2 – Background

2.1 Geography

The Dowagiac River watershed lies within the St. Joseph River Basin; the river is located in the southwestern corner of Michigan's Lower Peninsula in Cass, Van Buren, and Berrien Counties (Figures 1 and 2). The headwaters region begins in the lower tier of townships in Van Buren County, encompassing a muck soils area near the city of Decatur. The Dowagiac River flows diagonally across Cass County in a southwesterly direction to its confluence with the St. Joseph River in Berrien County, at the northern edge of the city of Niles. Extensive groundwater discharge along the entire stream provides a continuous source of cold, clean water. The DRS is unusual in southern Michigan due to its relatively high baseflow and the river's larger size in comparison to other groundwater-fed streams (MEANDRS project 1996).

2.2 Dredging of the Dowagiac River

Similar to other regions of the country, at the turn of the century, farmers in the headwaters region were complaining about poor drainage of their muck-land fields. In response to this demand for better drainage, the Dowagiac River was dredged. In the first phrase (1902-1904), the headwaters portion and the stretch in Cass County to the southern Pokagon township line were dredged. However, farmers in the headwaters region still had problems getting on their fields in the spring and after heavy rains. Therefore the Van Buren and Cass County Drain Commissioners approved a second dredging phase to dig a deeper and longer portion of the river. In the second phase (1915-1928), nearly the entire river from the headwaters in Van Buren County to just north of the Niles dam was dredged to a depth of 8 feet below the adjacent land surface.

Changing the Dowagiac River from a naturally meandering river to a straight, swift flowing channel has resulted in the loss of normal ecological functions such as decreases in flood storage, size and functioning of riparian wetlands, and channel diversity. The normal flow regime where floodwaters are stored in wetlands is disrupted (Poff *et al.* 1993). Desirable species such as trout and other coldwater organisms no longer flourish within the Dowagiac River since they require a natural pool-riffle sequence to provide varied habitats for foraging, resting, and spawning. Because of lack of seasonal flooding, terrestrial flora and associated fauna is also less diverse.

2.3 Review of the Channelization Literature

Rivers have been channeled for flood control, drainage, and navigation purposes. These purposes continue to provide society with many benefits. However, we are becoming increasingly aware of the environmental costs of altering natural drainage patterns. Environmental consequences include alteration of natural flow regimes; disruption of sediment erosion, transport, and deposition processes; decreases in biological diversity; and decreases in recreational benefits.

The following sections contain a summary of the scientific literature on channelization in agricultural settings. Included here are the purposes of channelization; and its effects on physical, biological, and socio/economic systems. Additionally, this section contains information on the effects of channelization on the DRS.

2.3.1 Purpose of Channelization

Historically there have been several reasons for channelizing river systems, including flood control, wetland drainage, erosion prevention, and navigation improvement (Brookes 1985, 1987; Keller 1975). Urbanization and wetland drainage for human uses necessitated the modification of stream channels (Keller 1975). Modifications to channels generally result in a wider, nearly straight channel with a uniform and higher gradient, a trapezoidal cross-section, deeper incision into the landscape, and disconnection from the floodplain (Keller 1975).

Several channelization methods are typically employed. Re-sectioning makes rivers wider or deeper, and is intended to increase the conveying channel's cross-section so that water, which would previously have spread onto the floodplain, is contained. Re-sectioning of a river is usually combined with regrading, or adjusting the slope, of the bed to form a more uniform sloping channel. Regrading of the bed and widening the channel may also be necessary to adjust water levels for drainage or increased stormwater outfall from urban developments (Brookes 1985). In agricultural settings, channels are often straightened and deepened to lower the water table in lands adjacent to the river and its floodplain, to improve agricultural potential, and to obtain the required channel dimensions for a stable artificial channel (Brookes 1987).

Realignment involves straightening a river's channel. Straightening shortens the channel by creating artificial cutoffs, which separates individual meanders from the new channel, and leaves fragmented oxbow ponds. Cutoffs result in reduced local flood heights because of increased gradient and faster flow velocity. However, this can lead to exacerbated flooding in downstream areas that do not drain as quickly as the channelized reach. Cutoffs also facilitate navigation by removing bends in the river and shortening the river's length (Brookes 1985).

Bank stabilization, or protection, involves the armoring of banks with rock riprap[1], gabion baskets[2], concrete, vegetation, wood, or other structural materials to protect against abrasion and bank slip. These structural methods are frequently used at locations where the swiftest water currents contact the bank, potentially undermining the bank and causing impediments to flow (Brookes 1985).

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[1] Riprap consists of broken rock piled against the bank that is large enough to resist being picked up and transported by flood flows.
[2] Gabion baskets are wire mesh containers filled with tightly packed rocks.

2.3.2 Effects of Channelization

"Stream systems are dynamic and their pattern, dimension, and profile are determined by an interaction of process variables, such that a change in one variable sets up a mutual adjustment in the others" (Leopold, *et al.* 1964 in Rosgen 1993, p. 784). While this statement was originally intended to describe physical and morphological channel responses, it also explains additional systems adjustments as discussed below. Since biological and human socio/economic systems exist within the context of the physical environment, adjustments to the channel will initiate biological and socio/economic responses (Brookes 1987).

As discussed in this section, the modification of channel conditions often results in a wide range of physical, biological, and socio/economic responses. These responses frequently affect the overall nature of a river system, with conditions typically considered as degraded when compared to the original, unmodified system.

2.3.2.1 Physical Effects

Physical responses to channelization are numerous, and are largely dependent upon the characteristics of individual rivers and their channels. A number of process variables interact with each other, to shape channel morphology (i.e., channel width, depth, and slope). These variables include velocity, flow resistance, stream discharge, sediment size, and sediment load (Nunnally 1978; Rosgen 1993).

As these process variables are all linked, a change in one variable leads to a change in the other variables. For example, straightening a river increases the channel slope, which leads to an increase in flow velocity. Higher flow velocities pick up and transport more sediment than was supplied at the upstream end of the channelized reach. This new potential for sediment transport erodes and incises, or downcuts, the straightened channel, leading to an excess of both suspended and bed loads, which are then transported to a location downstream of the channelized reach. If the downstream reach is flatter (with slower velocities) the load is deposited, filling holes and pools, and leading to a loss in habitat for aquatic organisms (Brookes 1985; NRC 1992; M.J. Wiley, Associate Professor, University of Michigan, School of Natural Resources and Environment, personal communication, 1997). Other impacts from channelization include bank degradation, bed scour, channel migration, uniform velocity, homogeneous substrate, and vertical disconnection from floodplains (Brookes 1985, 1987; Keller 1975).

Finally, Rosgen (1993) pointed out that a common problem with designed channels is their "one size fits all" approach. A natural river essentially contains three different channels: carrying water in the lowest longitudinal points along the stream bed at low flows; at bankfull at normal high flows; and flooding overbank during flood flows. Designed channels typically are too wide to handle normal flows and sediment loads, and end up accumulating sediment. Sediment accumulates because the increased channel width spreads out and decreases the water velocity and depth, causing sediments to drop out of suspension. This process of excessive sedimentation leads to either lateral channel migration[3] or islands (Rosgen 1993). Portions of the Dowagiac River may fit this scenario, while others may not. Additionally, river channels typically attempt to recover but may not have sufficient erosive power to reestablish meanders (Brookes 1995). A comparison between a natural and constructed channel is shown in Figure 3.

2.3.2.2 Biological Effects

Moderate variability within physical systems creates diverse habitats for plant and animal communities within an ecosystem; this habitat diversity allows a consistent community pattern to emerge (Allan 1995). Habitat diversity is important because many organisms utilize distinct and different resources to meet their complex life cycle needs. For example, alternating riffle-pool sequences offers varied habitat that is important to the welfare of game fish such as trout, because it provides areas for feeding, breeding, and cover (Keller 1978; Diana 1995; Hunter 1991)(Figure 4). It should be noted, however, that too little or too much environmental variation can negatively impact biotic diversity by favoring a few strong species (Allan 1995).

When rivers are modified, the stream environment becomes much more uniform (NRC 1992). This uniformity often causes fish numbers and biomass to decrease, and sometimes fish are even completely eliminated (Brookes 1985, 1987). Reasons for these declines within channelized systems include: the loss of riffle-pool sequences for low flow habitat; stressful temperature and oxygen conditions at low flows; absence of shelter during exaggerated high flow events when an unmodified river would have stretched out onto its floodplain; altered width and depth creating shallow and unnaturally laminar flows; and disruption of the substrate, which may lead to excessive suspended sediment load which is deposited elsewhere, burying existing habitat (Brookes 1987).

Although modified river systems tend to be more uniform and less diverse than natural systems, the dynamic nature of the fluvial system may prove to be advantageous when attempting to rehabilitate rivers. Flowing-water communities are accustomed and adapted to a wide range of variable environmental conditions. This adaptation to a dynamic environment may enable stream communities to recover more quickly from certain types of disturbance (NRC 1992).

2.3.2.3 Social/Economic Effects

As briefly touched upon in Section 2.3.1, rivers have been channelized to provide flood protection, drain wetlands, prevent erosion, and improve navigation (Brookes 1985, 1987; Keller 1975). In flood-prone areas, channelization has been utilized to widen and

[3] River channels are not fixed in place. Through the process of bank erosion, they can move laterally over time.

straighten rivers. This modification increases the channel's capacity and velocity, which facilitates drainage, thereby preventing storm water from spilling onto the developed floodplain. Similar channel modifications, in which the channel is also incised deeper into the ground, are used to lower the groundwater table and drain wetlands. In erosion-prone areas, or in areas where localized erosion threatens the integrity of structures (i.e., buildings, bridges, and important natural features), channelization has been used to harden river banks, thereby preventing lateral erosion and migration of river channels. Waterborne navigation has also been aided by the channelization of rivers through deepening and straightening of the channel. Deepening of the channel allows access for larger ships, while straightening shortens the river's length and removes tight bends for ships to navigate (Brookes 1985).

Such channelization projects have provided a number of substantial social and economic benefits to humans. Flood control projects have allowed society to build in areas which would have previously been too risky, and to protect streamside areas from erosion once they have been developed. The drainage of wetlands has opened land area that would otherwise be unavailable for human development, often providing fertile agricultural lands. Waterborne transportation has also been improved through the reduction of transit times and by facilitating the transport of goods.

However, social and economic costs also result from channelizing rivers. Channelization and subsequent loss of habitat often have a significant impact on populations of sportfish, which appear to be threatened more by habitat loss than by over-harvesting (NRC 1992). Research indicates that as the human population within the U.S. increases, more people will participate in fishing. This trend in human population growth also implies a further reduction of fish habitat as human development impacts ecosystems; leading to even fewer fish per angler (NRC 1992).

As discussed in Section 2.3.2.1, channelization also increases the velocity of stream flow. This increase can result in limiting river access to wading anglers, as wading becomes more difficult and personal safety is threatened. A decrease in wading anglers can then lead to reduced income for the local sportfishing industry. The number of boating anglers might increase as a result of greater wading difficulties; however, faster water velocities could also hinder navigation (Hendrickson and Doonan 1972)..

A 1976 study of Michigan warmwater lake anglers indicated that the top four motivations for fishing were, in order of mean importance: 1) experiencing nature, 2) escaping, 3) making a mental change, and 4) exploring (Driver and Knopf in Fedler and Ditton 1994). This information suggests that the experience and aesthetics are also important components of the whole fishing experience. Channelization can be aesthetically unappealing and detract from the angler's experience at a particular location. Lessening of the experience may discourage the angler from returning to the channelized location.

2.3.3 Restoration of Channelized Reaches

Unmodified stream channels are the product of a dynamic equilibrium between erosional and depositional processes. This equilibrium fluctuates over time; and typically, stream channels are able to recover after disturbance events such as flood pulses or temporary influxes of excess sediment. The stability of a channel refers to the degree that this equilibrium swings, with greater swings being less stable. Channelization imposes constraints on a fluvial system that may not allow a morphologically-stable channel to develop, even after a considerable time (Keller 1975, 1978). Streams that have high power resulting from a steep gradient, high discharge, or a combination of both factors, are more likely to recover on their own (Brookes 1995; M.J. Wiley, personal communication, 1997). Keller (1975) noted that channelized streams in early stages of recovery typically have poorly developed and unstable pools and riffles. Nevertheless, many rivers have insufficient stream power to erode non-alluvial beds and banks (Brookes 1995). As discussed in the Physical Profile, the DRS is considered a low-power system because of its low gradient and lack of high peak flows, and is now incised approximately 8-feet into non-alluvial materials.

New methods for rehabilitation of channelized rivers have emerged over the last few decades. These successful methods are based on emulating the natural form and processes that take place in an undisturbed, meandering channel (Brookes 1985,1987; Newbury and Gaboury 1993). The goals of rehabilitating channelized systems via this method include: increasing channel stability because pools and riffles help dissipate energy; reducing disturbance to biotic systems through the maintenance of habitat diversity; and the improvement of many intangible benefits which arise from greater visual, aesthetic, and recreational potentials (Brookes 1987; Keller 1975).

Rehabilitation projects attempt to re-create selected processes that shape natural systems; often the results of these projects only approximate natural systems (NRC 1992). Fluvial ecosystems are very complex, and their reconstruction is often based on considerations of stream hydraulics. This approach is centered on the observation that organisms live where there is suitable habitat, and suitable habitat is formed by diversity in the stream's hydraulic conditions (Petts 1995). Under this approach, developing variability in hydraulic conditions will lead to increased morphological (habitat) diversity, and ultimately, to increased biotic diversity. The variable nature of fluvial systems also necessitates that channel improvement plans be tailored to a particular site (Brookes 1985). Although there are many examples of successful components of rehabilitation projects cited in the literature (Keller 1978; Brookes 1987, 1990, NRC 1992; Newbury and Gaboury 1993; Kauffman *et al.* 1993), little information on the overall success/failure of rehabilitation efforts has been published (Brookes 1995).

The natural linkages that exist between upland, riparian, and aquatic ecosystems must be maintained for these ecosystems to function as they should (Kauffman *et al.* 1993). For example, riprap placed on the outside of a bend in the channel will protect the bank from erosion, but it will also hinder the transport of organic matter into the stream from riparian vegetation. In this example, the riprap effectively breaks the critical linkage between the riparian and aquatic ecosystem because it lessens the amount of woody debris available to aquatic organisms for use as habitat and food.

The restoration of riparian vegetation is fundamental to the success of stream rehabilitation projects (Kauffman *et al.* 1993, Brookes 1987). Riparian vegetation provides many benefits to aquatic ecosystems; these are discussed in further detail in Section 4. Kauffman *et al.*(1993) suggested that 100-foot (30 meter) forested buffers be preserved along both sides of rehabilitated streams.

The success of a rehabilitation project in the DRS is not a foregone conclusion. As previously noted, restoration of natural systems is a very complex task that involves a vast number of natural and human variables that must be accounted for in the planning, design, and construction phases. There are a number of approaches that may be used to help avoid, minimize, or mitigate many of the obstacles facing rehabilitation projects.

A phased approach should be used for rehabilitation of aquatic ecosystems. Brookes (1990) recommended a project framework consisting of seven phases: 1) establish detailed project objectives, 2) perform a feasibility/planning study, 3) develop project design and engineering plans, 4) implement project construction, 5) conduct post-construction clean-up, 6) perform on-going maintenance, and 7) perform post-project monitoring. The monitoring phase is critical to evaluating the success of the project as well as contributing to the overall knowledge base on rehabilitation of stream ecosystems (Brookes 1990, 1995; Toth *et al.*1995; NRC 1992; Kondolf 1995; Kauffman *et al.* 1993). Kondolf (1995) also suggested that each project be considered an experiment, an opportunity to learn and to disseminate findings.

2.3.4 Engineering and Cost Considerations

This section is not intended to provide an exhaustive review of engineering and cost considerations, however, it does introduce a number of important engineering issues and provide some examples relating to the cost of rehabilitation projects.

There are a number of engineering considerations involved with rehabilitation of fluvial systems. Of primary importance, proposed rehabilitation projects must be considered within the context of on-going management efforts within the entire watershed. Current management efforts, which are largely shaped by political boundaries and single management objectives, may result in either systemic or localized affects (Lyons and Courtney 1990). A holistic approach, which considers riparian, aquatic, upland, hydrological, social, economic, and political variables within a watershed or ecosystem context is best suited to understanding and eliminating the root causes of problems (Kauffman *et al.* 1993; NRC 1992). Understanding the driving forces behind a situation will enable better prediction of a watershed's response to changes over time. Additionally, addressing the symptoms of the response may merely serve as a quick fix, while correcting the root cause of a watershed condition may require a long-term effort but offer a long-term solution (Lyons and Courtney 1990).

Incision of the river channel can also serve as a major impediment to the rehabilitation of channelized rivers. Incised channels are often situated at a level below the original channel elevation, which is either a result of downcutting, design, or both (Hey 1996). This elevation difference poses a problem when trying to utilize portions of the original channel because it is necessary to create an overall gradient that is stable given the path of the rehabilitated meanders. To accomplish a stable gradient that connects channels of different elevations, the former meander fragments will have to be dredged out to meet the same grade as the current channel. Another option would be to construct a series of check dams that would back water up into the newly created/restored meanders. However, a series of check dams would hinder navigation, and adversely affect instream and bankside habitats throughout the river system (Hey 1996).

Increasing the channel capacity and incision of the river has also lead to the disconnection of the river from its floodplain. As previously discussed, the creation of a wider and deeper river decreases the river's natural tendency to overflow its banks to dissipate floodwaters and energy. When nutrient and sediment-laden floodwaters cannot spread onto the floodplain, benefits such as the temporary storage of floodwater and sediment, as well as the nutrient cycling that takes place in riparian ecosystems are disrupted (Large and Petts 1996). One option, although it is expensive and aggressive, is to lower the elevation of the existing river margin areas to bring them in line with the elevation of the river (Hey 1996).

Several other engineering issues should also be considered. These considerations include how to divert the river during construction, what to do with the channelized channel after rehabilitation, and what will be the effects on drainage during construction. Finally, original floodplain soils, which act as a seed bank for later revegetation, and original stream-bottom sediments must be retained.

The cost of rehabilitation projects can vary as widely as the scope of the actual rehabilitation projects themselves. Several cost estimates for rehabilitation projects were identified in the literature. These projects focused mainly on the installation of instream habitat structures and not the re-meandering of a channelized system. These habitat structures were used to provide overhead cover for trout, reduce bank erosion, and scour the channel. Vetrano (1988) noted that log wing deflectors cost $419/unit to build and install in 1980, while in 1988 Lunkers structures cost $297/unit to construct and install, and were more stable and resisted higher flows. Two portions of Timber Coulee, a Wisconsin trout stream suffering from severely eroded banks, were rehabilitated in 1985-1986. One section of Timber Coulee, with an average width of 18 feet, cost $34,000/mile for rehabilitation. The other section of Timber Coulee, with 12-foot high banks and averaging 29 feet in width, cost $41,000/mile (Vetrano 1988). Hunt (1992) noted that the average rehabilitation costs from three Wisconsin streams was approximately $286/structure, or $42,620/mile (142 structures/mile). Hunt (1992) also noted that wages for the professional rehabilitation crews amounted to approximately 65% of the total cost.

The largest river restoration project is taking place on the Kissimmee River in southern Florida (SFWMD 1998). The primary objective of this restoration project is to reestablish the pre-channelization habitat structure and function (Toth *et al.*1995), an approach similar to the holistic approach discussed above. The 103-mile long, winding Kissimmee River was channelized in the 1960s for flood control and navigation purposes by the U.S. Army Corps of Engineers (ACOE). Channelization efforts resulted in a 56-mile long, 30-foot deep, and 328-foot wide canal. Even before the project was finished, concerns over the loss of biodiversity resulted in state and federal efforts to restore the integrity of the river in order to recover some of the lost benefits provided by the original pre-channelized river (Riverwoods Field Laboratory 1998). This project is being carried out by the South Florida Water Management District and the ACOE, and is expected to take 20 years to complete, with work commencing in 1998. Project costs are estimated to be $600 million, and will attempt to restore 40 square miles of river/floodplain ecosystem, including 43 miles of adjacent river channel, and 27,000 acres of floodplain wetlands to their pre-channelized conditions (SFWMD 1998). Although the Kissimmee restoration project addresses a river that is larger and situated in a different geological, hydrological, and biological setting than the DRS, information from the Kissimmee's demonstration project may prove to be a useful reference to MEANDRS.

