Report to the Michigan Legislature
in response to 2006 Public Act 34

Groundwater Conservation Advisory Council July 2007

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

In 2006 Michigan enacted new laws to manage large water withdrawals in the state using science as the basis for decision making. This report describes a "Water Withdrawal Assessment Process" that was designed in response to these new laws. The design of this process has Great Lakes regional context, as well as state and national contexts.

In 2001 the governors and premiers of Great Lakes states and provinces signed an Annex to the Great Lakes Charter. In Annex 2001 the governors and premiers reaffirm their commitment to the principles and provisions of the Charter and further commit to

> developing an enhanced water management system that is simple, durable, efficient, retains and respects authority within the Basin, and, most importantly, protects, conserves, restores, and improves the Waters and Water-Dependent Natural Resources of the Great Lakes Basin.

In order to adequately protect these, the governors and premiers committed to

> develop and implement a new common, resource-based conservation standard and apply it to new water withdrawal proposals from Waters of the Great Lakes Basin.

Among the principles on which a new decision-making standard would be based, Annex 2001 states two that are integral to understanding the motivation behind the work described in this report:

- *no significant adverse individual or cumulative impacts on the quantity and quality of the Waters and Water-Dependent Natural Resources of the Great Lakes Basin* (emphasis added); and
- compliance with applicable state, provincial, federal, and international laws and treaties.

Annex 2001 includes further commitments that are very pertinent to this report, including:

- establishing programs to manage and regulate new or increased withdrawals;
- implementing effective mechanisms for decision making and dispute resolution;
- developing a mechanism by which individual and cumulative impacts of water withdrawals can be assessed; and
- *improve the sources and applications of scientific information regarding the Waters of the Great Lakes Basin and the impacts of the withdrawals from various locations and water sources on the ecosystems* (emphasis added).

Two definitions in Annex 2001 are also relevant. "Waters of the Great Lakes Basin" means the Great Lakes and all streams, rivers, lakes, connecting channels, and other bodies of water, including tributary groundwater, within the Great Lakes Basin. "Water-Dependent Natural Resources" means the interacting components of land, water, and living organisms affected by the Waters of the Great Lakes Basin.

In December 2005, the Governors endorsed the Great Lakes-St. Lawrence River Basin Water Resources Compact. Each of the Great Lakes States, including Michigan, would need to adopt State legislation to implement the Compact within the State. When all States have so adopted the Compact into Law the agreement then moves to the U.S. Congress for final ratification. Michigan has previously taken steps to address important aspects of the Compact such as passage of 2003 PA 148 and a set of laws from February 2006 dealing with related issues. Nevertheless, additional work would be needed to ensure that Michigan conforms to language and requirements of the Compact should the State pursue such adoption.

In February 2006 Public Act 34 became law, together with four associated laws. Among other things, 2006 PA 34 reconstituted the Groundwater Conservation Advisory Council (the Council) within the Michigan Department of Natural Resources (MDNR). In addition to tasks assigned to the Council when it was originally formed by 2003 PA 148 within the Michigan Department of Environmental Quality (MDEQ), 2006 PA 34 required the Council to:

- develop criteria and indicators to evaluate the sustainability of the state's groundwater use;
- design and make recommendations regarding a water withdrawal assessment tool; and
- study and make recommendations as to whether the state should consider as part of its groundwater conservation programs, proposals to mitigate adverse impacts to the Waters of the State or to the Water-dependent Natural Resources of the State that may result from groundwater withdrawals.

Furthermore, the Council was required to consult with a technical advisory group it would form and with MDEQ, MDNR, and Michigan Department of Agriculture (MDA) to do all of the following:

- design a water withdrawal assessment tool that can be utilized to protect and conserve the Waters of the State and the Water-dependent Natural Resources of the State. The water withdrawal assessment tool shall be designed to be used by a person proposing a new or increased Large Quantity Withdrawal to assist in determining whether the proposed withdrawal may cause an adverse impact to the Waters of the State or to the Water-dependent Natural Resources of the State;
- make factually based recommendations for the policy-based parameters and variables of the water withdrawal assessment tool; and
- recommend an appropriate timetable for periodic updates or changes to the water withdrawal assessment tool or to the water withdrawal assessment tool's parameters or variables.

Finally, the Council was required to submit a report, approved by a majority of the voting members of the Council, to the Senate Majority Leader, the Speaker of the House of Representatives, and the standing committees of the legislature with jurisdiction primarily related to natural resources and the environment on our findings and recommendations. This document fulfills this final requirement.