Land acquisition considerations should also be considered during the planning and implementation phases of a rehabilitation project. Rehabilitation projects will involve considerable activities on private and/or public lands. These activities can change land use patterns, create wetlands, alter the latitudinal path of the river, and create additional public access points. MEANDRS has stated it will only gain access to lands along the river through a voluntary process. Therefore, lands or access to those lands must be gained through outright purchase, granting of public access by the current landowner, or via an alternative arrangement. A number of land preservation and acquisition tools have been presented in Appendix 5.

2.3.5 Effects of Channelization within the Dowagiac River System

Channelization within the DRS has resulted in many changes to the river. The Dowagiac River was re-sectioned and realigned during its original modifications. These modifications were successful in that they increased surface and groundwater drainage from the watershed, thereby facilitating agriculture in areas that were previously too wet to farm. According to Moffett (1940), drainage effects from channelization may have been too successful because crops in both upland and lowland areas are sometimes stressed by a low water table in dry summer months. Modifications to the river network also resulted in physical changes such as a steeper gradient, an incised channel, bank erosion, deposition of sediment behind the Pucker Street Dam, and increased sediment transport capacity. Ecological changes resulting from channelization included a loss of riffle-pool habitat, loss of suitable substrate material, separation from the floodplain, and subsequent changes in the composition of the biological community.

Channelization may have affected the social and economic potential of the watershed by limiting trout fishing, other recreational opportunities, and visual and aesthetic appeal.

2.4 Baseline Profile Summaries

Baseline profiles for physical factors (geology, hydrology, channel morphology, etc.) and biological communities (aquatic and terrestrial) were developed to help MEANDRS assess the present condition of the river and associated floodplain community. To set the stage, a historical overview of the area and its people is provided. To better understand the watershed as a region and current concerns of stakeholders; economic, agricultural, social, and recreational issues are presented.

2.4.1 Historical Profile

The Potawatomi were the principal tribe of southwestern Michigan and occupied the region about 1460. Around 1640 they were driven out of the area by the Iroquois, who sought to control the fur trade. For a time, the Potawatomi sought refuge near Green Bay, Wisconsin; but they began drifting back to the St. Joseph River Valley in the 1680s (Clifton 1986). Potawatomi were the favored tribe among the French trappers, but their status fell as the British entered the area.

The first European settlers arrived in Cass County in 1826 from Indiana and other southern states. After the opening of the Erie Canal (1825), settlers began to arrive from New York State. A second wave of immigration occurred in Cass County with the arrival of the railroads in 1848.

Increased European population, plus newly acquired statehood in 1837, meant increased pressure for the Potawatomi's lands. Many Potawatomi were forced by the Army to march to Kansas. A local chief, Leopold Pokagon, obtained an exemption for the Catholic Potawatomi that allowed them to stay in the area; his tribe then purchased land in Silver Creek Township (Clifton 1986). As a result of these events, the Potawatomi still maintain a local presence.

Cass County had a unique role in the Underground Railroad passage of escaped slaves into Canada. Two main lines, the "Quaker line" and the "Illinois line", came together in Cass County. The Quakers in Cass County were opposed to slavery, and assisted one out of every four fugitive slaves that escaped into Canada (Hesslink 1968). Because of favorable treatment by the Quakers, many African-Americans remained in Cass County. By 1960, 1/10 of the population of the county was African-American (Hesslink 1968).

The Dowagiac River has influenced the region and has its own rich history. Even without a steep elevation gradient, good groundwater influx along the Dowagiac River provided sufficient flow for water-powered mills on the main river and its tributaries. The building of mills and their associated dams was the first major human-induced modification made to the streams of the area. Over 90 mills were identified as having been in operation in Cass County (1860-1900). A peak of 50 water-powered mills was reached in 1870 before being replaced by electric generators (Hamper 1993).

By the early 1900s, farmers in the headwaters region were complaining about poor drainage of their muck-land fields. In presettlement times, much of the northern extent of the Dowagiac River was part of the Dowagiac Swamp; and the creek was probably a small channel in the headwaters region (Figure 5). In response to the demand for better drainage, the Dowagiac River was dredged. In the first phrase (1902-1904), the headwaters portion and the stretch in Cass County to the southern Pokagon Township line was dredged. However, farmers in the headwaters region still had problems getting on their fields in the spring and after heavy rains. It was determined that a second dredging phase was required to dig a deeper and longer channel. In the second phase (1915-1928), nearly the entire river from the headwaters in Van Buren County to just north of the Niles dam was dredged.

Interest in restoration of the Dowagiac River System began in the 1940s. Fishermen expressed their approval of the State's trout stocking program, and could see an even greater potential for developing a self-sustaining trout fishery. A property on Sink Road adjacent to the Dowagiac River was purchased and a preliminary proposal was developed for instream devices to improve trout habitat; however, no action materialized at that time. In 1994, a team of volunteers formed a watershed partnership because they recognized the unique hydrology of the Dowagiac River. They were impressed with its potential for a high quality trout fishery and as a greenway corridor through the agricultural landscape of Cass County. In 1995, the group became formally known as MEANDRS. This non-profit group, works with various partners including: the Michigan Department of Natural Resources (MDNR), the Michigan Department of Environmental Quality (MDEQ), Drain Commissioners from Cass and Van Buren County, Sauk Trails Resource Conservation and Development Council, the Southwestern Michigan Planning Commission, the Southwest Michigan Land Conservancy, Western Michigan University, and riparian citizens including local farmers. MEANDRS continues to study issues relating to rehabilitation of the Dowagiac River System.

2.4.2 Physical Profile

The DRS is a relatively large, coldwater system with a high connection to groundwater. In Michigan, most rivers with stable flows and cold water temperatures are found in the northern part of the state making the Dowagiac River unique for its size in the southern Lower Peninsula. The glacial geology and physiography of the Dowagiac watershed are largely responsible for the river's cold water temperatures and relatively stable flows, characteristics that make it similar to well-known northern Michigan trout streams. This similarity is an indication of the ecological and recreational potential of the river system if the effects of channelization are mitigated. Channel straightening and incision have resulted in extreme velocities, poor aquatic and riparian habitat, and channel instability.

Characteristics of the DRS are defined by climate, geology, soils, and physiography of the watershed, which in turn influence hydrology, water quality and channel morphology. Due to its proximity to Lake Michigan, the climate of the watershed is characterized by relatively high precipitation and moderate temperatures. The lake-modified climate results in a long growing season for watershed agriculture; the northwestern township, Silver Creek, is part of the fruit-belt. The structure and composition of different landforms lend themselves to certain land cover types and land uses. For example, the low relief of the extensive outwash plains is amenable to agriculture. High precipitation and high groundwater recharge lead to large amounts of groundwater storage, which helps maintain a high baseflow in the river and provides ample water for municipal uses and irrigation.

The Dowagiac River flows across a broad outwash plain with a high ridge of coarse-textured till and ice-contact material to the east known as the Kalamazoo Moraine (Figure 6). The high groundwater contribution to the DRS is largely a function of extensive coarse-textured glacial deposits and the Kalamazoo Moraine. Approximately 80% of the watershed is assumed to be important for groundwater recharge; an average recharge rate was estimated to be 15.7 cubic inches per year per square mile of the watershed (Kirby and Hampton 1997). These conditions result in a relatively high groundwater table, especially in the northern part of the watershed in areas close to the river and its tributaries. When the watershed's groundwater table intersects the river or its tributaries, these high yields flow directly into the river, constituting baseflow. High baseflow, cold water temperatures, and stable flows contribute to the special ecological potential of the DRS. However, a high water table can lead to ponded surface water or wetlands in low-lying areas near the river. Channelization and the creation of artificial drains was the response to this condition.

Most soils in the watershed are well drained sandy loams representative of glacial deposits found in the basin. The soils along the river provide insight to the natural floodplain of the river prior to channelization. The mucky, poorly developed, alluvial Glendora-Adrian-Cohoctah Association is closely associated with the river's original floodplain and broad riparian wetlands (W. R. Farrand, Professor of Geology, University of Michigan, personal communication, 1997). These soils are underlain by outwash plain deposits and do not impede the delivery of groundwater to the river. However, their poorly drained nature prevents infiltration and requires artificial drainage in agricultural areas.

The high groundwater contribution to the river helps keep surface water quality good. The pH is slightly alkaline and the amount of suspended sediments is relatively low. Current water quality meets federal and state designated uses including the more stringent state standards for coldwater fish streams. A high water table is more vulnerable to leaching of contamination from fertilizers, pesticides, and leachate from septic systems. Agricultural activities appear to be contributing increased nutrients to both the groundwater and surface water in the watershed (Cummings *et al.* 1984; Brennan and Stamm 1991). However, contributions from point sources such as industries in the basin are small and localized.

The mean discharge for the Dowagiac River at Sumnerville over the period of record is 300 cubic feet per second (cfs), with a standard deviation of 133 cfs (U. S. Gelogical Survey 1960 - 1996). Annual stream flow stability in the DRS is stable, particularly when compared to other southern Michigan stream of similar size. The relatively high stability results from the dominance of permeable soils and surficial geology across most of the watershed. Standardized flow duration curves for several Michigan streams show that the Dowagiac River is more similar to northern coldwater streams in terms of stability than to rivers in southern Michigan (see Appendix 2 Section 5.2.2). In particular, the Dowagiac River has a high volume of flow during dry summer months. Low flows can have major impacts on stream ecology (Poff and Ward 1989; Allan 1995) and human uses such as recreation, navigation, and aesthetic appeal (Hendrixson and Doonan 1972). However, the Dowagiac River is still less stable than northern rivers like the AuSable and Manistee. Channelization of the river has likely reduced hydrologic stability, especially disconnection from its floodplain, which helps to modify extreme flows (Brooks *et al.* 1997). While channelization may reduce flooding by containing floodwaters, high flows in a channelized system can have significant impacts, mostly due to extremely high velocities that are not tolerated by most aquatic organisms.

Stable, groundwater-driven systems like the Dowagiac typically permit strong biotic interactions with well-developed biological communities. Flow stability is positively correlated with fish abundance, growth, survival, and reproduction (Seelbach 1986, Hay-Chmielewski *et al.* 1995; Poff and Ward 1989). This is because changes in annual flows are a problem for fish and other aquatic organisms (i.e., the river loses its high flow character in the spring), whereas environments with more stable baseline flows yield stronger biotic interactions (Poff and Ward 1989).

The hydrologic stability of the DRS is reflected in its high baseflow. Approximately 86% of discharge can be attributed to baseflow, with 14% being surface runoff. For comparison, the Manistee, one of Michigan's most stable river systems, is approximately 89% groundwater fed (Berry 1992). Examination of hydrographs for the Dowagiac River indicate that human activities such as channelization, drain construction, irrigation, and urban development are affecting daily flow stability by causing more movement of storm water over the land surface, which affects the quality of the river system (Wesley and Duffy 1997; Berry 1992; Dunne and Leopold 1978).

Channelization has dramatically affected the morphology of the Dowagiac River and therefore its ecological potential. The originally meandering stream was straightened and deepened, and the gradient became steeper. Channelization also disconnected the river from its floodplain and reduced the ratio of channel width to channel depth. One effect of these changes has been a reduction in hydraulic diversity, an important factor in determining habitat quality. Rivers with higher hydraulic diversity have habitat conditions that offer enough variety to support various life histories of different aquatic organisms (G. Whelan, unpublished data; Trauntman 1942 in Hay-Chmielewski *et al.* 1995). While low-gradient rivers, like the Dowagiac, could be classified as having low hydraulic diversity, meanders and associated riffle-pool sequences create habitat diversity. In addition, higher gradients created by channelization do not increase diversity, as channelization results in a majority of straight run habitat.

Disconnection of the floodplain from the main channel has cut off associated riparian wetlands, which are important to the function and quality of aquatic habitat in addition to modifying high flow events. Data collected from various cross-sections along the river (Seelbach and Wiley 1997) are further morphological evidence that the river system is degraded. These cross-sections are narrower and deeper that would be expected given the geology, physiography, and hydrology of the watershed and exhibit generally poor instream cover. Furthermore, by decreasing the valley cross-sectional profile (which includes the floodplain), the river experiences greater maximum velocities and higher bank-full discharges, which leads to channel modifications through erosion (Rosgen 1996).

The Dowagiac River was a meandering system prior to channelization but is now mostly straight. Streams are seldom straight for any appreciable distance, and straightening of channels usually leads to a state of disequilibrium and instability (Rosgen 1993, 1996). Currently, parts of the river system, such as the reach below Pucker Street dam and Dowagiac Creek are meandering systems. Additionally, as an indication of the river's past, there are several cut-off meanders or oxbows along the main stem that were part of the river prior to channelization. Sinuosity of tributaries such as Dowagiac Creek (1.34 feet/feet) likely represents what sinuosity of the main stem of the Dowagiac River should be. Currently, the main stem has a sinuosity of 1.12 feet/feet; a sinuosity of 1.0 feet/feet is straight. The fact that the Dowagiac River is a low power system and is deeply incised makes it unlikely that the river would naturally restore itself back to a meandering system (Brookes 1995).

Channel morphology appears to be the limiting factor in terms of the DRS meeting its ecological and recreational potential. The proposed re-connecting of meanders could significantly improve channel morphology by moderating velocity and creating heterogeneous habitat conditions. However, upland activities such as agriculture, residential property use, and other land uses could be impacted by a reduction in velocity resulting from a reduction in gradient. A lower velocity means that water is moving less quickly through the system causing the water to "back up." This could possibly reduce the drainage potential of the land in certain areas. In fact, the purpose of channelization is to increase drainage and move the water off the land quickly and efficiently. While a resulting increase in wetlands may benefit the aquatic and riparian ecology, there could be economic and lifestyle impacts to riparian landowners and users. However, the unusual hydrologic stability of the system should moderate this effect. Additionally, carefully selecting the number and location of restoration sites will minimize these impacts.

2.4.3 Biological Profile

There are few early historical records of fishes in the DRS. Based on historic habitat conditions, it is suspected that mottled sculpin and blacknosed dace occurred in the cooler sections of the Dowagiac River. In the mid-1800s, an 80-pound lake sturgeon was reported as having been caught in the Dowagiac River (Ballard 1948). At that time, sturgeon were able to ascend the St. Joseph River from Lake Michigan and use the river as spawning grounds. In 1873, one of Michigan's first fish hatcheries was established along the Dowagiac River at Crystal Springs (B. Cook, Supervisor, Pokagon Township, personal communication, 1997). A variety of non-native fish species were either released or escaped from this fish hatchery, including brown, brook, and rainbow trout. Additionally, lake trout were reported to spawn upriver from Niles during the mid-1800s (Ballard 1948). Current trout management within the DRS is primarily conducted by the MDNR-Fisheries Division (MDNR-FD). Stocking levels within Dowagiac Creek have declined in the last ten years. In contrast, stocking levels within the Dowagiac River have remained consistent from year to year, with 8,500 brown trout planted in seven locations in 1997 (J. Wesley, Fisheries Biologist, MDNR-FD, Plainwell, MI, personal communication, 1998).

According to the Michigan Natural Features Inventory (MNFI), there are no endangered or threatened fish species found in the Dowagiac River (MNFI 1997b). Lake Sturgeon is listed as a state-threatened fish species, but has not been reported for the Dowagiac River since the mid-1800s.

Channelization of the Dowagiac River in the mid-1920s eliminated instream habitats such as riffles and pools, and increased sediment load. Water quality decreased and critical invertebrate and fish habitat, used for foraging, resting, and spawning, were replaced with less suitable substrate and a uniform swift run habitat. This lack of variation in habitat caused by channelization has resulted in degraded habitat for aquatic organisms.

Due to habitat degradation and uniformly swift flow, current fish species are predominantly warmer-water fishes. Current warmwater fish species include the blackside darter, white sucker, common shiner, and hornyhead chub. Stocked brown trout are able to live but not reproduce in the Dowagiac River because of the degraded habitat conditions. In contrast, brown trout are able to reproduce and maintain their population in Dowagiac Creek, an unchannelized tributary. The Dowagiac River has suitable coldwater qualities, but is limited by its channel form. With rehabilitation, the Dowagiac River has the potential to sustain a naturally reproducing trout population and become a high-quality coldwater trout stream.

Because there is limited information available on aquatic invertebrate species occurring within the Dowagiac River, it was not possible to determine if the river contains any invertebrate species with special status. A 1996 MDEQ Surface Water Quality Division survey of the Dowagiac River found the river's overall biological quality to be "generally excellent". This evaluation appears to have been based primarily on the diversity of macroinvertebrates and habitat, while fish were only qualitatively considered and coldwater species were not graded separately. Additionally, habitat was only determined to be “fair” (moderately impaired) upstream of the Pucker Street Dam during the 1996 survey (MDEQ 1997b).

One of the most common river-associated mammals, the beaver, has begun to reestablish its populations in southwestern Michigan during the last 15 years (M. Bailey, Wildlife Biologist, MDNR, personal communication, 1997). Its presence in the DRS is important since the beaver's dams are responsible for many of the natural wetland habitats near rivers. Other common mammals associated with riverine habitats include mink, muskrats, and raccoons. Several smaller bats are frequent foragers upon insects as they emerge from their larval aquatic form.

The prairie vole, a state-threatened species, is an inhabitant of higher ground and has not been seen in Cass County for 30 years (Evers 1992). Similarly, the Indiana bat, a federally endangered species, is known from the adjacent county of St. Joseph but has not been reported in the DRS (Evers 1992).

Both amphibians and turtles are dependent on wetlands adjacent to the river corridor (Harding and Holman 1990). Several species of amphibians were spotted in cut-off meanders during the summer of 1997. A spring survey of singing frogs is needed to determine which species are using the river corridor. The northern water snake is likely to be found in the river, while special concern species such as the black rat snake and massasauga rattlesnake reside in bottomland areas. The map turtle is a powerful swimmer and will inhabit fairly swift currents such as those found currently in the Dowagiac River. The spiny softshell prefers either sandy or muddy bottoms. In contrast, old oxbows provide favored habitat for the painted turtle, spotted turtle, and snapping turtle (Harding and Holman 1990). Species favoring the old oxbows could be adversely affected if all these oxbows were reconnected to the main channel.

Several reptiles are listed as special concern in Michigan. The spotted turtle has been found along Dowagiac Creek in Volinia Township (MNFI 1997b), and the eastern box turtle is known to reside in the moist wooded areas of the Dowagiac Woods (Hotzman *et al.* 1994). The black rat snake, also known from Dowagiac Woods, is listed as a state special concern, along with the eastern massasauga rattlesnake. Two state-endangered species of snakes were previously reported for Cass County, the northern copperbelly and the Kirtland's water snake (MNFI 1997b).

Several bird species are closely associated with the river, taking advantage of either food sources, nesting sites, or both. The belted kingfisher and heron species feed on small fish and frogs. The barred owl is a bird of prey associated with mature bottomland forests. As aquatic insects emerge, birds such as the Arcadian flycatchers and cedar waxwings gather to feed. Cedar waxwings also come to riverine environments when the berries of shrubs such as the gray dogwood mature. The spotted sandpiper often nests along the shores of rivers. Warblers are important nesters in mature bottomland forests (Brewer *et al.* 1991). Bank nesters include belted kingfishers, bank swallows, and rough-winged swallows. Many other bird species use the river corridor as a flyway. Birds that nest along the river would likely benefit the most from a restoration effort, as the banks of the present river are highly eroded and many mature trees are falling over into the river when their roots are undercut by erosion.

Three state-threatened bird species occur in the three-county area. None are likely to be impacted by rehabilitation efforts. The yellow-throated warbler is currently known only from the Galien River in Berrien County. The red-shouldered hawk, a bird of prey favoring bottomland areas, is a confirmed breeder in Berrien and Van Buren Counties, but not Cass County. The least bittern, a marsh dweller, is a confirmed breeder in Van Buren County and a probable breeder in Berrien County (Brewer *et al.* 1991).

Comparison with presettlement land use shows that when the settlers arrived, 87% of Cass County was forested with either beech-maple or oak forests (Kenoyer 1933). Today only 23.6% of the land in Cass County remains forested (MASS 1996). Lake, river, and wetland vegetation accounted for 9% of presettlement area, compared to 3.2% of the current acreage (MASS 1996).

Periodic flooding is a natural disturbance along riparian corridors. Vegetation in a natural river floodplain generally develops according to a zonation pattern based on frequency of flooding (Mitsch and Gosselink 1993). The natural pattern of zonation of first and second bottom has become less distinctive along the Dowagiac River due to the absence of periodic flooding. The high banks of the levee (dredge spoils) and the downcutting of the river have meant that the Dowagiac River has not flooded its banks since the dredging operation in the mid-1920s. The levee has become the site for both bottomland and more upland species. With time, upland forest species are likely to replace the characteristic bottomland species unless the connection with the floodplain is restored. A rehabilitation effort including reestablishment of some of the connections to the floodplain would result in a more natural plant zonation pattern.

The Dowagiac River corridor is characteristic of southern bottomland forests which are dominated by silver maple, red ash, and American elm (MNFI 1996). Black willow, cottonwood, and sycamore are found along with black walnut, black maple, and box elder. Among oaks, swamp white oak and chinquapin oak are found along the Dowagiac River. Shrub species common to the Dowagiac River System include gray dogwood, nannyberry (*Viburnum*), bladdernut, prickly ash, American hazelnut, and clones of paw paw. Refer to Section 4.1.4 of the Biological Appendix for further detail.

Benefits of mature riverine vegetation include: control of bank erosion, filtering of nutrients thus improving water quality, shading of habitats resulting in lower water temperatures in summer, providing large woody debris that serves as valuable habitat for invertebrates and fish, flow moderation, and temporary water storage following storm events (Hawkins 1991).

The Michigan Natural Features Inventory lists 71 plant species as either having protective status or under study for Cass County (MNFI 1997a). None of these plant species has federal protective status. Three plants are listed as endangered and 41 plants are listed as threatened for Cass County. Prairie plants account for the largest percentage: 66% of endangered, and 28% of threatened plant species. Rich woods plants account for another 20% of Michigan's threatened plant species found within Cass County.

Few threatened plants are found only in river floodplains. However, wisteria (*Wisteria frutescens*), at its northernmost distribution in the southern tier of counties in Michigan, is found specifically in floodplain woods. Wisteria has been found along the Dowagiac Creek. Threatened plants found adjacent to the Dowagiac River include the log fern, ginseng, goosefoot corn-salad, prairie trillium, and showy coneflower (MNFI 1997b).

Besides the southern floodplain forest, several other unique plant community types are found in Cass County such as dry sand prairie, wet-mesic prairie, and prairie fen (MNFI 1997b). A remnant of the southern swamp remains in Wayne Township, south of the river on private property. In the headwaters region, a good example of a coastal plain marsh occurs at Hamilton Coastal Plain Preserve, a Michigan Nature Association preserve.

2.4.4 Social and Economic Profile

2.4.4.1 Demographics and Community Profile

The human population in southwest Michigan (SW MI) peaked in the 1970s, and has since been declining. Berrien County has experienced a significant population decline since the 1970s, while Cass County has seen only a small decline since the 1970s. Van Buren County's population, on the other hand, continued to increase during the 1980s. Responsible for this decline (in Berrien and Cass) are the migration patterns observed in the region, which show that more people left SW MI during the 1980s than it entered. During that period, people left Berrien County at a faster rate than they left Cass and much faster than Van Buren County (US Bureau of the Census (USBC) in Southwestern Michigan Commission (SMC) 1994).

SW MI contains a smaller percentage of minorities than the State of Michigan in general, with African-Americans being the most important group. The proportion of Native Americans living in SW MI, and especially Cass and Van Buren Counties, is greater than that observed in Michigan. All minorities have increased since 1980, but their numbers remain well below state averages (USBC in SMC 1994).

The SW MI region lags behind the state in educational achievement. Michigan shows significantly higher percentages of its inhabitants having completed high school and possessing advanced degrees than SW MI (USBC in SMC 1994).

In spite of the population decline of the 1980s, the number of households increased by 4% as a result of a reduction in household sizes observed during that decade. Increases in the number of households are reflected in increases in the demand for housing units and, during the 1980s, much more houses were built in Van Buren County than in Cass County (2.5 times as many) and Berrien County (3.5 times as many). Residential development pressures are clearly higher in Cass and especially in Van Buren County than they are in Berrien County (USBC in SMC 1994).

The majority of households in SW MI and the entire state remained family-occupied by 1990. However, the type of households changed during the 1980s. Family households, especially married-couple households, lost ground to non-family households, especially to single-occupant household (USBC in SMC 1994).

As of 1990, owning or renting a house in SW MI was significantly cheaper than the state average. The demand for housing for rent was significantly higher in Berrien County and the state than it was in the more agricultural counties of Cass and Van Buren. Correspondingly, vacancy was significantly higher in Cass and Van Buren than in Berrien County or the state. Most of these vacant houses were used seasonally or for recreational purposes (USBC in SMC 1994).

The great majority of houses in Cass and Van Buren Counties obtained their water supply from wells and disposed of their sewage using cesspools or septic tanks, while in Berrien County and the state, most residences were connected to public water provision and sewage disposal systems. Such heavy reliance on underground water needs to be acknowledged when considering a rehabilitation project for the DRS (USBC in SMC 1994).

2.4.4.2 Local Economy

Most families in SW MI rely on wages and salaries for income generation (USBC in SMC 1994). Since wages in SW MI are lower than those paid elsewhere in the state (Michigan Industrial Wage Survey in SMC 1994), incomes earned by individuals and households in SW MI are significantly below state averages, which ultimately results in weaker spending power. During the 1980s, per capita incomes showed a significant increase both in the region and the state, and the gap between the state and SW MI was reduced. Van Buren County had the lowest incomes in SW MI as well as the slowest income growth (USBC in SMC 1994).

The SW MI region as a whole presented higher poverty levels than the state as a whole in 1989. However, Cass County’s levels are significantly lower than those observed in the state and in Berrien and Van Buren Counties. In spite of having higher per capita incomes than Cass County, both Berrien County and the state have higher percentages of people earning below the poverty line. Van Buren County's poverty levels are the highest in the region. The percentage of people living below the poverty line increased in all three counties of SW MI and the state in general during the 1980s (USBC in SMC 1994). This should clearly be a reason of concern for all persons involved in social projects in the watershed.

Unemployment levels in Cass County, as of 1993, were the lowest in SW MI, and lower than state averages. Berrien and Cass' unemployment levels, on the other hand, were higher than the state's. However, unemployment levels in general were in a downward trend as of 1993. Unemployment levels among minorities are much higher than among Caucasians, although this gap shrunk during the 1980s (Michigan Employment Security Commission in SMC 1994).

SW MI relies much more heavily on blue-collar occupations as sources of employment than does the State of Michigan as a whole. Manufacturing and retail trade are clearly the main sources of employment and income, with agriculture having a limited importance as a direct income generator and occupying a small share of the labor market. However, the region's reliance on agriculture is significantly greater than the state's (USBC in SMC 1994). Even though all sectors of the economy of the region experienced growth during the 1980s, all sectors but manufacturing experienced an increase in their share of SW MI’s total payroll (USBC County Business Patterns in SMC 1994), which suggests that the economy of the region is diversifying and that manufacturing is losing ground to other sectors .

A project such as the rehabilitation of the DRS could potentially have significant effects on the economy of the watershed, especially if the recreational potential of the area is realized.

2.4.4.3 Agriculture

As of 1992, 186,431 acres (59% of the land in Cass County) was in farms. Most of this was cropland with some portions occupied by woodlands and pastures (USBC 1994). The amount of land dedicated to farming has been decreasing since the 1950s, and that trend seems to have been intensified during the period between 1982 and 1992 (USBC 1962, 1967, 1977, 1980, 1989, 1994).

Hog farmers were responsible for 61% of all agricultural product sales in Cass County in 1992. Other livestock, poultry and crops completed the picture. Cass County is by far the greatest hog producer in Michigan (USBC 1992). The number of hogs raised has increased 3.8 fold since 1959 and the trend continued as of 1992. In general, agricultural sales increased until 1978 when they reached a plateau that continues as of 1992 (USBC 1962, 1967, 1977, 1980, 1989, 1994).

Corn is second in importance in revenues. In fact, cornfields occupied more land in the county than any other crop as of 1992, and corn’s importance has increased sine 1959. Soybeans and cattle are tied for third in total sales in the county. However, while the acreage, and importance, of soybeans is increasing, the number of cattle in Cass County is definitely declining, along with their importance to the county's agriculture (USBC 1962, 1967, 1977, 1980, 1989, 1994).

Most of the land in orchards in Cass County is used for the production of apples, grapes, and cherries, although some orchards are dedicated to the production of other fruits and berries. Most of these farms are located in the western portion of the watershed. In general, fruits and berries contributed $2.9 million to the total agricultural sales of the county ($59 million) in 1992, but their importance seemed to be declining as of 1992 (USBC 1992).

Snap beans, sweet corn, asparagus, and tomatoes were the main vegetables produced in Cass County in 1992, although other vegetables such as squash, sweet peppers, cabbage, and pumpkins were present in some operations. Vegetable cultivation in general is increasing its importance in the county and the acreage dedicated to vegetable production has surpassed that in orchards (USBC 1962, 1967, 1977, 1980, 1989, 1994).

Hay and wheat also occupy significant acreage in Cass County. However, their share of total sales is limited. Hay's importance for the county's agriculture is markedly declining, while wheat seems to have reached stable levels since 1978 (USBC 1962, 1967, 1977, 1980, 1989, 1994).

Agriculture in Cass County is evolving over time. The size of farms is increasing and the number of farms is decreasing. In fact, since 1959, the number of farms has been reduced to less than half of the original number and the size of the average farm has almost doubled (USBC 1962, 1967, 1977, 1980, 1989, 1994).

The average operator in Cass County is a middle-aged male mainly dedicated to his work in the farm, who partially or fully owns the farm, resides on it, and has already worked in the farm for a long period of time (USBC 1992).

The number of farmers in Cass County is decreasing and agriculture does not employ as many people as in the past. Most of the operators of farms in the county fully or partially own the farm they work on. However, full ownership is losing ground to partial ownership and tenancy. Similarly, the number of individual or family-owned operations is decreasing rapidly, while partnership-owned operations are increasing both in number and in acreage (USBC 1962, 1967, 1977, 1980, 1989, 1994).

The age of the average farm operator is almost 52 years old and is increasing. Similarly, the average farmer has worked on the farm for almost 22 years (USBC 1962, 1967, 1977, 1980, 1989, 1994). These numbers suggest that young people are no longer going into farming, a trend that could have serious implications for the future of farming in the county.

The value of farmland increased steadily until 1978 when it peaked, and has since been declining. In general, farming produced positive profits for the county in 1992. However, the returns to farming are low for most farms in Cass County. A small number of large, prosperous farms inflate the numbers, but there are a great number of farms operating with relatively low revenues. In fact, more than half of the farms in the county reported losses in 1992 (USBC 1962, 1967, 1977, 1980, 1989, 1994), which suggest that individual farmers take non-monetary considerations into account to justify their decision to continue farming.

Less than half the farms in the county used hired labor, and 80% of those hired four workers or fewer. In fact, farms hired less than 8% of the total labor force in the county. It is clear that agriculture's importance to the labor market is very limited (USBC 1992). However, it is likely that the farmer's immediate family also works on the farm but receives no recorded payments.

Most farms were using commercial fertilizer in 1992, half were applying chemical pesticides, and 11% were irrigating their crops. All three activities show an increasing trend in the county (USBC 1962, 1967, 1977, 1980, 1989, 1994). Southwest Michigan has the highest rate of irrigation in the State (Berry 1992).

2.4.4.4 Recreation

The DRS offers many recreational opportunities to residents and non-residents alike. Activities range from hunting and fishing, to canoeing and self-pick farms. The self-pick farms of SW MI, along with its wineries, are well promoted. SW MI’s share of the $5 billion spent each year on recreation in Michigan is 4.6% (D. Spotts, Michigan State University- Michigan Travel, Tourism, and Recreational Resource Center, personal communication, 1998). There are no State Parks within the DRS, although Cass County supports a system of eight parks. These parks are utilized mainly by county residents, although some areas such as the Russ Forest, and Dodd and Lawless Parks have qualities that attract visitors from as far as 100 miles away (R. Johnson, Road Master, Cass County Road Commission, personal communication, 1998).

Although there are no publicly owned lands open to hunting within the DRS, there are several areas open to public hunting within Cass County and nearby counties. One of the largest areas is the Crane Pond Recreational Area in eastern Cass County. Also, fishing is an important activity in SW MI. Angler license plates counts show that visitors from as far as California, Colorado and Florida come to fish for salmon and steelhead trout in the lower DRS (J. Wesley, personal communication, 1997). However, realizing the DRS’ potential for a self-maintaining coldwater fishery could attract an even greater number of anglers to the area.

Boating is very popular within the DRS because of the great number of inland lakes found in the area (Michigan Society of Planning Officials (MSPO) 1995). Also, canoeing the Dowagiac River is a popular activity for the residents of the watershed, although only two canoe liveries of modest size operate in the watershed (Southwestern Michigan Tourist Council 1997).

There are at least five campgrounds in the Dowagiac River watershed, providing space for over 500 campsites. Lodging in Cass and Van Buren Counties was estimated at less than 1,000 guestrooms and was increasing slowly as of 1991 (MSPO 1995).

2.5 Highlights of the Dowagiac River System

The Dowagiac River is located in the southwestern corner of Michigan's Lower Peninsula. Ground water discharge along most of its length provides a source of cold, clean water, making this relatively large river system unique in southern Michigan (MEANDRS project 1996). The Dowagiac River's location, as well as its similarity to well-known northern Michigan trout streams is also an indication of the ecological and recreational potential of the river system.

In order to facilitate agriculture in areas that were too wet to farm, the Dowagiac River was dredged first in the early 1900s and again in the mid-1920s to improve drainage. These drainage improvements led to physical modification of the river network such as a steeper gradient, an incised channel, increased bank erosion, redistribution of substrate material, the loss of riffle-pool sequences, and increased sediment transport capacity. These factors have resulted in a degraded river that is faster flowing and has a more uniform velocity and morphology than the original river. With rehabilitation, some of these modifications could potentially be reversed through the re-introduction of morphological diversity while still maintaining the cold, stable baseflow. Re-connection of meanders to the river channel is also likely to raise the elevation of the groundwater table in some areas and alter some of the agricultural benefits of enhanced drainage.

Ecological changes induced by the physical modification of the river system included a loss of riffle-pool sequences, a loss of suitable substrate material, separation of the river from the floodplain, and subsequent changes in the composition of the biological community. Much of the DRS has been designated as a coldwater system capable of supporting trout. However, trout are not able to naturally reproduce because of degraded habitat conditions, and only stocked brown and rainbow trout are present (MDEQ 1997a, 1997b). Adding meanders will help provide more diverse habitat and flow velocities, cover, and well-sorted gravel substrate for spawning beds (Hunter 1991).

Another biologically important feature of the area is its proximity to the confluence of three different ecoregions: the Great Lakes, the Great Plains, and the glaciated regions of the northern states. The watershed's location allows it to serve as a transition zone between the three ecoregions, resulting in a unique and highly diverse mix of flora and fauna.

Water quality within the Dowagiac River watershed is currently good. With the exception of elevated nutrients in several locations, the watershed meets the relatively stringent requirements set by MDNR for coldwater systems (MDEQ 1997a, 1997b).

While Cass County does not have many tourists visiting the county, neighboring Berrien County is ranked third highest in the state for tourist dollars. Cass County can never offer access to Lake Michigan, nor does it have a major highway entering the state from Indiana, but it is reasonable to assume the county's recreational appeal could be increased. Recreational opportunities that are currently available within the watershed include trout fishing, canoeing, self-pick farms, camping, and golfing. Rehabilitation efforts that improve the quality of the trout fishery, expand and connect greenways, and provide additional recreational amenities and related infrastructure would provide quiet, aesthetically pleasing recreational opportunities

2.6 Future Trends within the Watershed

Although loss of agricultural lands in Cass County is not as great as in many other counties in southern Michigan, the overall trend is towards a reduction in agricultural land in the area. During the 10-year period between 1982 and 1992, Cass County lost over 12,000 acres of farmland to other uses (1982-1992 Agricultural Census). This trend seems to indicate that without the project, agriculture will continue to lose ground to other land uses and economic activities.

Farming generally losses out to urbanization for various reasons. Among these is the "impermanence syndrome." Nelson (1992) refers to the "impermanence syndrome" in the following manner: "impermanence syndrome is characterized by the belief among farmers that agriculture in their area has limited or no future and that urbanization will absorb the farm in the not-too-distant future. It is manifested by disinvestment in farming inputs, sale of farmland tracts for hobby farm or acreage development, and shifting of crops from those requiring labor or capital intensity, such as berries and orchards, to those requiring little labor or investment such as pasture or annual crops." He goes on to state that "once farmers become uncertain about the viability of agriculture in their area, farmland production falls and so does farming income. Ultimately, the critical mass of farming production needed to sustain the local farming economy collapses." (Nelson 1992)

In New York State, Hirschl and Bills (1994) found that in addition to the closeness to urban core areas, non-demographic factors such as the value of farm real estate (opportunity cost), farm size, net farm income, and the percentage of cropland are very important (and often essential) to the fate of the farmland base.

Furthermore, large-scale modern farming is an industrial operation with noise, dust, odors, and pesticide and fertilizer use that many non-farm, rural residents might find incompatible with their idealized vision of a rural lifestyle. The MEANDRS survey of riparian landowners in Cass County identifies some of these concerns. Several rural non-farm residents expressed concerns with present farming operations, particularly with hog farmers, who the riparian residents believed were responsible for impacted water quality in local streams (MSU Extension 1997).

If and when this "impermanence syndrome" occurs in the Dowagiac River watershed remains to be seen. However, even though the area remains predominately agricultural in nature, the possibility of residential and industrial development displacing agriculture is real, and the current trends support this concern.

Cass County is the number one hog-producing county in Michigan, almost double the production of the next highest county. Development within the watershed is expected to increase in the future, especially as people move from nearby cities to live in a more rural environment (exurbanization). As exurbanization continues, it is possible that the new neighbors would object to the odors and other nuisance factors associated with hog farming. The new residents could create an increased demand for vegetable crops, fruits, and self-pick farms. Since this type of farming is already occurring in the headwaters region and Berrien County, a shift to this type of agriculture could be possible.

Exurbanization could increase due to the influence of the new daily high-speed Amtrak rail line that extends from Chicago to the watershed. This process could have considerable impact in the future of the watershed. Not only is it likely that more people will come into the area, but the composition of the community will change. People from Chicago could commute daily. More people from Elkhart and South Bend, Indiana continue take up residence in the southern tier of townships in Cass County. Areas in the southern part of the watershed could become impacted next. These bedroom and weekend residents will have different interests and needs from many local residents who grew up in the area where their parents lived. Without vision and planning, the effect could be a loss of the rural character of the community.

Without the project, a decrease in water quality is anticipated over time. Development pressure may potentially impact water quality within the DRS. Land use conversion away from agriculture within the DRS could place additional pressure on the natural systems' ability to balance water and nutrient cycles. An increase in impervious surfaces would result in more runoff rather than the rapid infiltration and contribution to groundwater currently characterizing the DRS. If water quality deteriorates, this could negatively affect the aquatic habitat.

The river is currently in an ecologically degraded state due to the swift, straight flow. Bank erosion and a degraded system with less desirable fish species is likely to continue to be the norm without the project. Without the project, aquatic habitat conditions are expected to remain fair to poor and may become worse due to increased erosion caused by the swift flows and a straight, incised channel (Rosgen 1996). Many aquatic species, including trout, are unable to reproduce without pools and suitable substrate for breeding. Currently a relatively poor level of plant diversity exists along the river corridor due to the lack of periodic flooding. Without the project, the trend towards more upland woody species replacing the characteristic floodplain plant species is expected.

There is already an expressed interest in natural areas preservation within the county as evidenced by the formation of MEANDRS, the recent enhancement of several county parks (Arthur Dodd, Russ Forest, and Lawless), and the contribution of funds (20% from the county) for the protection of Dowagiac Woods. It is anticipated that with the project interest in both natural and farm land preservation would accelerate. Without the project, it is unclear whether interest in farmland preservation would be addressed since there is currently no initiative other than individual farmers signing up for Michigan's tax incentive program PA 116 (Refer to Appendix 5 for further details).