Report Terminology

Four additional public acts became law concurrent with 2006 PA 34. These are public acts 33, 35, 36, and 37. Definitions of terms in this report, such as "Large Quantity Withdrawal," "Adverse Resource Impact," "Index Flow" and so on, are consistent with usage in these laws and are seldom restated within the report.

One term used in 2006 PA 34, "water withdrawal assessment tool" is not used further in this report. During our work, the Council determined that development of any tool could not be completely separated from the process within which that tool might be used. In particular, discussion of issues such as policy-based parameters, Adverse Resource Impacts, and mitigation within the context of developing a tool required consideration of both tool and process. In this report, therefore, the Council uses the term "Screening Tool" to describe an automated tool that can be used by a person proposing a new or increased Large Quantity Withdrawal to assist in determining whether or not the proposed withdrawal may cause an adverse impact to the Waters of the State or to the Water-dependent Natural Resources of the State. The Council uses the term "Impact Assessment Model" to describe the use of the Screening Tool or Site-specific Analysis to determine the degree of ecological risk for any specific withdrawal scenario. Considerations of mitigation and other policy determinations are included within the overarching decision structure termed the "Water Withdrawal Assessment Process."

This report contains frequent use of the term "authorization" in a variety of contexts discussing how the Water Withdrawal Assessment Process might work. The Council held some divergent opinions about the use of this term, indicating differing concepts of how the Water Withdrawal Assessment Process should work. Generally, these concepts contrasted use of the Water Withdrawal Assessment Process to inform individual decision-making with use for regulatory purposes. This report discusses the Water Withdrawal Assessment Process within a decision-making framework, using the term "authorization" to denote an agreement that a water withdrawal is not likely to cause an Adverse Resource Impact. The Council acknowledges a range of water management roles and responsibilities for private citizens and government. We recognize that both the concept of how the process should be used to manage water withdrawals, and various authorization responsibilities, will need to be clearly defined in further discussions among interested parties.

Purpose and Scope

The purpose of this report is to address the charges to the Council set forth in 2006 PA 34. The scope of this report is primarily focused on the Water Withdrawal Assessment Process and the Impact Assessment Model. This report only briefly describes the technical aspects of the Impact Assessment Model with the intent of providing a basic understanding of how it works and how it relates to the Water Withdrawal Assessment Process. The technical design team that worked on the Impact Assessment Model and its component models will publish peer-reviewed reports describing the underlying science.

A large amount of material describing Council meetings, discussions, and subcommittees is available on the Internet and is not reiterated in this report. The Council recommends that

these documents be preserved on permanent URLs by MDEQ so that references within this report to those documents can be maintained.

Two important timing issues significantly affected the scope of this report. The first was the amount of time between 2006 PA 34 becoming effective (February 28, 2006) and the date this report was due (July 1, 2007). Discussion of major issues, such as policy-based parameters, mitigation, and adverse-resource impacts, could not begin in earnest until the Screening Tool was near completion and the Water Withdrawal Assessment Process had been discussed, which was spring 2007. Because development of a science-based Screening Tool is complex, challenging, and time-consuming, the Council was not able to consider some issues as fully as they had hoped.

The second timing issue was that Executive Order 2007-8 terminated the Council effective July 15, 2007 and turned over its duties to MDEQ. Thus parts of this report that might have described or anticipated future Council activities have not been included. For instance, the Council anticipated seeking public input into final development of the Screening Tool after finalizing its design by July 1, 2007. The Council recommends that MDEQ pursues public input, that it does so using an inclusive and collaborative approach, as the Council has done, and that it completes development of the Screening Tool by September 30, 2007 following the Council's design of the Screening Tool.

Council Operations

The derivation of Council membership is stated in 2006 PA 34, and members and their affiliations are provided in Appendix A. There are three key differences between the Council created in 2003 PA 148 and that created in 2006 PA 34: administrative responsibility for the Council moved from within MDEQ to within MDNR; the number of members was increased from 13 to 17; and MDEQ, MDNR, and MDA representatives changed from non-voting to voting members.

The Council continued to use subcommittees to perform much of its work. In July 2006, the Council formed technical subcommittees to work on sustainability, mitigation, legal considerations, and the Screening Tool. Together these subcommittees comprised the technical advisory group mentioned in 2006 PA 34. The content of discussion and participants in these subcommittees had significant overlap because few substantive issues one subcommittee might consider were isolated from the issues of other subcommittees. The technical screening-tool design team met weekly and several Council members regularly participated in these meetings.