The discussion of rehabilitation needs to include consideration of future changes in land use, and associated changes in surface water flow regimes. The focus and interest stimulated by the proposed river rehabilitation offers an excellent opportunity to proactively address these development pressures before they become problems, regardless of whether rehabilitation actually occurs.

Section 3 – Methodology and Approach

Our approach to studying the feasibility of rehabilitating meanders and the river corridor in the DRS consisted of four major stages:

- Definition of the MEANDRS vision and scope of rehabilitation
- Gathering of baseline information
- Prediction of potential effects of rehabilitation and completion of an evaluation matrix
- Overall synthesis of information

In addition, a groundwater sensitivity study was undertaken which provided scientific support to the last three stages of this feasibility study (Methodology for this analysis is covered in Section 3.5).

3.1 Definition of the Scope of Rehabilitation

In order for us to perform a feasibility analysis of rehabilitating the DRS, a clear definition of what was meant by "rehabilitation" was needed.

To reach that objective we led a meeting with MEANDRS in which we presented them with a set of questions and discussed several potential options for rehabilitation. Through this process the area of rehabilitation was defined as "a variable-width river corridor, which would provide an area of size sufficient to preserve biological integrity without substantially interfering with the agricultural nature of the watershed." This area would tentatively extend from Pucker Street Dam in Niles, up-river to the Cass-Van Buren County line. Channelization was undertaken in the first place to drain the muck-lands in the headwaters (Van Buren County) for agriculture, which are currently dedicated to the production of specialty crops. This definition of the rehabilitation scope leaves out these muck-lands, avoiding major potential disruptions to this important agricultural area. Furthermore, limiting the rehabilitation area to one county (Cass) greatly improves the administrative feasibility of the rehabilitation. (Loomis 1993)

3.2 Baseline Information

Once the scope of rehabilitation had been defined, we proceeded to gather information regarding baseline conditions and existing trends in the watershed. In order to produce accurate predictions about potential effects of proposed projects, solid knowledge of the baseline conditions and of any trends in these conditions is crucial (Flynn & Flynn 1981). We therefore devoted an important portion of our efforts to gather the most complete and accurate information on different aspects of the watershed. Although personal biological surveys and well location field checks were undertaken, we mainly relied on secondary information sources to accomplish this task. We put together four profiles that were modeled after the MDNR-Fisheries Division's River Assessments but with a broader focus. We looked at the history of the river, emphasizing the history of the local people and the channelization process. We described the physical and chemical characteristics that define existing habitats within the watershed. We described terrestrial and aquatic biota that use the habitat. Finally, we looked at economic and social conditions within the watershed, with a considerable emphasis on agriculture.

Concurrently, we researched case studies and interviewed people with expertise in different aspects of stream rehabilitation. We also reviewed pertinent literature to enable us to predict how different characteristics of the DRS would evolve over time, both given status quo management, or if an intervention, such as a rehabilitation project, were to occur in the system.

3.3 Development of Criteria for Evaluation, and Methods of Assessment and Evaluation

Prediction of the potential effects of rehabilitation was the next logical step. Since a river system is a complex aggregate of elements, processes, and interactions among those elements, we focused on specific characteristics that were relevant to the feasibility analysis.

To gain insight into the concerns and interests of riparian landowners regarding their relationship with the DRS we used data from a survey of riparian owners in the watershed (MSU Extension 1997) and interviewed MEANDRS members and other residents in the watershed. Through this process, we developed nine broad categories that would serve as indicators of the success or failure of any rehabilitation process within the DRS.

Those categories are as follows:

- Surface and Groundwater Drainage

  We defined drainage as the ability of the landscape system to evacuate water. More specifically, we were concerned with the way this ability to evacuate water, or lack thereof, affects the depth to groundwater table. Drainage has system-wide importance, as it affects most characteristics of the watershed.

- Wetlands

  Wetlands are areas that are periodically flooded, soils are hydric, and vegetation adapted to those conditions is present (Mitsch and Gosselink 1993). Wetlands provide invaluable ecological services and recreational appeal and were identified as an issue of concern in the riparian survey.

- Water Quality

  Water quality refers to the physical and chemical characteristics of the water in the Dowagiac River that are relevant for the well-being of the biota that uses the system. Water quality affects other elements in the watershed, especially aquatic habitat and recreational appeal.

- Biological Integrity

  Biological diversity refers to how well the ecological processes within the watershed are functioning. The functionality of the processes is closely related to the primary goal of meeting the ecological potential of the watershed.

- Potential for Sustainable Fishing

  This category examines whether conditions necessary for a sustainable trout population are achieved in the DRS. This was one of the original driving forces behind the rehabilitation movement, as realizing the DRS' potential as a recreational trout fishery would have significant implications for the watershed and, probably, southwest Michigan in general.

- Recreational Potential

  Recreation includes the recreational activities available in the channel, in the riparian corridor, or elsewhere in the watershed. Recreation was also one of the original objectives for undertaking a rehabilitation project in the DRS.

- Agriculture

  Agriculture refers to the nature and status of agricultural activity in the area, especially Cass County. The watershed's landscape is agricultural in character: 59% of the total land in the watershed is farmland. Not interfering significantly with the agricultural activity in the watershed was one of the original constraints for any rehabilitation project in the DRS.

- Natural Resources/Open Space Conservation

  This category refers to those activities that deal with the conservation of the watershed's natural resources and the nature of the watershed; whether rural, agricultural, or simply open space. Natural resource and open space conservation policies are important in shaping the future of the watershed. If the project should influence conservation in the watershed, it is important to know in what manner and whether that influence is desirable.

- Community Social Well-being

  This category addresses the interests of the different publics that have a stake in the rehabilitation process. It gives insight into who in the watershed would be affected, and in what way, so that possible sources of opposition or support can be identified when deciding to take the rehabilitation project to the next level. We divided the actors into four categories that are not mutually exclusive.

  – General Public – Those individuals who reside in the watershed but have no direct relationship with the DRS.

  – Farmers within the Rehabilitation Area – Those individuals who own or operate a farm in the watershed, or those who receive some income from farming.

  – Riparian Landowners – Those individuals who own property, residential or otherwise, that borders the Dowagiac River. This property can be residential, agricultural, or otherwise.

  – Recreational Users – Those individuals, residents of the watershed or otherwise, that as of now make use of the DRS for recreational purposes.

Information on the categories was integrated into an evaluation matrix. This matrix was a checklist matrix with two project alternatives (with or without) and two temporal dimensions (short and long term). A matrix was chosen as the evaluation method because our main objective was to be predictive: we wanted to help MEANDRS understand the effects associated with rehabilitation, both positive and negative, and the matrix provided us with a systematic way of identifying and evaluating the desirability of impacts (Loomis 1993). The matrix is also a powerful presentation tool; by providing MEANDRS with the complete matrix containing all predicted changes, we allow them to consider all basic information and ultimately decide what, if any, activities should be undertaken as a follow-up from this study.

The “with project” and “without project” alternatives fulfilled the goal of separating changes due to rehabilitation from changes that would occur regardless. Current trends in the watershed will continue to shape the area even if no rehabilitation takes place. From these observed trends, we projected what specific conditions would be like in the future if no rehabilitation took place. The strength of our study does not rely on the accuracy of these predictions but in the determination of a qualitative relationship between rehabilitation and existing trends in the region. These “without project” predictions serve as a point of reference for the effects brought about by rehabilitation.

We arbitrarily divided time into two periods. The first period, “short term,” begins at finalization of the construction phase of the rehabilitation project. The second period, “long term,” begins when the system stabilizes following the rehabilitation project and extends indefinitely into the future. Our definitions of short and long term do not have an absolute time reference. They are working definitions that helped us to better organize the potential impacts of rehabilitation. Depending on how rehabilitation is undertaken, the duration of the phases described could vary considerably.

Evaluation of each category was conducted by disaggregating a category into subcategories important for understanding impacts. Further subcategories were created until we had a clear idea of how rehabilitation was going to influence a factor and its relationship with the category that it was determining. Once the whole tree was crafted, the prediction of changes was undertaken, starting with the most elementary factors. For each factor, a direction and magnitude of change was predicted. Then by gathering all factors in a given subcategory, we made a prediction for the whole subcategory. Once the changes for all subcategories were forecasted, we gathered all subcategories in a category and proceeded to predict a magnitude and direction of change for the whole major evaluation category.

As an example, consider groundwater table level:

- **Groundwater table level**
  - Groundwater storage potential
    - *Storage capacity*
    - *Surface water velocity*
      - Slope
      - Route of travel

Groundwater table level is the major evaluation category. *Groundwater table level* is a function of *Groundwater storage potential*, which in turn is a function of *Storage capacity* and *Surface water velocity*. *Surface water velocity* is itself a function of *Slope* and *Route of travel*. We have finally arrived to a point where the factors were sufficiently elementary: *Slope* and *Route of travel* will be directly affected by rehabilitation and we have a clear idea of how. We know that *Route of travel* will be extended and *Slope* will decrease. Together they result in a reduction of *Surface water velocity*. We then go to the next tier of the tree. *Storage capacity* was unaffected and, because *Surface water velocity* decreased, we predict a decrease in *Groundwater storage potential*. Finally, moving to the next tier we reach the major category. *Groundwater table* levels would likely rise.

The evaluation process consisted of assigning scores to the different categories according to MEANDRS rehabilitation goals. Each category was assigned a “desired” direction of evolution and scores were assigned according to whether river area conditions would head in the “desired” direction as a result of the rehabilitation project.

As an example, consider the Groundwater table level category. The desired status required that no rise in groundwater table level should occur. However, the project would likely cause groundwater table level to rise, moving away from the desired status. Therefore, the category was assigned a negative score. Our evaluation also allowed for considerations of magnitude of the effects by assigning either a single or a double positive (or negative) score to a category.

In comparing “with” and “without project” alternatives, we considered existing trends in the watershed and predicted whether rehabilitation would exacerbate, ameliorate, revert, or not affect the observed trend for each specific characteristic of the system and indicated so in the evaluation matrix with the appropriate (Table 2).

Our analysis of changes incorporated three different components:

- What would a given category status be without the project?
- How would it change with the project?
- Why it would change with the project?

We integrated all information and arrived at a conclusion for every major evaluation category. That conclusion addressed the question of whether the predicted change for the category would be in accord with the community’s goals. We limited ourselves to identifying and forecasting issues of contention that MEANDRS might encounter if they decide to advance the rehabilitation process.

3.4. Synthesis

We synthesized information from individual categories into an overall picture identifying issues of contention and trade-offs involved. Changes in one category could offset, complement, or exacerbate changes in another, producing a much more complex result than an analysis of individual categories might reveal. MEANDRS will ultimately have to decide how to balance the trade-offs identified in this process.

3.5 Groundwater Sensitivity Analysis

Groundwater sensitivity analysis was undertaken to provide support for our prediction of effects and evaluation of changes resulting from the rehabilitation process. This sub-section provides detailed information about the methodology employed for this analysis.

Watershed hydrology was analyzed because one possible watershed response to re-connection of meanders involves raising the elevation of the groundwater table. This could potentially affect drainage in areas immediately adjacent to the river, areas near the downstream ends of the Dowagiac’s tributaries, or where the water table is close to the ground surface. These effects could have very significant repercussions across the entire system. For that reason we conducted a groundwater sensitivity analysis, which involved two main components: groundwater table mapping and Geographic Information Systems (GIS) analysis.

3.5.1 Groundwater Table Mapping

A map of the groundwater[4] table (potentiometric surface map) was created using well depth records obtained from the Cass County Department of Community Health for Pokagon, Silver Creek, and Wayne Townships. These three townships were used since the majority of the potential rehabilitation area lies within their boundaries. The methods used to develop this groundwater map follow the approach developed by the Regional Groundwater Center of the University of Michigan-Flint (RGC).[5]

The potentiometric surface represents the static head of groundwater measured in wells and defined by interpolating contour lines between well points. Well records are completed by commercial well drillers and contain information such as location of the well, type of geological material encountered during drilling, and well construction data. Once a well is completed, relative depth to groundwater is recorded.

The first step was to select appropriate wells for analysis. Due to the thickness of glacial drift in the area (100 to 600 feet), bedrock aquifers were not considered. Therefore, we only used wells set in glacial drift. Additionally, based on the glacial history of the area, it was assumed that there were no regionally-confined aquifers to be concerned about. Wells were then placed in one of the following three categories based on the detail of the location information provided.

- Good: distances from major roads and intersections or the street address provided, indicating specific location of the well.
- Fair: some distances or address information provided.
- Poor: limited or no location information provided.

Only wells in the good category and field-located wells in the fair category were used (Appendix 2).

The approximate location of each well was placed on the U.S. Geological Survey (USGS) 7.5-minute Topographic Quadrangle maps for the study area,[6] using location information from the well log. Figure 7 shows the location of the wells used in the study. To ensure adequate coverage, we attempted to have a distribution of at least two wells per square mile. Studies performed by the RGC found this distribution to be appropriate for township and watershed scale analyses (Hill-Rowley and McClain 1996). In order to fine-tune well locations, locate wells with less-detailed information, and to check the accuracy of the provided information, well locations were field checked and

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[4] For a description of the groundwater and hydrogeology of the Dowagiac River Watershed see Appendix 2

[5] The Regional Groundwater Center is an outreach and research arm of the Laboratory of Land and Water Management at the University of Michigan-Flint. Similar studies have been performed in Livingston, Washtenaw, and Genesee Counties.

[6] USGS Topographic Quadrangles used were: Sister Lakes, Twin Lakes, Dowagiac, and Sumnerville.

appropriate adjustments were made. Topographic maps provided a geographic reference point for the wells and the land surface elevation of the well relative to mean sea level.

Once wells were plotted across the study area,[7] groundwater elevations were calculated by subtracting static water depth from topographic elevation. In many cases, elevations of lakes and streams, assumed to represent points where the groundwater surface intersects the land surface, were also used as local groundwater elevation points. Information on the hydrology of the watershed and from the contouring process itself supported this approach. In addition, wetlands were used as guides to estimate the water table contour pattern if soil, topographic, or hydrologic information indicated that they were likely to be groundwater-fed.

The regional groundwater table was represented by interpolating groundwater contours between elevation points. Contours were drawn manually at 10-foot intervals reflecting the data as well as the logical hydrogeologic patterns expected. Interpretation used ratio estimates and the hydrologic principle that the groundwater table is a subdued reflection of the topographic patterns of the land, flowing downgradient as a continuous body of water, and seldom changing in an abrupt manner. Reported water levels that indicated extreme, or hydrologically illogical, results were assumed to be anomalies and not included in the contouring process. The derived potentiometric surface map enabled an estimation of the groundwater surface elevation at any point within the study area (Figure 8).

This analysis provided an accurate representation of the groundwater surface at a regional scale. However, the process also makes several assumptions and relies on data with some limitations. Potential sources of variability in the data include: well location, measurement error, seasonality, annual precipitation, and segmentation by time (range in years at which measurements were taken). However, studies at the RGC have found that, in regionally scaled studies, the distribution of two wells per square mile provides an accurate representation of the water table, typically overriding these possible sources of variation (Hill-Rowley and McClain 1996). Nonetheless, the following issues are important to remember:

First, groundwater elevation is not static over time and will vary from day to day and from season to season. Over the long term, the range of fluctuation in the regional groundwater table should not vary significantly, assuming that the long-term balance of water inputs and outputs to the aquifer does not change. For reference, data recorded from USGS observation wells are presented to provide a sense of how groundwater elevation changes over time (Table 3). The wells presented are water table wells located in southern lower Michigan and are set in glacial deposits at depth ranges consistent with the wells used in this study.

[7] For the groundwater elevation mapping, the study area consists of a sub-area of the watershed where restoration is desired.

Since glacial deposits in the basin have a relatively high hydraulic conductivity and the Dowagiac River has a high baseflow, daily and seasonal groundwater table fluctuations greater than 10 feet would not be expected.

Table 3: Groundwater Level Data, USGS Observation Wells. Water Year 1992

Well Location	Aquifer Material	Well Depth (ft.)	Water Year 1992 Depth Range (ft.)	Period of Record Depth Range (ft.)	Years of Record
Kalamazoo County	Glacial Deposits	36	2.4	6.42	58
Kalamazoo County	Glacial Deposits	38	2.54	3.7	22
Kalamazoo County	Glacial Deposits	102	0.97	3.9	5
Livingston County	Glacial Deposits	29	1.28	9.48	19

Source: Blumer, *et al.* 1993.

Second, the well logs used span a period of over 30 years of record and represent water levels measured at various times of the year. However, annual and seasonal differences are not expected to be major influences in the groundwater table in the DRS due to the high degree of stability in the system, the control presented by the number of data points used, the connection between surface water and groundwater in the area, and the scale of the analysis (regional water table map contoured at 10-foot intervals). However, recently observed increases instream discharge may be a function of changes in groundwater discharge (Berry 1992).

Third, the recorded static water level may not represent the water table elevation accurately in all cases. By using 10-foot contour intervals, we are allowing for an error of plus or minus five feet between reported and actual water table depths. Work done at the RGC has indicated that using data with a measurement error of plus or minus five feet is reasonable for hydrogeologic settings similar to the Dowagiac Watershed (T. McClain, RGC, personal communication, 1998). Although error is expected on a well to well basis, by examining the groundwater elevation pattern on a regional basis, and by considering the hydrologic controls provided by surface topography and surface hydrology, this measurement error in our data was expected to be within this acceptable range.

Due to the limitations discussed above, we used a relatively conservative approach in subsequent analyses by allowing for a range in elevation of plus or minus five feet. Likewise, future use of this map or the associated analyses should be used at a regional scale only. Issues regarding specific locations within the study area should only be addressed with information obtained from a more comprehensive hydrogeologic analysis.

3.5.2 Geographic Information Systems Analysis

We used GIS as a tool to analyze and display spatial data within the Dowagiac River watershed. Our GIS analysis had two main objectives: first, to summarize collected watershed data and develop presentation graphics that would be readily understood by a broad audience; second, to analyze watershed hydrology and predict the sensitivity of selected areas to potential changes in the groundwater table that may result from restoration activities. As part of the second objective, a series of maps identifying land uses within different areas of sensitivity were developed. Two Environmental Systems Research Institute, Inc. GIS software products were utilized for this analysis: ArcView 3.0a on a Windows NT platform and ARC/INFO 7.1.1 on a Unix platform.

Digital data for the GIS, termed coverages in ARC/INFO or "themes" in ArcView, were obtained from a variety of sources. In general, data were available for either each of the three counties (Cass, Van Buren, and Berrien) or for the whole state. XTOOLS, an ArcView extension tool developed by the Oregon Department of Forestry, was used to join counties where necessary, and clip attributes of the Dowagiac watershed from the larger spatial datasets while maintaining topology. Coverages projected in Universal Transverse Mercator (UTM) coordinates were re-projected to Zone 3 (southern region) of Michigan's State Plane coordinate system using ARC/INFO.

The Michigan Resource Inventory Systems (MIRIS) database developed by the MDNR provided: base maps digitized from 1:24,000 USGS 7.5' Topographic Quadrangle Maps, land use information obtained from 1978 1:24,000 aerial photographs [the most current land use information available in digital format], and presettlement (pre-1800s) land cover developed from the original survey notes. Watershed and county boundaries, hydrologic features from a 1:100,000 digital line graph (DLG), Quaternary geology from a 1:500,000 map, and a coverage of groundwater discharge based on Darcy's Law[8] were obtained from the Michigan Rivers Inventory (MRI) project developed by Seelbach and Wiley (1997). The Natural Resource Conservation Service's STATSGO soils data were downloaded from the Internet from Pennsylvania State University, Earth Systems Science Center. A 1:250,000 digital elevation model (DEM) was obtained from the USGS's Internet web site.

The groundwater contours we developed (discussed in detail in section 3.5.1) were digitized using the CMAP software package and converted into ARC/INFO format. Using the GRID program TOPOGRID in ARC/INFO, the digital version of the map was

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[8] Darcy's Law: $Q = k_v A \frac{\Delta H}{L}$, where Q = groundwater discharge (cm^3/sec); k_v = hydraulic conductivity (cm/sec); A = cross-sectional area (cm^2); H = change in head (cm); and L = length of the soil column (cm). From Brooks, *et al.* 1991.

turned into a grid of cells, each with its own elevation. This continuous groundwater surface is statistically derived by the program's algorithms and estimates the groundwater elevation at any point in the study area.

GIS was used to assess the relative sensitivity of areas to a potential increase in elevation of the groundwater table. For agricultural land uses, soils can become too wet to grow crops, use as pasture, operate machinery, or build upon if the water table is too close to the land surface. A high water table may also affect basements, septic systems, or other domestic or industrial land uses. Usability of land depends upon factors such as depth to groundwater, drainage characteristics of the soil, location and type of wetlands, and estimates of groundwater discharge based on Darcy's Law.

Critical depth to groundwater was identified as approximately three to four feet below the ground surface[9]. In setting this critical depth, we considered factors such as crop sensitivity, field accessibility, soil drainage potential, and non-point source pollution. Crop sensitivity is a function of root depth, maturity level, and resilience to saturation. Many crops, especially field corn with its deeper root system, become impacted when the groundwater table is less than 3-4 feet below the ground surface. Shallow depths to water typically result in quicker soil saturation during storm events, creating accessibility problems for farm equipment and requiring several days to dry out before farmers can take equipment back into the fields. Well drained soils recover from storm events faster than less well drained soils. In addition, shallow depth to water typically results in higher groundwater impacts from non-point sources of pollution, such as animal manure and agricultural chemicals.

Depth to groundwater for subsequent analysis was then divided into three categories: 0-10 feet, 10-20 feet, and greater than 20 feet. These depth-to-water categories were selected for several reasons. Groundwater levels fluctuate seasonally, typically with higher levels during wetter periods of the year and lower levels during dryer periods. The 1:250,000 DEM used for the surface elevation provided relatively coarse data that may not adequately represent variation in the topographic surface of the watershed. Unfortunately, a finer-scale DEM was not available. The groundwater mapping methodology (based upon data reported by well drillers on well log forms filed with county health departments) is typically accurate within an error bound of five feet (Lajavic, unpublished). The 0-10-foot sensitivity interval includes areas that could have a depth to water of five feet or less, based upon this error bound. Since the critical depth to water for most agricultural land uses within the watershed is 3-4 feet, the depth to water categories are also broader than they could be, providing a safety margin.

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[9] Interviews with Allen Butchbaker (Cass Co. Drain Commissioner), Dan Rajzer (Cass Co. Extension Director), Alex Bozymowski (NRCS Resource Conservationist), and several watershed farmers in which critical depths to water for various crops and soil types within the watershed were discussed. Based on these interviews, a conservative depth to water of 3-4 feet was chosen as a guide for our analysis. The actual depth used in our model was five feet below the ground surface.

Therefore, the sensitivity categories are conservative estimates in that they include most areas that are likely to be affected by drainage changes.

Drainage characteristics of the watershed's soils were originally classified on the digital coverage using the Natural Resources Conservation Service's Hydrologic Soil Groups (Groups A through D). Areas with similar soil characteristics had been delineated into polygons and assigned attribute data. Attribute data consisted primarily of a classification of each polygon by its percent composition of each of the four soil groups. For example, a polygon of poorly drained soils might have been classified as being composed of 10% A, 20% B, 40% C, and 30% D soils. For this analysis, the Hydrologic Soil Groups were re-classified by developing a weighted mean for the soils, giving a higher weight to more poorly drained soils. This re-classification was then used to classify each soil group polygon as one of the four drainage classes (i.e., very poorly drained, poorly drained, moderately drained, and well drained).

The presence of wetlands indicates areas that are saturated during part of the year. Current wetlands were utilized in our analysis because they indicated areas that, even with the lowered water table resulting from channelization, remain saturated enough to support wetland vegetation. Wetland vegetation types vary according to environmental conditions, including water supply. Coniferous wetlands often are indicators of groundwater discharge areas, where the level of the wetland is lower than the surrounding water table (Mitsch and Gosselink 1993; M.J. Wiley, personal communication, 1997; D.A. Wilcox, Branch Chief, Coastal and Wetland Ecology, USGS-Great Lakes Science Center, personal communication, 1998). Thus, presettlement coniferous wetlands were used as an indicator of pre-channelization groundwater discharge areas; these areas would likely become re-wetted if the water table elevation were to be restored to its former levels.

Groundwater flow estimates, based on Darcy's Law (M.J. Wiley, personal communication, 1997), were incorporated into our GIS analysis because they indicate the volume of groundwater flow accumulation, which can be used as an indicator of wetting potential. Darcy's Law is frequently used to model the volume of groundwater flow in hydrogeologic investigations. It incorporates area, hydraulic conductivity, and head pressure, or in other words, the discharge of water that flows through a given soil/geology type, allowing for slope and area.

Groundwater sensitivity areas were then delineated in ArcView according to the criteria in Table 4. Following the delineation of the sensitivity areas, current land use within each of the groundwater sensitivity areas was summarized[10].

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[10] While land uses in specific locations can be identified by this analysis, the authors warn against the use of this model at a site specific scale. However, from a regional perspective, the amount of each land use class in acres and as a percent of the watershed area is useful for analyzing the feasibility of restoring meanders, and to identify portions of the river system that are less sensitive to changes in the water table.

Table 4: Groundwater Sensitivity Criteria

Groundwater Sensitivity Rating	**Criteria**
High Sensitivity	Area with a depth to water from 0-10 feet + current wetlands and pre-settlement coniferous wetlands + very poorly or poorly drained soils. **Or** Area with a depth to water from 0-10 feet + Darcy Flow > 0.5 Standard, Deviation. from the watershed's mean.
Moderate Sensitivity	Area with a depth to water from 0-10 feet but not in the High Sensitivity Area.
Low Sensitivity	Area with a depth to groundwater > 10 feet and ≤ 20 feet.
Very Low Sensitivity	Area with a depth to groundwater > 20 feet.

Using this process we produced a geographical representation of different levels of sensitivity to groundwater changes observed throughout the watershed. These maps provided the information required to assess the magnitude of potential effects of drainage changes in categories such as agriculture and wetlands. The importance of these tools to validate some of our predictions and evaluation was paramount.

Section 4 – Results and Discussion

This section examines the findings from our investigation into the feasibility of rehabilitating the DRS. Our results and discussion of those results have been combined to provide continuity and clarity. The reader may wish to follow along with the evaluation matrix (Table 2).

4.1 General Matrix Results

4.1.1 Surface and Groundwater Drainage

Rehabilitation is expected to decrease drainage function somewhat, and therefore decrease drainage within the DRS over both the short and long-terms.

Presently drainage is not a problem in the DRS because of extensive historical channelization and use of agricultural drains, especially in the headwaters region. In fact by the 1940s, farmers were complaining that their lands had been excessively drained (Moffett 1940). Without the project, drainage conditions within the watershed are expected to remain relatively unchanged from their present state.

Changes resulting from the project would most likely be limited to areas lateral to, and immediately upstream of, the rehabilitated portions of the river. Based on the groundwater map and other data previously discussed, four groundwater sensitivity areas were identified within the DRS. Plate 1 shows the four sensitivity areas (High, Moderate, Low, and Very Low) and the 1978 MIRIS land use within each area. Table 5 identifies the percentage of the watershed encompassed by each sensitivity area.

Table 5: Percent Coverage of the Watershed by each Groundwater Sensitivity Area

Groundwater Sensitivity Area	**Percent of Watershed**[11]
High	6
Moderate	7
Low	9
Very Low	30
Total Area	*52*

Changes in drainage are likely to increase the elevation of the groundwater table (Brookes 1995), which may impact lands adjacent to and immediately upstream from rehabilitated portions of the river. Logically, an increase in the water table elevation would be expected because channelization was originally performed to lower the water

[11] Percentages do not add up to 100 because the sensitivity study area was limited to the portion of the watershed being considered for rehabilitation, as identified by MEANDRS' scope of rehabilitation.

table and the goal of rehabilitation is to undo some of these drainage enhancements. The High and Moderate Sensitivity Areas (Figure 9 and Plate 1, respectively) showed that the middle to lower portion of the study area is less likely to be impacted by a potential increase in the elevation of the water table and might be better suited for rehabilitation efforts.

There are several potential positive effects of the proposed rehabilitation on watershed drainage, none more important than the reconnection of the floodplain. Reconnecting the floodplain should restore some of the vital floodplain functions to the DRS (Toth 1995). The river is currently disconnected from its original floodplains due to the incised channel and adjacent high dredge-spoil banks. Disconnection from floodplains disrupts important ecosystem functions including the temporary storage of floodwaters, sediment deposition, and nutrient enrichment (Hawkins 1991). Floodplains also offer periodic habitat for aquatic flora and fauna during high water events. An additional benefit of rehabilitation would be the creation of new wetland areas, as well as improving the hydrologic connection of existing wetland areas along the river (Toth 1995).

The major negative effect is the potential for decreased depth to groundwater in areas immediately adjacent to, or upstream of, the project area. These effects are most likely to impact agricultural practices by causing fields to be too wet for certain crops or for farm machinery. Residential property owners may also be affected by the increase in water table elevation, which may create problems for septic systems or lead to flooded basements. Additionally, the water storage capacity of the watershed’s soils would be reduced by an increase in the water table elevation, which could increase local surface runoff.

4.1.2 Wetlands

An increase in the number of riparian wetlands, the size of wetlands, and the ecological functioning of wetlands is expected with the project.

Wetland loss (Figures 5 and 10) within the DRS has predominantly occurred as a result of channelization and subsequent enhanced drainage within the basin. However, our groundwater contour map indicates that many of the wetlands along the Dowagiac River likely receive fairly constant groundwater inputs (Figure 8). As noted in the Physical Profile, the magnitude of groundwater inputs to the DRS is regionally exceptional, indicating that many of the region’s wetlands are influenced predominantly by their groundwater hydrology. Therefore, rehabilitation should increase the amount and enhance the quality of wetlands in both the short and long-term.

Without rehabilitation, the total area of wetlands within the watershed is expected to continue to decline. This trend is also occurring nationally due to development pressures (Mitsch and Gosselink 1993).

Wetlands occur in areas where three conditions overlap: soils are periodically saturated, soils are hydric[12], and vegetation adapted to wet conditions is present (Mitsch and Gosselink 1993). Changes in drainage and reconnection of the floodplain will aid in restoring some of the wetland hydrology that was disturbed when the river was channelized. Once a more natural hydrology has been returned to the DRS, wetland vegetation will begin to re-colonize the rehabilitated areas. However, re-colonization of wetland vegetation requires the presence of wetland soils. It is likely that wetland soils still remain in many former wetland areas in spite of possible disturbances during channelization and agricultural activities. These soils may have taken tens to hundreds of years to form (Ritter *et al.* 1995) and act as a seed bank for future germination and growth (Mitsch and Gosselink 1993). An important management consideration during rehabilitation will be minimizing the loss of these soils during construction activities.

Rehabilitation of wetlands can provide a number of benefits. Wetland areas along the river will provide temporary flood storage during more severe storm events. During periods of high water, wetlands and riparian areas also act to temporarily trap and store sediments in transport (Large and Petts 1996; Mitsch and Gosselink 1993). This sediment storage function not only replenishes nutrients in the soil, but also acts to reduce the river's sediment load (Mitsch and Gosselink 1993). Wetlands and riparian areas along rivers act as buffer strips between aquatic and terrestrial systems by filtering non-point source pollution from surface runoff before it enters the river channel. Wetlands are also a source of external nutrients for aquatic ecosystems, and provide organic matter in the form of dissolved nutrients, decomposing plant and animal biomass, and woody debris (Large and Petts 1996). Riparian wetlands provide important habitat for many species (Large and Petts 1996; Mitsch and Gosselink 1993). Moreover, rehabilitated wetland areas will provide humans with additional recreational opportunities related to more abundant and diverse wildlife (Large and Petts 1996).

Several drawbacks can be associated with the rehabilitation of wetland areas along the DRS. Traditionally, wetlands have been viewed as wastelands, with little economic value (Mitsch and Gosselink 1993), and this attitude may still be present among the population within the DRS. Agricultural and residential land in areas near the river may be affected both by the actual conversion to wetlands as well as by the loss of enhanced drainage provided by channelization. The cost of restoration of wetland areas is also likely to be viewed as a drawback. Finally, some of the wetlands in current cut-off oxbows will be lost as a result of the reconnection of these oxbows to the channel.

[12] Hydric soils develop under anaerobic conditions which result from periodic saturation, and are often characterized by their gray/blue or rust colored, mottled appearance (Mitsch and Gosselink 1993).

4.1.3 Water Quality

Water quality in the DRS is generally good with some indication of elevated nutrients associated with agricultural land uses. Rehabilitation should only improve water quality, although some short-term impacts may occur during project construction.

Water quality within the watershed is currently good, meeting State and Federal standards. Although elevated nutrient levels were reported in several locations, the watershed meets the relatively stringent requirements set by MDNR for coldwater systems (MDEQ 1997a, 1997b). Water temperatures, concentrations of dissolved oxygen (DO), and levels of suspended sediments are adequate to support trout.

Without the project, a long-term decrease in water quality is anticipated. Data indicate that agricultural land use is declining while residential use is increasing within the DRS (Census of Agriculture 1959-92). Allan (1995) noted that although agriculture has probably been most responsible for the widespread degradation of aquatic systems, urban and industrial development is likely to have caused the most intensive changes within restricted areas. Therefore, land use conversion away from agriculture within the DRS could place additional pressure on the natural systems' ability to balance water and nutrient cycles and maintain the current quality of the water. Watershed management practices such as treatment of municipal effluent could be utilized to address this trend. However, if the portion of the watershed covered with impervious surfaces surpasses a critical threshold, water quality could be seriously affected.

While water quality may diminish slightly in the short-term as a result of project construction activities, levels of suspended solids, nutrients, and contaminants are expected to show improvement in the long-term, as enhanced wetlands and reconnected floodplain areas act as buffers. Good water quality is important for recreational and ecological functions, and therefore is a clear benefit of rehabilitation. In addition, watershed planning and management efforts implemented during rehabilitation should increase public involvement and participation, which in turn could help limit or mitigate future land use impacts to water quality.

With the project, several factors could degrade water quality in the short-term. The scale and scope of the project will determine the magnitude of many of these effects. Possible effects include the localized disturbance of vegetation along the river margins. This could reduce the natural buffering capacity of the riparian zone, increase sedimentation and erosion, and thereby increase the river's turbidity, nutrient concentrations, and biological oxygen demand (BOD) (Brookes 1985). Rehabilitation is likely to include replanting and restoring natural vegetation in the project area; however, full recovery will take time. Fortunately, rivers are flow-through systems and are fairly resistant to short-term impacts (NRC 1992; Wiley and Seelbach 1997). Therefore, long-term impacts such as the development of land, irrigation, and agricultural drainage, can lead to much more severe problems and are of greater concern (Allan 1995).

Reconnecting the floodplain and assuring full establishment of riparian vegetation will enable the river system to trap suspended sediments during flood flows and filter non-point source pollutants from surface runoff entering the river system. Riparian vegetation also helps cycle needed nutrients between terrestrial and aquatic environments. Minor reductions in DO concentrations are likely to result from decreased flow velocity, decreased channel roughness, and an increase in BOD. Current concentrations of DO in the river are acceptable for a coldwater system, and the magnitude of change is expected to be small.

An increase in elevation of the groundwater table may also lead to an increase in the type and concentrations of toxic substances entering the river, including animal wastes, agricultural chemicals, road salt, fuels, and industrial chemicals. An increase in water table elevation will bring these compounds into contact with groundwater sooner than would presently occur. Insoluble compounds tend to remain within the soil column; however, compounds that dissolve in the groundwater may be taken up by drinking water or irrigation wells, or discharged into the river system as part of the baseflow. Improvements to water quality resulting from the rehabilitation project should offset this effect. However, this fact highlights the need for embracing serious watershed management practices, similar to what would be expected for a northern trout stream.

4.1.4 Biological Integrity

Rehabilitation will lead to a substantial increase in ecological health and an improved functioning of interrelationships within aquatic and terrestrial ecosystems. A more natural river system will improve biological integrity and quality by providing better habitat for trout and other organisms, thereby bringing the DRS closer to its ecological potential.

4.1.4.1 Aquatic habitat

The Dowagiac River is a relatively large, coldwater river, making it unique in southern lower Michigan. High groundwater contributions, cold water temperatures, and good water quality indicate that with channel rehabilitation, the Dowagiac River could become a prime trout stream, rivaling northern trout streams such as the AuSable River. Due to channelization the Dowagiac River is unable to realize its ecological potential and only those species that are able to tolerate the force of a continually swift current persist (Appendix 3). Disconnection from the floodplain also limits the river's ecological potential (Appendix 2). As a result, the DRS is unable to support a sustainable, environmentally sensitive coldwater community.

Without the project, aquatic habitat conditions are expected to remain poor and may become worse due to increased erosion caused by the swift flows and a straight, incised channel (Rosgen 1996). Water quality, which is currently good, could also deteriorate without the project, negatively affecting aquatic habitat. (see Section 4.1.3)

As discussed in Sections 2.3.2.2 and 2.3.3, emulating the natural form and processes that take place in an undisturbed, meandering channel by rehabilitating the hydrology and channel morphology will bring about an increase in aquatic habitat diversity (Brookes 1985,1987; Petts 1995). Aquatic habitat diversity is defined as the quantity and variety of niches for species to inhabit. Rehabilitation will also greatly improve the quality of habitat in the DRS by creating better resting, feeding, spawning, and nursery areas for species such as trout (Appendices 2 and 3). As a result of better and more diverse habitat, species richness and biological integrity are expected to improve significantly (Allan 1995). The increase in aquatic habitat diversity is one of the most important long-term benefits of rehabilitation.

Anthropogenic disturbances to the aquatic ecosystem may increase with the project, but this trend is likely to continue even without the project. Urban development, with its related increase in impervious surfaces, will lead to more runoff and less stability for streamflows. Furthermore, an increase in angling and other recreational use of the river increases the potential for aquatic pest species to become established via the release of live bait and transport of organisms on equipment.

4.1.4.2 Riparian habitat

Currently the riparian forest is isolated from the river. As a result, many plant species are grouped together on the levee, and bottomland plants are being replaced with more upland species such as oaks and hickories. This is due to the lack of seasonal flooding expected if the river were connected to its floodplain. Presently there is considerable undercutting of tree roots due to bank erosion, much more than would normally occur in a naturally meandering system. Furthermore, the current (predominately southwesterly) orientation of the channel does not meet the sunlight requirements of as many plants as a meandering system would.

Without the project, a relatively poor level of plant diversity (as is currently observed) is likely to dominate the riparian zone along the Dowagiac River. Increasingly more upland and weedy species are likely to become established because of the lack of periodic natural flooding (Mitsch and Gosselink 1993).

In riparian areas, habitat diversity of both flora and associated fauna will increase with the project. A meandering river will vary in orientation to the sun, allowing plants to specialize according to their shade/light tolerance (Barnes and Wagner 1981). If the connection to the floodplain is restored, bottomland plants should develop normal zonation patterns characteristic of first and second bottoms, and terraces. As a result, a more diverse mosaic of plant community types should develop (Toth 1995). In addition, seasonal soil enrichment along the floodplain has not occurred since the original dredging because of the high levees and channelization. Connection to the floodplain will lead to enhanced nutrient cycling and natural sedimentation processes, and will provide additional habitat (Toth 1995).

Vegetation along the riparian margins of a river system provides many beneficial functions to both aquatic and terrestrial ecosystems. Vegetation acts as a filter between the two ecosystems: it temporarily stores sediment deposited during high water events, and it plays a major role in the cycling of nutrients between the two ecosystems. Greater variety in plant species will provide more food and shelter for small mammals and birds, thus leading to a greater diversity in fauna. For example, after a rehabilitation effort along the Skunk River in central Iowa, the state-endangered plains pocket mouse was found (L. Lown, Board member, Polk County Conservation Board, Iowa, personal communication, 1997). Renewed interest in conservation and better ecosystem functioning have also led to the reintroduction of river otter to the Skunk River system (Stone 1997).

Initially bank erosion may be a problem after construction. Also, newly exposed banks provide a convenient place for establishment of invasive plant species such as purple loosestrife. The Des Plaines River Restoration Project near the Illinois/Wisconsin border has experienced increased populations of purple loosestrife, reed canary grass, and common buckthorn (D. Hey, Project Manager, Wetlands Institute, Des Plaines River Project, personal communication, 1998).

Furthermore, some mature trees may be lost as a result of the construction; these could take 40-100 years to recover (B. Barnes, Professor, University of Michigan, School of Natural Resources and Environment, personal communication, 1998). It will likely take nearly 20 years if saplings are planted for a riparian community to begin to reestablish itself, and even longer if left to reestablish by itself. It should be noted that the river ecosystem is likely to recover more quickly than the natural riparian vegetation, because rivers tend to be more dynamic (NRC 1992) and species living in rivers do not have life spans as long as many woody plants.

4.1.5 Potential for Sustainable Fishing

A good quality trout fishery is anticipated with implementation of channel rehabilitation because the Dowagiac River is a groundwater-fed, coldwater stream.

The Dowagiac River has the potential to become a high quality trout stream. As previously discussed, the DRS is characterized by cold temperatures, good water quality, and high baseflow; these are indicators of trout streams. However, in its present state the Dowagiac River supports only a marginal-quality coldwater fishery. Channelization has degraded the diverse habitats needed for vital functions such as feeding, hiding, resting, spawning, and developing (Hunter 1991).

Without the project, the system is expected to remain unable to support a sustainable trout population.

If meanders are restored, we expect to see an alternating sequence of pools and riffles develop, which will lead to an increase in habitat diversity. Water temperatures are already cold enough to maintain trout, but velocities are too swift and habitat is too homogeneous. Over time, the river would sort its substrate and good gravel beds would become established in riffle sections formed by the rehabilitated meanders. Initially after restoration, it may be necessary to add coarse substrates to provide feeding and spawning places for trout. Trout stocking would need to continue to provide an initial source population until they can reproduce and maintain themselves. If the above-mentioned measures are implemented, a sustainable trout fishery could develop in the DRS.

A potential positive effect of the project is a projected increase in recreation because of improved fishing. With a successful rehabilitation effort, the Dowagiac could become a prime trout stream located near to several urban population centers in Michigan, Indiana, and Illinois. This will be discussed further in Section 4.1.7.

A possible negative effect of the project could be the potential for overuse of the resource, which could result in conflicts between fishermen, landowners and other users such as canoeists. Planning should not be focused only on trout fishing; other recreational activities need to be considered so that a broad segment of the community benefits.

4.1.6 Agriculture

With a decrease in soil drainage, some agricultural land could be rendered unsuitable for farming, resulting in economic losses and alteration of livelihood for some farmers in the area.

The Dowagiac River watershed remains predominately agricultural. Cropland and pasture represent 59% of the watershed acreage (US Census of Agriculture 1992). Cass County is the number one county in Michigan for hog production. There is also some beef production. Crops include corn, soybeans, and wheat, along with vegetables and fruit (MASS 1996). Figure 10 indicates the 1978 land use coverage within the watershed.

The headwaters area in Van Buren County, near Decatur, is in the muck-land area drained by the Dowagiac Drain (which eventually becomes the Dowagiac River). Specialty crops such as cucumbers, asparagus, and bush beans are grown in this headwaters region (MASS 1996).

Trends observed in the watershed indicate a reduction in the total amount of land in farms, combined with a reduction in the number of farms and an increase in the size of farms in the area (Census of Agriculture 1959-1992). The result of these trends is agriculture supporting fewer inhabitants within the watershed. Furthermore, residential and industrial development pressures seem to be increasing (US Census of Agriculture 1992) (see Appendix 4). This seems to indicate that without the project, agriculture will continue to lose ground to other land uses and economic activities, which could change the agricultural nature of the watershed in the future.

The rehabilitation project could negatively affect agriculture in two different ways. First, the water table is expected to rise somewhat, decreasing the drainage capacity of soils, which might result in farmland losses. Many crops such as corn require the water table to be at least 3 to 4 feet below the surface. Implementation of the project for the entire stretch of the river in Cass County could cause, in the worst case, a maximum of 4,046 acres, or 4.5% of the agricultural land in the watershed, to become unsuitable for farming (Plate 1). This change would most likely be accompanied by production and profit losses. Moreover, indirect economic loss of sales for the agricultural support industry could occur, causing disruption in the agriculture economy of the area. Even though the anticipated land losses are not that great from a watershed perspective, at the individual farmer level land losses could be so significant as to result in the loss of an individual farmer's entire livelihood. These farmland losses are the greatest concern regarding the feasibility of rehabilitating the DRS. However, strategies for mitigating the impact of these losses are available and are discussed in detail in Section 5.

Second, as the river becomes more scenic due to reconnecting of meanders and increased biological diversity, residential pressure for riparian lands and agricultural land is expected to increase. As was mentioned before, this general trend of increasing development pressures is already occurring without the project, but demand for residential sites near the river might increase if the project improves the residential appeal of riparian lands.

Furthermore, it is possible that increased tourist demand due to the river rehabilitation project could stimulate a shift from row crops and hog production, to specialty crops such as vegetable crops or self-pick farms. However, as Nelson (1992) points out, when urbanization forces are set in motion, farmer's reaction to the threat of agricultural unviability is a switch towards less capital or labor-intensive types of crops such as corn and pastures. Still, self-pick farms have been successful in the adjacent counties of Berrien and Van Buren due to summer tourist trade near Lake Michigan, and increased visitation to the Cass County portion of the DRS could impel some farmers towards this kind of enterprise. A 1993 study by the American Farmland Trust showed that 86% of the fruits and vegetables produced in the United States are grown on the edge of urban areas (AFT 1995).

Direct marketing by roadside stands can be an important bonus income for farmers. However, many farmers enjoy farming because they take pride in working with the land, but do not enjoy dealing with the public on a daily basis. Self-pick farms represent a different way of doing business and marketing from the current row crops. Someone in the family needs to enjoy meeting the public on a daily basis for the self-pick enterprise to be successful.

On the positive side, it is possible that the rehabilitation project could result in an increased interest in conservation of natural areas along the river corridor that could eventually lead to an increased awareness and concern for farmland protection, alleviating some of the pressures on the agriculture of the area. This possibility will be addressed specifically in Section 4.1.8.

4.1.7 Recreational Potential

The diversity of recreational opportunities and quality of recreational experiences in the watershed will increase with the proposed rehabilitation.

As described in Appendix 4, the Dowagiac watershed offers many outdoor recreational opportunities to residents and non-residents alike, including fishing, canoeing, hunting, hiking, self-pick farms, and several parks and nature areas. As indicated in the evaluation matrix, these activities will be greatly enhanced with an improvement in the natural and physical characteristics of the DRS.

Many residents of the Dowagiac Watershed enjoy the current recreational opportunities available to them. However, there is recognition that the recreational potential of the DRS and its adjacent lands could be enhanced (MSU Extension 1997). At the same time, there are concerns with the current and future levels of recreational use of the DRS, especially over possible disrespectful or destructive behavior of recreational users and infringements of private property rights (MSU Extension 1997).

Without rehabilitation, the recreational potential of the watershed is not likely to change substantially over time. Recreation would therefore remain a relatively minor feature of the watershed. Of the 83 counties in Michigan, Cass is ranked 36th, Van Buren is ranked 30th, and Berrien is ranked 9th in terms of their statewide market share of tourism and recreation (D. Spotts, personal communication, 1998). Over the long-term, potential changes in the land use of the watershed such as development along the river may lead to some loss of river-related recreational opportunities.

Both instream and off-stream opportunities are predicted to increase in the short-term and increase substantially in the long-term with rehabilitation. Specifically, rehabilitation will improve the ecology, especially habitat for trout (Hunter 1991) and the aesthetic quality of the river and riparian area, along with biological diversity (Section 4.1.4) (Hendrickson and Doonan 1972; Poff and Ward 1989). The proposed rehabilitation will likely include some access and near shore improvements as well, which would complement the aesthetic and ecological improvements.

Increasing the recreation potential of the DRS will also benefit the local economy (Diamante *et al.* 1984; Burt and Brewer 1971; Hoehn *et al.* 1996; Vaughan and Russell 1982) and community well-being (Caldwell 1991; Higgs 1997; Noss and Cooperrider 1994). These benefits are discussed in more detail in Section 4.1.9. In short, an increase in the recreational potential may draw more people to the area to take advantage of the enhanced opportunities. This would result in an influx of money into the watershed communities through dollars spent on meals, lodging, canoe livery fees, gasoline, and equipment purchases. In terms of community well-being, the increase in the recreational opportunity will likely draw more people who live in the watershed to the river. In addition, recognition of the DRS as a high quality recreational area could have many benefits to community well-being as discussed in Section 4.1.9.

Without careful planning, an increase in recreational potential may lead to crowding and overuse of the resource; as well as an increase in conflicts both between users, and between users and area residents. For example, conflict between riparian landowners and users of the river could increase if problems such as littering, trespassing, and noise escalate. The direction and degree of these impacts are dependent on the level of management, the behavior of the users, and the amount and type of access provided. MEANDRS needs to consider ways to avoid, minimize, or mitigate undesired impacts on individuals living along the river. Trade-offs may be settled by carefully choosing adequate levels of infrastructure, management, and enforcement. Some strategies will be discussed in Section 5.

In the short-term, users would need to adjust to changes in the physical and aesthetic nature of the river system such as a reduction in trees and vegetation in some areas. While some people may miss the "canopy-like" effect of the trees, others may enjoy the increased diversity of views along the river. Furthermore, while recreational infrastructure such as restrooms, parking lots, and access points to the river make the quality of the experience better, it may also take away from the natural integrity and scenic quality of the resource. Therefore, as part of the rehabilitation effort, MEANDRS needs to balance the level of infrastructure necessary to accommodate recreational users with the level desired by the community and riparian landowners.

4.1.8 Protection of Natural Resources and Open Space Conservation beyond the River

By increasing awareness of the needs for, and benefits of, conservation; the proposed river rehabilitation can serve as an impetus for conservation both along the river and elsewhere in the watershed. Therefore, the level of regional open space protection and natural resource conservation should increase, especially over the long-term.

Presently there is some uncertainty regarding the direction that the watershed is heading in terms of exurbanization. Issues such as the future of high-speed rail access to Chicago make it difficult to predict the future desire for conservation of natural resource and open space among residents. Nonetheless, efforts such as the formation of MEANDRS itself and the protection of Dowagiac Woods are good evidence that many residents are conservation-minded. When the Michigan Nature Association purchased the land for Dowagiac Woods, 20% of the funds came directly from Cass County residents (Holzman *et al.* 1994).

Without the project, it is uncertain how much effort people in the watershed will put toward natural resource protection and open space conservation. It will likely be dependent on the mobilization of other conservation goals, interests, and efforts within the community, as well as the level of awareness concerning the need for these efforts.

Protection of natural resources and conservation of open space in the watershed could be an important offshoot resulting from rehabilitation efforts. Since MEANDRS wishes to take a holistic approach to rehabilitation, land conservation beyond the river channel will likely be a critical part of the project. Enhancement of the DRS may foster a sense of the watershed as a "home-place" among residents. By enhancing the quality of the DRS, people could identify the river and its watershed as a defining feature of their community and, upon recognizing the benefits of additional conservation of lands to protect their investment in the river rehabilitation effort, more land conservation schemes could be implemented.

Rehabilitation also provides an opportunity to protect open space from unplanned residential development. MEANDRS may wish to include land conservation strategies in the rehabilitation plan. Watershed citizens, interviewed as part of this study, described the area they live in as rural, agricultural, and quiet. Descriptions included references to natural resources such as the DRS, wildlife, and wooded areas as unique and valuable features of the watershed. There are several reasons for people wanting to preserve prime farmland. Perhaps the most important of these motivations is open space preservation, but other functions of farmland such as the provision of certain public goods including flood absorption, air cleansing, and water filtration are also very important. Finally, the fact that the conversion of prime farmland near exurbanization nuclei is compensated for by incorporating marginal land into production at greater environmental and economic cost provides another strong incentive for prime farmland preservation programs (Nelson 1992). Several respondents felt that it is important to protect and preserve the natural and rural features as well as the agricultural nature of the area (MSU Extension 1997). Therefore, for most individuals, river rehabilitation could complement the desire to preserve the rural and agricultural character of the area.

Some indirect benefits of rehabilitation and resulting land conservation include the following. First, the rehabilitation project will serve as an example of conservation at work, providing a stimulus for other efforts. Second, as will be discussed in Section 4.1.9, the land and resources protected by these efforts can become important assets to the community, benefiting social and economic well-being. Rehabilitation offers the opportunity to combine these efforts, optimizing conservation objectives.

However, some people may feel that economic benefits are being forgone by choosing conservation over other uses of the land such as residential development. This opportunity cost needs to be weighed against the benefits of conservation and protection. As previously discussed, tax revenues generated from residential properties do not always cover the associated cost of infrastructure and services. Therefore, preserving farmland and open space is not necessarily a financial liability to the community (Arend *et al.* 1996).

Additionally, there is likely a threshold in the desire among residents to preserve and conserve resources within the community. Realizing that not all conservation desires can be met, people's willingness to support conservation projects must be carefully balanced. Therefore, it is important to determine if the river is really where people in the area want to focus their conservation capital, or whether there are other issues with a higher priority such as farmland preservation, as rehabilitation efforts could compete with land conservation opportunities beyond the river.

4.1.9 Community's Social Well-being

As discussed in Section 3, the social well-being portion of the evaluation matrix focused on four broad stakeholder groups: the general public, farmers, riparian landowners, and recreational users. Since the proposed rehabilitation will affect these groups differently, we decided to evaluate the relationship between rehabilitation and social well-being for these groups separately.

4.1.9.1 The General Public

The social well-being of the general public is expected to change in five ways as the result of rehabilitation: attitude about the community, community identity, aesthetic quality, environmental quality, and educational opportunities. While both positive and negative impacts were identified, the cumulative effect of these changes is expected to be a benefit to the community's social well-being in both the short and long-term.

The general public includes all of those individuals who reside in the watershed but have no direct relationship with the DRS per se.

Individuals are expected to benefit as a result of increases in the recreational potential and quality of the watershed, enhancement and protection of the natural environment and ecology, and improvements in the scenic quality of the river and adjacent lands. While not everyone is expected to personally benefit from these changes, there is likely to be a positive increase in the general public's attitude about, and perception of, the watershed.

As Hoehn *et al.* (1996) state in introducing their model for valuing recreational angler resources in Michigan, "resource services provide benefits to people; they are things people care about, such as catch rates for fishing, variety of bird species for birdwatching, visual amenities, or the knowledge of the existence of the resource in a particular condition."

Without the project, attitudes toward the DRS are not expected to change substantially. However, the loss of agricultural land, wetlands, and open space and the continuous (although subtle) deterioration of the river are expected to continue. These trends could lead to a gradual decrease in the public's well-being.

A change in the general public's attitude about their community is expected due to improvements in the ecological and recreational potential of the DRS. It is argued that there is a link between rehabilitation and benefits to nearby communities (Caldwell 1991; Higgs 1997; Cairns 1995). When the potential of the DRS is realized, the sense of the watershed as a home-place will be enhanced and its residents should develop an increased sense of pride, respect, and stewardship for the resource, realizing that it offers new opportunities that are benefits to the community such as trout fishing, high biological diversity, tourism, and regional recognition. Hoehn *et al.* (1996) found that rivers supporting good self-sustaining stocks of desirable game fish have significant value. This change in the general public's attitude about the community is likely to be a substantial benefit in the long-term.

The aesthetic qualities of the watershed are likely to increase as a result of rehabilitation. Rehabilitation will attempt to restore sections of the river to a more natural state that includes meanders, pool-riffle sequences, connections to the floodplain, and natural vegetative zonation. In the MEANDRS Riparian Survey, watching the river, bird watching, and strolling were identified as the most frequent activities associated with the river (MSU Extension 1997). Therefore, improving the aesthetic quality of the river would be a long-term advantage of rehabilitation. However, the time frame for vegetation to grow back after restoration and for people to become accustomed to changes in the river's appearance may have a negative effect on the community's social well-being in the short-term. Increased use of the river and the need for infrastructure and access may also be viewed as an adverse impact of rehabilitation.

Enhancing the environmental quality of the watershed should improve the social well-being of the community (Noss and Cooperrider 1994). Studies have shown that buyers are willing to pay more for property with higher environmental amenities such as cleaner water, more natural areas, or greater biological diversity (Freeman 1995). This fact serves as evidence that the well-being of the communities is also being increased as environmental quality improves.

Both formal and informal educational opportunities could increase as a result of rehabilitating the DRS. For example, people of all ages could experience the DRS through field trips, interpretive centers, and nature discovery networks, and school curriculums could include lessons from the river and the rehabilitation process.

While, in general, the proposed rehabilitation is seen as a benefit to the general public's social well-being, some individuals may disagree. People who are satisfied with or benefit from the status quo may be resistant to change. Our study did not assess community attitudes at a level sufficient to fully address these issues. Nonetheless, it is important to realize that change will occur with or without the project. In this regard, rehabilitation provides the opportunity to actively plan the directions of change and to address current trends such as the loss of agricultural land in the watershed. In addition, if the rehabilitation plan fails to include approaches that benefit the community's well-being and avoid adverse impacts, then the benefits to the public are not likely to be realized.

4.1.9.2 Farmers within the Rehabilitation Area

In general, two effects are anticipated as results of rehabilitation: a loss of some land for farming and a possible increase in land value within the rehabilitation area. These project effects could lead to changes in how a farmer can use his/her land, the opportunity cost of farming, and the tax value of the land. At the individual level, some farmers will gain from these changes and some farmers will be adversely affected. As a collective, a significant reduction in the amount of farming in the area could affect the viability of farming in the area.

Loss of agricultural land is an existing trend in the watershed area (Census of Agriculture 1959-92). If exurban development pressures increase, this trends will likely be accelerated (Lisansky 1986; Hirschl and Bills 1994; Nelson 1992). Therefore, similar social impacts on farmers are likely either with or without the project. The difference is that the rehabilitation process offers the opportunity to involve farmers and to help protect future losses of farmland in the area. On the other hand, rehabilitation might also accelerate the process of agricultural land loss by making the riparian area more appealing to developers.

Changes in drainage could have a negative effect on how farmers are able to use some lands. Agricultural property that is located in the high sensitivity area (Plate 1) could experience a decrease in drainage regardless of whether a riparian farmer chooses to participate in the rehabilitation process. Therefore, even though MEANDRS does not intend to physically take land or impose mandatory zoning in the rehabilitation area, some farmers may face limitations to their current farming operations.

Rehabilitation is expected to increase land value along the river by creating a more pleasant place to live and by increasing the quality of environmental amenities (Freeman 1995). This may cause a change in the use of a farmer's land, which could impact their status and role in the community. As a result, some farmers may experience social and psychological effects related to losses of income, livelihood, and identity associated with losing one's personal business.

If enough land is impacted, it may affect an individual farmer's ability to continue farming. A gain in land value may offset some effects of the loss of land. However, the cumulative effects on the agricultural community are expected to be negative. At the same time, some farmers may see this change as an opportunity to sell their land, especially if property values increase. Since fewer people are choosing farming as an occupation (Census of Agriculture 1992), older farmers in the area may already be planning to sell their land and retire.

Rehabilitation does provide opportunities to improve the social well-being of farmers. MEANDRS could work with farmers to develop strategies that sustain farming (Nelson 1992) and improve the river's environment at the same time. A number of farmland preservation tools are presented in Appendix 5. Farmers who view themselves as stewards of the land may be more willing to develop mutually beneficial rehabilitation outcomes. For example, if MEANDRS can work farmland protection into the rehabilitation effort, then farmers as a group could gain in terms of maintaining the viability of agriculture. Another option may be to promote self-pick farms in the area, capitalizing on the potential increase in recreational tourism in the watershed.

4.1.9.3 Riparian Landowners

Riparian landowners are expected to experience some changes in their social well-being as a result of the proposed rehabilitation. Specifically, their property values are expected to increase due to improvements in the environmental quality of the DRS, and they are expected to have some of their lands impacted due to a rise in the groundwater table and the resulting change in drainage potential. Depending on how recreational use is managed, individual riparian landowners may also be affected by an increase in recreational activity associated with the river.

Without the project, there is not likely to be a change in the relationship between riparian landowners and the river. However, there may be a slight decrease to the scenic quality of the river in certain locations, due to possible increased erosion and water quality problems.

Improving the hydrology, channel morphology, environmental quality, and visual quality of the river will result in social benefits to riparian landowners. Since they live on the river, riparian landowners especially will experience the benefits of rehabilitation on a regular basis. For example, by removing the high banks currently present, riparian landowners will have an improved view of the river. Reconnecting the floodplain and changing the river's morphology will place their property in a more natural and ecologically healthy setting, and they could fish for trout. As discussed in Section 4.1.9.1, improving these environmental amenities will increase the value of their property (Freeman 1995).

A possible negative impact to riparian landowners is that they may be subject to increased annoyances, infringements of legal rights, misuse or abuse of their land, and liabilities as a result of anticipated increases in recreation use of the river and adjacent lands. However, many people live adjacent to public resources such as rivers, enjoying the benefits while experiencing limited negative impacts on their lives. MEANDRS and riparian landowners should keep in mind that the river is a public resource and riparian landowners have legally assumed both the positive and the potential negative aspects of owning adjacent land. Also, the rehabilitation process could present an opportunity to address current conflicts between landowners and recreational users.

The balance between the advantages and disadvantages will depend significantly on the final rehabilitation plan. For example, if the levels of access and use are carefully planned and managed, the likelihood of overuse and abuse should be diminished. By working closely with riparian landowners, the appropriate level of use and access will be determined. In addition, establishing rules and special ordinances such as prohibiting alcohol on the river could minimize inappropriate behavior. However, if use increases without any planning or management, current problems with trespassing, noise, and littering are likely to get worse, thereby reducing the social well-being of riparian landowners. This would also alienate riparian landowners from the project and reduce the chance of long-term success. Therefore, a trade-off exists for riparian landowners between a potential increase in conflict with users and increasing the value of riparian lands and improving the scenic quality.

4.1.9.4 Recreational Users

Recreational users will benefit substantially from the increase in quality and diversity of recreational opportunities anticipated from rehabilitation. These changes will benefit current and future recreational users in the DRS by increasing the quality of the experience.

Presently many people living in the Dowagiac River watershed take advantage of existing recreational opportunities for fishing, canoeing, and hiking in public areas such as Dodd Park or Dowagiac Woods. The Dowagiac River in its degraded state does not provide high-quality trout fishing. If trout fishing and other recreational opportunities along with needed infrastructure were improved, it is anticipated that more people outside of the local area would take advantage of the increased recreational potential of the DRS (Hoehn *et al.* 1996).

Without rehabilitation, there will likely be a gradual decrease in the social benefits of recreation. For example, channelization causes bank instability and erosion (Rosgen 1993, 1996). The result is a degraded aquatic and riparian environment for recreation including washed out banks, trees falling across the river, decreased water quality, and excessive siltation. The low power nature of the river, the degree of channel incision, and the height of spoil banks makes it difficult for the river to rehabilitate itself over time (Brookes 1995).

As discussed in Section 4.1.7, changing the hydraulics and channel morphology of the DRS will enhance instream recreation like fishing and canoeing, as well as off-stream recreational opportunities such as hiking, bird watching, and nature discovery. Hoehn *et al.* (1996) found the quality of streams to be a significant determinant of their recreational value and demand. Improvements in water quality, aesthetics, and the natural integrity of the DRS will also benefit recreational users directly, making the experience more pleasant and memorable.

In addition to improving fishing opportunities, rehabilitation could also benefit psychological and philosophical aspects of fishing and other recreational experiences, as people desire and benefit from more than just the physical act of recreation. For example, many anglers do not participate in the activity purely for the purpose of catching fish. Being part of the natural setting and feeling connected to the river is also part of the experience (Vaughan and Russell 1982; Driver and Knopt in Fedler and Ditton 1994); these aspects should be considered when planning the rehabilitation.

The disadvantages of rehabilitation to the well-being of recreational users focus around the level of use. As discussed in Section 4.1.7, improving the recreational potential may lead to crowding, overuse, and unwanted behavior such as littering, trespassing, and excessive noise. As with riparian landowners, adequate planning and management are essential to avoiding any negative effects on the well-being of recreational users.

4.2 Summary of Results

As part of assessing the feasibility of rehabilitation, it is important to consider the interactions between criteria evaluated. In Section 4.1, we discussed the results for each evaluation criterion separately, with limited discussion of the relationships between criteria or their compound effects. Table 1 summarizes our findings. However, many important relationships exist between the evaluation criteria. Therefore, in this section we discuss our findings in an integrated manner, highlighting interactions among categories and providing a holistic view of the predicted changes and effects resulting from rehabilitation.

Currently, the channelized nature of the river prevents the DRS from meeting its ecological and recreational potential by creating extreme hydraulic and morphologic conditions. Channelization causes extreme velocities and homogenous habitat conditions, creating instream habitat that is too harsh for many species to survive. In contrast, meandering systems have natural pool-riffle sequences that provide more diverse habitat conditions needed for feeding, resting, development, and breeding. Disconnection from the floodplain reduces critical ecological functions such as nutrient cycling, sediment regulation, and breeding/nursery habitat, as well as decreasing the hydrologic stability of the system (Appendices 2 and 3). Improving channel morphology, reconnecting the floodplain, establishing the natural riparian vegetation zonation, creating new wetlands, and preserving open space and natural resources through rehabilitation will enhance the quality and diversity of aquatic and floodplain habitat. Streams with stable discharges, heterogeneous velocities, and diverse habitats throughout the channel system yield more robust biological communities (Allan 1995; Poff and Ward 1989). Therefore, reconnecting the river to its floodplain and adding meanders back into the channel should substantially improve the ecological functions and quality of the DRS.

In addition to improving the ecological functions of the DRS, rehabilitation could result in many substantial benefits to watershed communities. These benefits include increasing the quality and diversity of recreational opportunities in the watershed, stimulating the local economy, and enhancing the social well-being of many watershed residents.

Changing the morphology, hydrology, and biology as proposed should greatly increase the recreational potential of the DRS (Section 4.1.7). Anticipated habitat improvements should help establish a naturally reproducing coldwater fishery. Morphological improvements could help create a more aesthetically pleasing environment for both instream and off-stream recreational activities. Combined with a well-thought-out recreation plan, these changes could enhance opportunities for activities such as fishing, canoeing, hiking, and nature discovery.

Rivers with high groundwater delivery, heterogeneous substrate, high baseflow, and stable discharge typically meet the habitat requirements for trout (Hunter 1991). Rivers of substantial size with sustainable populations of trout and high aesthetic qualities are prime recreational resources (Hendrickson and Doonan 1972). Coldwater river systems in the northern part of the state are tremendous economic assets to the surrounding communities. Under more natural conditions, the recreation potential of the Dowagiac River could rival northern coldwater rivers like the AuSable and Manistee Rivers, making the Dowagiac River a rare resource for southern Michigan and the Midwest.

Benefits are expected to extend well beyond the watershed boundaries of the DRS. By creating a sustainable coldwater fishery, anglers from large population centers such as Kalamazoo, MI, South Bend, IN, and Chicago, IL will be within a two-hour's drive, and a potentially shorter train ride, of a large trout fishery. Improving the diversity of current velocities, channel patterns, and river scenery could also make activities like canoeing a more pleasant and rewarding experience, potentially drawing from a more regional user group (Hendrickson and Doonan, 1972).

The local economy could receive a substantial boost from anticipated ecological and recreational improvements (Diamont *et al.* 1984). Studies have found that outdoor recreation, especially trout fishing, has significant economic value (Burt and Brewer 1971; Vaughan and Russell 1982; Hoehn *et al.* 1996). Much of the economic boost will come from an increase in demand for services such as angler shops, canoe liveries, guide services, restaurants, and gas stations brought about by visiting recreational users. Rehabilitation will help recover recreation's economic value, which was reduced when the decision to channelize the river was made (Caldwell 1991).

An increase in the recreational potential of the DRS and associated economic boost should have major benefits to the social well-being of recreational users. Studies have shown that many variables, including the aesthetic quality of the resource, are at least as important to participants as the presence of fish to catch (Vaughan and Russell 1982). Therefore, creating a more natural setting and aesthetically pleasing environment consisting of hiking trails, parks, and river access points is as important as the presence of trout (Diamont *et al.* 1984).

In addition to economic benefits, the general public may gain in terms of social well-being due to an increased sense of pride and ownership associated with the DRS becoming a popular destination for recreation. Aesthetic improvements are often a substantial community benefit of rehabilitation efforts (Higgs 1997; Caldwell 1991). The general public will also benefit from knowing that the resource will be in a more natural condition, redeeming destructive past actions, and providing new opportunities for current and future generations (Higgs 1997). In this context, rehabilitating the DRS can be seen as an investment in which an individual hopes to receive dividends in the future when the river is restored to a more natural state. (Diamont *et al.* 1984; Noss and Cooperrider 1994). This could help people who live in the watershed identify more with the river as an important and special feature of their community, thereby creating a sense that the watershed is their home place.

Other indirect benefits associated with enhancing the ecological function of the DRS include reducing non-point source runoff, improving the waste assimilation capacity of the river, reducing the amount of erosion and bank degradation, and increasing educational opportunities associated with the river.

While there are substantial potential benefits to the proposed rehabilitation, it is equally important to consider possible adverse effects. The main areas of concern center around impacts to agriculture, related effects on the local economy, potential issues associated with an increase in recreational use, and monetary costs of the project. Through careful and conscientious planning, MEANDRS can develop a project that avoids, minimizes, or mitigates these effects. Some recommended strategies are discussed in Section 5.

Due to the agricultural nature of the watershed, the potential effects of rehabilitation on the drainage characteristics of the land are a critical issue. The characteristics of topography, physiography, and hydrology in the DRS (Appendix 2) result in a relatively high groundwater table. A high groundwater table can impede land uses including certain agricultural practices (see Section 3.5). As discussed in Section 2.3.1, channelization and drain construction are deliberate attempts to dry out land in areas with a high water table in order to control moisture content of the soil, making the land more amenable to agriculture.

Section 4.1.1 describes how the groundwater table is expected to change as a result of rehabilitation. In general, lengthening the Dowagiac River by adding meanders will slow the movement of water through the system causing the water table to rise in some areas of the watershed. Based on the groundwater map and other data previously discussed, four groundwater sensitivity areas were identified within the DRS. Some residential properties in the high sensitivity area may also be affected, possibly losing land to inundation or basement flooding problems.

The impact on drainage is largely an issue that affects agriculture properties on a case-by-case basis. In other words, certain farms or parts of farms will be affected while others will experience little or no effect. Issues such as the type of farm (pasture versus crop), the type of crop (corn versus cucumbers), and the location of the farm (headwaters versus middle reach) all determine the site-specific effect that a rise in the water table will have. For the most part, our analysis could not consider these site-specific issues. Our analysis used a conservative approach by considering the drainage needs of field corn, which are substantially more demanding than most other crops found in the watershed.

The social well-being of farmers could change as a result of the proposed rehabilitation. This largely depends on decisions made by the individual farmer. Rehabilitation will likely increase the value of land along the river due to improved aesthetic quality, environmental amenities, and enhanced recreational opportunities. As a result, the opportunity cost of farming will increase, which could lead to some farmers deciding to sell their farm. The increased development potential along the river could also make farmland a prime target for real-estate investors. However, MEANDRS could acquire some rights to these parcels of land.

Currently, there is a decreasing trend in the amount of farming in the watershed (Census of Agriculture 1959-1992). The loss of land due to rehabilitation may serve to accelerate this trend, and decrease the viability of farming in the area. A decrease in the number of farmers affects their critical mass and leads to impermanence syndrome as discussed in Section 4.1.7 (Lisansky 1989; Hirschl and Bills 1994; Nelson 1992). The rehabilitation decision process presents an opportunity to address this problem and work to preserve and protect farmland in the DRS. For example, the rehabilitation plan could include or promote programs that put development restrictions on farmland or increased incentives to keep land in agricultural production, such as tax breaks. These and other strategies will be discussed further in Section 5.

Increased recreational potential could also lead to conflicts over use of the river corridor. As improvements are made that provide recreation opportunities, more people will come to the DRS. Many people are concerned that increased recreational potential will lead to overuse of the river, and an increase in disrespectful and destructive behavior (MSU Extension 1997). In addition, citizens may be opposed to developing new access points or infrastructure associated with recreational use. These attractions may lead to problems and nuisances for riparian landowners, as discussed in Section 4.1.7. Therefore, while recreational potential is seen as a major benefit of rehabilitation, it is not without its costs.

It is important to remember, however, that riparian landowners have chosen to live on a public resource and therefore should be somewhat accepting of the associated problems as they enjoy the many benefits. It is also important to keep in mind that many people live happily adjacent to public resources such as rivers. By choosing to live in these locations, they have demonstrated a conscious decision that the benefits were greater than the costs. While it is important to respect the concerns of riparian landowners and to keep them involved, MEANDRS needs to remember that in general, limits on some individual's freedom can be acceptable in protecting or enhancing the interests of the whole (Cairns 1995).

4.3 Synthesis

The purpose of this section is to tie together the effects of the proposed rehabilitation, beginning to address the question of feasibility. However, based on our findings, we feel that the ultimate decision regarding feasibility falls on MEANDRS. This group must consider the anticipated benefits and potential adverse effects in terms of both the agricultural context of the watershed, and the various stakeholders involved. Essential to achieving their goal, Meeting the Ecological and Agricultural Needs within the Dowagiac River System, is the development of a rehabilitation plan and strategy that realizes the ecological and recreational potentials of the river system within the agricultural context of the region.

Due to their dynamic nature, complex structure, and large landscape scale, river systems pose special challenges to natural resource decision-makers. Rivers also serve many important functions in the human landscape. Therefore, it is necessary to consider management decisions both within the natural environment and within the context of the social and economic conditions of their watershed and region. However, the complexity and diversity of these functions often result in conflicts around competing uses, making management decisions like rehabilitation even more difficult.

In the case of the DRS, there is an interest on the part of some citizens in shifting management strategies from one that focuses on the utility of the river as a drainage system, to one that balances ecological and recreational potentials with agricultural needs. This will involve an intervention where the system is rehabilitated in a way that realizes ecological potentials, while minimizing adverse impacts. The fact that managing the river system for drainage is the status quo makes rehabilitation a challenge no matter how substantial the benefits are. The uncertainty associated with these potential changes constitutes much of the concern over rehabilitation. Since the DRS is not in an obvious stage of crisis, watershed residents may lean in favor of maintaining the status quo unless concrete and clear benefits of rehabilitation are made public, stakeholder interests are heard, and adverse impacts are addressed.

In order to assess the feasibility of pursuing rehabilitation within the physical, biological, economic, and social settings of the Dowagiac River watershed, we need to identify who or what will gain from the benefits, and who or what could be adversely impacted. It is also important to consider to what degree stakeholders and institutions are affected.

Improvements to the DRS discussed in Section 4.1.9 will largely benefit the general public and recreational users both within and outside of the watershed. These benefits will come from knowing and appreciating that the ecosystem is healthier, participating in improved recreational opportunities, sharing in the economic gains, and enjoying the enhanced aesthetic quality of the watershed. Economic gains associated with improving environmental amenities, increasing recreational potential, and maintaining the agricultural viability of the region could be substantial. Less tangible but equally important benefits, such as increases in community pride and identity, come from an increased connection to the watershed.

When considering these less tangible benefits, it is important to keep in mind that some people may feel that the potential loss of farmland associated with rehabilitation is a more critical issue than the rehabilitation benefits. Therefore, these individuals may not enjoy all the benefits associated with rehabilitation as rehabilitation involves the loss of something they value dearly (farmland and agricultural character) in exchange for something they do not value as much (ecological enhancements to the DRS). However, the agricultural nature of the watershed may be threatened even in the absence of rehabilitation; while rehabilitation may exacerbate this process or offer opportunities to minimize and control this process, leaving the river as it is will not guarantee protection of the area's rural character.

Due to predicted changes in drainage capacity of some lands in the watershed, effects on agriculture are anticipated to be a major concern. MEANDRS can minimize these effects by focusing on areas most favorable to rehabilitation, namely the very low to moderate sensitivity areas (Plate 1). Using our GIS analysis as a guide, MEANDRS can identify areas where hydrologic conditions are less likely to cause a significant change in drainage or where land uses are more compatible with wetter conditions (e.g., forested areas). Plate 1 shows a large area of moderate to low sensitivity stretching from Pucker Street Dam approximately five miles upstream to the area where Peavine Creek joins the river. We recommend that MEANDRS focus their efforts on this portion of the river.

Focusing on this reach of the river has several benefits, in addition to being an area of lower sensitivity to changes in drainage. First, the dominant land use in this area is forest and open space according to the 1978 MIRIS land use coverage. This will need to be confirmed in the field or with a future land use coverage[13]. Some of this area includes public and conservation lands such as Arthur Dodd Memorial Park and Dowagiac Woods, respectively. Supportive private landowners living along this reach of the river may be willing to incorporate portions of their property into the project as well. By adopting this strategy, effects on agriculture are likely to be quite low, relative to benefits associated with rehabilitation.

Initially focusing on the lower reaches of the river has several added benefits. For one, it enables MEANDRS to adopt an adaptive management strategy that monitors for changes in the groundwater table upstream from a rehabilitation site. The groundwater table will respond to changes in river morphology and hydrology in an upstream direction. Therefore, if rehabilitation were designed to progress upstream, the resulting change could be monitored and assessed in a controlled fashion. Essentially, rehabilitation would proceed in an iterative fashion, gradually moving upstream as the hydrologic response is understood. Furthermore, as noted by Moffett (1940) channelization was determined after the fact to be more than was needed to adequately enhance drainage. In other words, the river was dug deeper and wider than necessary. Therefore, some leeway may already exist in terms of changing the drainage capacity of lands in the watershed.

An adaptive management approach also provides the opportunity to monitor and assess the biological responses to rehabilitation. This portion of the river has a greater potential for habitat improvements based on existing hydrology and morphology (Appendix 2). In addition, if the effects of a rise in the water table extend beyond the "feasible" reach into

[13] Western Michigan University is in the process of creating a 1995 land use digital coverage, which is expected to be ready in July, 1998.

the high sensitive area, then the first land uses encountered would be mostly forest or non-agricultural. This will provide a buffer that can serve as a safety net if the effects are greater than anticipated and would allow for alternative approaches to be taken or further studies to be conducted. This strategy provides protection from major changes in drainage to portions of the watershed with larger amounts of agriculture.

Finally, the section of river being recommended for rehabilitation appears to be the same portion of the river that was a well-established meandering channel prior to channelization (Figure 11). Before channelization, drainage in the headwaters area was likely more diffuse due to the characteristics of the soils, topography, and extensive presettlement wetlands. Focussing the rehabilitation effort in that section of the river has benefits in terms of engineering, construction, and long-term stability; taking advantage of existing meander fragments and remaining bends in the channel.

Farmers as a whole could be negatively affected by rehabilitation. For rehabilitation to be accepted in the community, MEANDRS must recognize and minimize or mitigate these adverse effects on the watershed’s agriculture. In doing this, MEANDRS can help stabilize the declining agricultural trend, making rehabilitation an asset to the agricultural community. Section 5 discusses some strategies and approaches for achieving this goal, such as establishing a program to purchase development rights (PDR), promoting a change in local tax laws that reduce the liability to agriculture, and working with government programs such as the Wetland Reserve Program.

The economic and social benefits related to enhancing the recreational potential of the DRS should out-weigh potential adverse impacts associated with an increased use of the river. To avoid and minimize these potential adverse impacts, it is very important to develop a recreation plan that adequately addresses the concerns of people in the watershed, especially riparian landowners. Some level of infrastructure is also necessary to properly manage the resource and avoid problems such as trespassing and littering.

There are several additional impediments to rehabilitation that were not a focus of our assessment but are important for MEANDRS to consider. In order to achieve the desired outcome, MEANDRS needs to acquire or access to land for reconstructing meanders and reconnecting the floodplain. Likewise, rehabilitation would change land patterns along the river, an issue that could be dealt with best by acquiring riparian lands. In addition to creating more wetlands and reconnecting the floodplain, meanders would cause the river to cut a new path through people’s property. Therefore, public and private property owners must be willing to be part of the project if rehabilitation is to be a success.

MEANDRS must recognize that there will be substantial engineering and construction costs associated with rehabilitation. While our analysis of the local economy indicates a likely influx of money into the community from the project, MEANDRS will need to muster significant financial support.

As discussed in Section 2.3.4, there are a number of engineering considerations that must be addressed if river rehabilitation is to be successful. The river has become incised as a result of channelization and subsequent adjustment processes and reestablishing a functional gradient will prove to be challenging. The incision of the river has also disconnected the river from its floodplain and this situation must be remedied if the physical and biological functions of the river are to be restored. Finally, original floodplain soils (seed banks) and original stream-bottom sediments must be retained.

Section 5 – Recommendations

This section highlights our recommendations in bulleted form, then provides a more detailed explanation in the text that follows. Physical and biological issues are presented in the first four sections. Stakeholder concerns and interests are presented under the headings of Community Participants, Farmers, and Riparian Landowners. Rather than specific recommendations on funding issues, the last section contains a number of questions that have been provided for MEANDRS to consider as they seek outside sources of project funding.

5.1 Drainage Issues and Site Selection

- Choose locations for meander rehabilitation that minimize land-loss from flooding.
  - Sites from mid to lower reaches of the river are less sensitive to flooding.
  - Forested or open lands may provide more desirable sites than agricultural lands.

We recommend that MEANDRS use the groundwater sensitivity analysis maps (Plate 1) as a guide for selecting rehabilitation sites for meanders. The lower sections of the watershed, such as the area around Dodd Park, show less likelihood of flooding. Plate 1 shows an area of low to moderate sensitivity stretching from Pucker Street Dam approximately five miles upstream to the area where Peavine Creek joins the Dowagiac River. In contrast, the upper regions of the watershed, which are influenced by the former Dowagiac Swamp, contain poorly drained hydric soils and low slopes.

The potentially negative effects of increased wetlands and loss of useable riparian lands can be mitigated by carefully choosing sites for rehabilitation from the middle to lower stretches of the river and working upstream. This recommendation is similar to the one made in the 1940s for the Gates drain located in Paw Paw, MI (Dowd 1991). Adaptive management and monitoring are recommended to assess whether to continue further upstream. That is, if the river begins to back up – drainage becoming poorer in areas that affect farming, further rehabilitation may not be desirable. There is also less agricultural land along the downstream reaches, which could make it easier to purchase properties or secure conservation easements. It may be that there will be some additional leeway in terms of changing the drainage capacity since Moffett (1940) found that the river had been dug deeper and wider than necessary and riparian farmers were complaining that their soils were excessively drained.

In forested areas, an increase in the elevation of the water table and the creation of wetlands may be particularly beneficial since it could result in the creation of additional floodplain habitat, and increased waterfowl and small game hunting opportunities.

5.2 Channel Rehabilitation Issues

- Rehabilitation to conditions similar to a comparable undisturbed river system is more practical than rehabilitation to a pre-disturbance condition.
- Utilize a holistic approach, which uses principles of fluvial geomorphology and hydrology to emulate natural forms and processes within the DRS.
- Anticipate and prepare for how future catchment land use changes will affect the restored channel.
- River channels are complex and dynamic systems. Features such as pools and riffles should be allowed to develop and redistribute sediments naturally. A natural floodplain allows for seasonal flooding and a recharge of the groundwater table.
- Long-term monitoring and maintenance programs should be established and funded.

Brookes (1995) noted that rehabilitation to a pre-disturbed condition may not be as appropriate (or as feasible) as rehabilitation to the present condition of a similar more natural river system. This is because over time, both naturally-occurring and human-induced alterations in a catchment’s landform and hydrology influence the dynamic equilibrium of fluvial systems. The current level of development within the DRS has most likely influenced the river system beyond the point to which it could realistically be returned to a predisturbance condition.

A holistic approach to river rehabilitation looks at a wide variety of interdisciplinary factors influential to shaping river systems, and attempts to emulate the natural forms and processes found within these systems (Brookes 1987; Petts 1995). In contrast, approaches that are more traditional are often limited to single objectives and therefore, only allow for a narrow range of conditions that are often exceeded. Holistic approaches have been successfully applied in a number of projects (Brookes 1995; Petts 1995), and this approach can be used to recreate the hydraulic conditions that determine where organisms live within the DRS. This holistic approach can also be used to address current and future changes in land use, as well as hydrologic and recreational interactions between humans and the river system.

Another important component of the holistic approach is to refrain from over-managing the rehabilitated channel. As previously discussed, the dynamic nature of fluvial systems works to reach equilibrium. Rehabilitated rivers should be allowed to modify and adjust their features naturally, including the development of pools and riffles, as well as the localized erosion and deposition of sediments (Brookes 1987). Allowing the river to adjust itself will not only produce a more natural system, but will cost less in the long run if managers let the river do most of the work. Areas undergoing excessive modification, such as the development of knickpoints – small drops in elevation of the stream bottom that erode towards the head of the stream, or undermining of bridges, should be protected using engineering controls (Brookes 1987). Rehabilitated rivers should also be permitted to extend onto the floodplain so that the natural floodplain functions, which dissipate energy, floodwaters, and sediments, can be reestablished.

Long-term monitoring and maintenance programs should be established and funded to enhance the viability of the rehabilitation. Monitoring of the physical characteristics as well as the biological communities prior to, during, and after the construction phase is critical to the success of the project. Monitoring allows managers to determine if the project has successfully met its objectives or not (Brookes 1987, 1990; NRC 1992), and it also helps managers to know when, where, and what needs to be maintained. Many rehabilitation projects lack adequate funding for long-term monitoring programs (NRC 1992); the acquisition of these funds should be a priority for MEANDRS. Monitoring should be performed frequently, immediately following construction activities, and with decreasing frequency once systems begin to stabilize.

5.3 Biological Issues

- Include floodplain connection as part of the rehabilitation to reestablish the link between the upland forest and the river.
- Field trips to more natural river systems are recommended for comparison.
- Identify and fill in data gaps for biological studies.
- Establish a long-term monitoring program.
- Use native plant species for immediate bank stabilization and other rehabilitation.
- Short-term habitat improvement may be needed to foster project success.
- Watch for establishment of invasive species and implement controls to prevent their establishment.

It is highly recommended that some connections with the floodplain be reestablished in order to re-create a more natural riparian ecosystem with first bottoms or backswamps, and second bottoms. Since the river is incised, reconstruction efforts may involve excavating or bringing the floodplain down to the level of the river in places. It would be helpful for rehabilitation planners to visit and examine the character and functioning of similar river systems that have remained more natural. One possible reference site is the Pigeon River Sanctuary, owned by Michigan Nature Association. This site is detailed under the unique plant communities in the Biological Profile. The Augusta floodplain of the Kalamazoo River, owned by The Nature Conservancy is another possible reference site that has been well documented by Michigan Natural Features Inventory. Although further away, it might be helpful to visit some of the northern Michigan trout streams with similar geology to the Dowagiac River.

Gaps in biological data, such as information on aquatic invertebrates, amphibians, and reptiles found along the DRS, should be identified and assessment studies performed. As previously mentioned in Section 5.2, a long-term monitoring program needs to be established and funded.

After implementation, certain enhancement activities may be necessary for the system to stabilize in a reasonable time frame. Establishment of an immediate vegetative cover for bank stabilization is imperative. Plantings of grass can reduce water velocities at boundary layers where erosion takes place by as much as 90% (Brooks 1987), resulting in less erosion of riverbanks. Use of native plant material is recommended for bank stabilization and to reestablish the natural river bank vegetation. Use of sapling shrubs and trees along with an initial planting of grass will speed up the process of native vegetation reestablishment, and make it less likely that invasive plant species such as common buckthorn (*Rhamnus carthartica*) will become established. Some existing vegetation may be saved during construction and replanted after construction to reduce costs and speed vegetative recovery.

Enhancements to the river channel itself may be desirable. It may take several seasons for the river to sufficiently sort the substrate. Therefore, it may be necessary to boost short-term habitat improvement by adding gravel and cobbles to the channel, thereby creating needed habitat faster than would have occurred naturally. Until a self-sustaining population becomes established there will be a need to stock trout each season.

Construction of meanders will result in disturbance to aquatic and riparian areas. Invasive species, such as purple loosestrife (*Lythrum salicaria*) or zebra mussels (*Dreissena polymorpha*), could become established as a result. Disturbance weakens biological communities, allowing aggressive colonizing species to become established. For example, bare soil from construction projects is frequently colonized by purple loosestrife. In addition, an increase in fishermen using and area's streams provides additional opportunities for aquatic pest species to be accidentally introduced on fishing boats and gear, or via disposal of unused live bait. Preventing the establishment of invasive species is the most effective way to address this threat. If establishment of invasive species is noticed, early and immediate control will be necessary to maintain a more natural aquatic or terrestrial community.

5.4 Water Quality

- Stream quality cannot be disassociated from existing conditions in the watershed.
- Protection of sensitive groundwater recharge areas will help to alleviate possible groundwater contamination.
- Best Management Practices (BMPs) can be used to mitigate the deleterious effects of development on water quality.

Stream water quality is directly linked to existing conditions within a watershed (Brookes 1995). As water quality is so dependent on catchment conditions, all water quality protection activities should involve remediating the pollution source within the catchment.

One of the most effective means to protect groundwater recharge areas is with vegetative buffer strips (Large and Petts 1996). Vegetation absorbs some toxic pollutants and prevents them from entering the groundwater.

Management practices can be, and have been, used to mitigate the deleterious effects of development on water quality. The use of BMPs, which are land management techniques, and other tools, such as watershed management, are increasingly being encouraged by water quality management agencies to control soil erosion, non-point source pollution, faulty septic systems, and other issues associated with rural land use.

5.5 Community Participants

- Develop educational/outreach materials.
- Promote and pursue existing and future watershed level and regional planning efforts.
- Consider incentive and cost-sharing programs to encourage participation.
- If appropriate, involve additional stakeholders such as Michigan Nature Association.
- A multi-functional view of the rehabilitation project should be taken.
- River restoration efforts will depend on the negotiation skills of MEANDRS and the goodwill and cooperation of landowners.
- Develop a negotiation forum to discuss mitigation and compensation options.

Educational materials need to emphasize the uniqueness of the Dowagiac River System and why this is a resource worthy of conservation. The river's importance, in the context of the entire southwestern Michigan region, needs to be explained. What is involved in a pilot meander rehabilitation and what the group expects to learn should be described. Educational materials need to explain what rehabilitation might mean for the DRS as a social and ecological system. People need to be made aware of the benefits of rehabilitation, and how they might gain from these changes. Materials should include information on the physical, biological, economic, and social aspects of the watershed.

Following are some specific suggestions for materials that could be developed. A brochure describing MEANDRS and their goals is needed so that the community can gain a better understanding of their mission. Using "Russ Forest Days" and similar events to target school children is one possible approach. A lesson plan on the ecological and physical functions of rivers, including how and why meanders are formed, could be developed. The planned display at the Southwestern Michigan College Museum will be a useful educational program. A traveling exhibit could be used in local libraries, at appropriate meetings, at focus groups, and at county fairs. Adapting our slide show presentation for use at local clubs should also help foster interest in the Dowagiac River and rehabilitation.

A watershed approach to managing the DRS, as opposed to a more traditional approach based on political boundaries, will offer the community several benefits. Using a watershed focus to plan and construct the rehabilitation project will allow for both local and system-wide effects of land use change, thereby creating a better, more stable rehabilitation project. Planning for future changes within the watershed will also protect the community's investment in rehabilitation by making allowances for and managing watershed responses to land use changes within the basin. Otherwise, factors such as land use practices and upstream activities could nullify the effort over time. A watershed focus can also help bring the community together around a unifying interest and stimulate the community to plan for the future. Whether or not the rehabilitation project is undertaken, changes are coming to the area; without proper planning there could be undesirable consequences to riparian owners and communities in the watershed. Finally, community participation in the planning effort is essential to the project's acceptance and success.

Incentive programs that encourage public participation in rehabilitation efforts should be offered. Technical assistance programs and volunteer efforts such as community workdays would also encourage public participation. Cost sharing programs are another approach that could be used to foster a sense of ownership in the program.

At some point later in the rehabilitation effort, it may be necessary and desirable to involve additional stakeholders. Gaining the support of additional stakeholder groups would be useful not only for the support of their constituency, but for the collaboration and coordination of resources. If any rehabilitation efforts are planned in the vicinity of Dowagiac Woods, then Michigan Nature Association should be consulted. If rehabilitation is planned in Wayne Township, then TNC's Michigan Chapter should be consulted as the hydrology of one of their protected areas may be affected.

When evaluating a project in terms of benefits and costs, it is important to look for ways to offset any losses associated with a project. People need to be made aware of the disadvantages associated with rehabilitation and they must be included in the discussion on ways to avoid, minimize, or mitigate the adverse effects. MEANDRS should involve stakeholders in planning and negotiation sessions that include opportunities to identify acceptable means of compensating individuals adversely impacted by rehabilitation.

5.6 Farmers

- Continue to work with farmers and promote Best Management Practices.
- Continue to include area farmers in the rehabilitation process from the early stages.
- Pursue the Wetland Reserve Program to mitigate loss of land value.
- Use natural areas preservation to spur interest in farmland/open space preservation.
- Make use of conservation programs and strategies to obtain land for a river greenway.
- If a shift to specialty crops is feasible and desirable, provide educational materials and training via the MSU Cooperative Extension Service and the Natural Resource Conservation Service in Cass County.

A number of BMPs have been developed to reduce movement of soils, agricultural chemicals and other compounds, which may become non-point source (NPS) pollutants (Braden *et al*. 1994). A recent U.S. Environmental Protection Agency study reported that prevention of NPS pollution is less expensive, by a factor of four to ten, then remediating its impacts (Braden *et al*. 1994). Examples of BMPs include contours, terraces, sediment detention basins, conservation tillage, integrated pest and nutrient management, crop rotation, livestock fencing, and constructed wetlands (Braden *et al.* 1994; Tim *et al*. 1995).

The use of buffer or filter strips along riparian ecosystems is an additional control method. Riparian vegetated buffer strips, especially those situated on organic-rich soils, have significantly reduced the nutrient load of surface water and groundwater entering streams. This filtering effect is particularly effective in decreasing NPS pollution from agricultural areas before it enters adjacent aquatic systems (Large and Petts 1996).

MEANDRS has several members from the farming community, including William Westrate who is the group's current Chairman. In addition, local focus groups have invited farmers to participate. MEANDRS should continue to strive to maintain adequate representation and involvement of farmers along the Dowagiac River.

There are many conservation techniques available to protect both natural lands and farm lands. Appendix 5 contains a review of current natural and farmland conservation techniques. In Polk County, Iowa, a conservation board has been successful in encouraging farmers to sign up for 30 year easements under the Wetland Reserve Program; farmers get 75% of the value of the land back from the United States Department of Agriculture (USDA). Polk County then buys the remaining property rights and assumes any liabilities, such as recreational trespass (L. Lown, personal communication, 1997). Having to come up with only 25% of the funds needed to purchase desired land is a substantial cost savings for the county, making establishment of greenways more feasible.

In Washtenaw County, Michigan, PDR is being proposed as a strategy for protecting farmland. Often with PDRs, more of the original land value needs to be raised locally. The most economically viable farms in the area may be eligible for either state funds through PA 116 programs or USDA funds to fund part of the purchase price. PDRs are more suitable for prime farmland than marginal riparian lands. Transfer of Development Rights (TDRs) has been used successfully in several communities, but their use requires considerable planning effort by the local community. Since the Cass County Planning Commission is not as active as it was in the 1970s and 1980s, TDRs will be difficult to utilize effectively in Cass County.

To develop greenways along the river corridor, it may be possible to take advantage of planned giving options if establishing a protected river corridor is a long-term goal. One type of agreement that could work well is the lease-back agreement. This program works well with older farmers near retirement that do not have children wishing to continue the farming operation. The farmer gives his land to a land trust; the land trust then leases the land back to the farmer until he decides to retire, or dies. The land trust is assured of the land gift and does not have to face uncertainties related to donors changing their mind or contested wills. Also, probating a will is time consuming; with living trusts or lease-backs, the transfer of title is handled more efficiently.

One issue of concern is Amtrak's high-speed, daily train service to Chicago. This might lead to rapid urbanization of Cass County and the remainder of the watershed as a residential area for commuters. In turn, urbanization pressures could force a reduction in hog farming and a shift away from row crops. If a shift to specialty crops such as vegetables and fruits seems desirable, then supporting educational materials and training would be necessary. The traditional sources of agricultural information such as MSU Cooperative Extension Service and Cass County Natural Resource Conservation Service could help provide these materials if this trend develops.

5.7 Riparian Landowners

- Provide maintained access points to prevent conflicts with landowners.
- Provide adequate number of restroom facilities and appropriate level of other services.
- Educate the public on responsible use of river resources.
- Work cooperatively with both riparian residential owners and farmers.
    - Encourage voluntary participation of landowners.
    - Provide property tax relief incentives for participation.
    - Seek conservation easements where appropriate.
    - In natural areas, seek permission and promote a riparian trail system.
- Establish local ordinances controlling undesirable behavior on or along the river.
    - Example: banning consumption of alcohol in public.

By planning for increased use of the river, many potential conflicts between users and riparian landowners can be avoided. Maintaining public access sites and adequate restroom facilities is likely to lessen trespass problems. Conflicts among various users and riparian landowners could be lessened if pamphlets explaining responsible use of the river are available at river access points, fishing license distribution sites, and canoe liveries. Signage at public access sites can also be used to inform the public about behavior appropriate for the respectful use of the river resource. The Upper Manistee River Association currently provides signage listing appropriate behavior (P. Seelbach, Research Biology Specialist, MDNR - Fisheries Division, personal communication, 1998). Local ordinances, such as banning consumption of alcohol on the river, and fines for littering and refuse dumping should be considered.

Participation of private landowners is voluntary whether they are allowing meanders to be reconnected or becoming part of an organized greenway. However, landowners who do not participate may still be affected by either increased usage or a change in drainage due to a meander being reconnected upstream from them.

Property tax abatement may be one possible way to reward riparian landowners for their participation in the DRS rehabilitation project. For example, a landowner choosing to permit the rehabilitation of a meander, the establishment of a buffer along the river, or allowing public access, could be eligible for property tax relief for a defined period of time, usually 10 year increments. The landowners could extend their period of participation. However, if landowners choose to prematurely withdraw their lands from participation, they should owe the township the amount of relief they had previously received on the property taxes. This local program could be administered similarly to programs offered under Michigan PA 116 for farmland tax relief (refer to Appendix 5).

A planned greenway may be desirable in some of the natural areas along the river. MEANDRS should explore public sentiment over whether to use conservation easements or outright purchase of riverine property. A conservation easement, usually offered in perpetuity, is an agreement between the owner and a non-profit organization such as MEANDRS or the Southwestern Michigan Land Conservancy to limit development on the land. The easement document can be tailored to the individual landowner's needs and desires. Once registered as a deed restriction, it holds any future landowner to the same restrictions. An easement is not required to provide public access, but if both the landowner and the land trust agree that public access is permissible, then this provision needs to be clearly indicated in the document. Any special conditions, such as no hunting, need to be clearly specified as well.

5.8 Funding Issues

This section does not contain specific recommendations, but rather a series of questions for MEANDRS to consider as they attempt to find funding for the rehabilitation project. MEANDRS indicated that any rehabilitation activities would be paid for through outside funding sources (e.g., federal, state, and private grants). Outside grantors are likely to look at the economic viability of the project as well as assess the level of commitment of the community. Locally raised funds may help attract, or even be required by potential grantors, as it would reflect the community's desire and commitment to implement and maintain rehabilitation efforts.

Funding Questions to Consider:

- Opportunity cost – If money is spent for rehabilitation of the Dowagiac River, what other projects are NOT pursued?

- Will fishing and other recreation dollars offset the losses to agriculture and landowners?

- If a fisherman brings in an estimated $35.00 a day (J. Wesley, personal communication, 1997), how many years does it take to pay for even one meander restoration?

- Will MEANDRS need 10-15% local funding, thereby making a statement that the community is committed to the project, in order to gain the interest of outside grantors?

- Even with outside project funding, will there be sufficient funds to provide for maintenance (e.g., bank stabilization, excessive erosion control, etc.), continued monitoring, and upkeep of facilities such as parking lots and restrooms?

Section 6 – References

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Tables

Figures

Appendices