The Council was committed to being open and inclusive in its meetings and deliberations. Council meetings were held in many locations across Michigan. Locations, agendas, and minutes were broadcast via e-mail to a large group of non-members and posted on the Council's web site. Many Council members provided briefings or presentations to interested groups and organizations.

The Council stressed scientific integrity in design of the Impact Assessment Model. The Council convened a team of respected scientists, agencies, and institutions to design the Impact Assessment Model. The Council convened a peer-review panel of nationally

recognized experts midway through model design and incorporated their comments and recommendations into subsequent design. Likewise, the Council convened a group of 44 experts and stakeholders from environmental, economic, and social sectors to develop criteria and indicators of groundwater sustainability. Reports from the peer-review panel and the sustainability workshop are posted at http://www.michigan.gov/deqgwcac.

The Council continued to operate with collegiality and with the goal of consensus building. No formal voting occurred. Most of the findings and recommendations in this report were broadly supported by the Council. The Council has attempted to clearly show within this report those recommendations that were based on consensus and those where consensus was not reached. Key points of agreement and recommendations are in **bold** within this report.

Acknowledgments

Clearly, meetings of the Council, subcommittees, design team, peer-review panel, and workshop required major time and travel commitments from members. Additionally, much work was accomplished outside of these meetings. The Council acknowledges and thanks the following organizations, companies, and agencies that generously provided for the time and travel of members: Ann Arbor Water Treatment Services, Consumers Energy Company, Grand Valley State University (GVSU)—Annis Water Resources Institute, Michigan Aggregates Association, MDA, MDEQ, MDNR, Michiana Irrigation Association, Michigan Environmental Council, Michigan Farm Bureau, Mersino Dewatering Inc., Michigan State University (MSU)—Agriculture and Irrigation Department, The Nature Conservancy—Michigan Chapter, Pearson Drilling Company, Prein & Newhof, The Rock on Drummond Island, Tri-County Regional Planning Commission, Trout Unlimited—Michigan Council, and Wayne County Department of Environment. In addition, the Council thanks the many member organizations and their affiliates for providing venues and/or luncheons for Council meetings.

The Council thanks GVSU—Annis Water Resources Institute for support in organizing, conducting, and summarizing the sustainability workshop, in particular Alan Steinman, Mary Ogdahl, and Elaine Sterrett Isely. The generous support of the Great Lakes Fishery Trust and The Joyce Foundation, via the Michigan Environmental Council, in providing support for the sustainability workshop and the assistance of Craig Hoffman and Tom Newhof in arranging the venue are greatly appreciated.

The Council is very appreciative of the work of Pat Fouchey (MDNR). Pat's administrative support was critical to Council operations. She ensured that meeting arrangements and minutes, web posting of documents, and internal and external communications were taken care of. The Council also thanks Ellen Johnston (MDNR) for word processing and desktop publishing assistance.

The Council thanks invited guests who made presentations on various topics critical to Council deliberations: Jeremiah Asher (MSU), Jim Bredin (MDEQ), Dave Hamilton, (MDEQ), Steve Miller (MSU), Jim Nicholas (U.S. Geological Survey (USGS)), Howard Reeves (USGS), Frank Ruswick (MDEQ), Ed Rutherford (UM), Mike Wiley (UM), and Troy Zorn (MDNR).

The Council thanks the design team for exercising their technical skills and their patience: Jeremiah Asher, Dave Hamilton, Dave Holtschlag (USGS), Howard Reeves, Ed Rutherford, Paul Seelbach (MDNR), Ric Sorrell (MDEQ), Mike Wiley, and Troy Zorn.

The Council is grateful to those scientists who participated in the peer-review panel for the Screening Tool for their time, keen insight, and frank feedback: Hal Beecher (Washington Department of Fish and Wildlife), Joe DePinto (Limno-Tech, Inc.), LeRoy Poff (Colorado State University), and Bill Woessner (University of Montana). We also thank Jon Bartholic and Lois Wolfson (Michigan State University—Institute of Water Research) for facilitating and coordinating the panel meeting.

The Council acknowledges and thanks the many members of the public who occasionally or regularly participated in Council and subcommittee meetings. This participation was substantial and extremely helpful to the Council in its deliberations.

Finally, the Council thanks Jim Nicholas, Director of the USGS—Michigan Water Science Center, for his significant contributions to much of the technical and operational aspects of the Council's work.

WATER WITHDRAWAL ASSESSMENT PROCESS

The Water Withdrawal Assessment Process described in this report addresses the requirements of 2006 PA 34 and fulfills many of the commitments of Annex 2001 summarized above. It also embodies the guiding principles stated in the Council's 2006 report.

In Annex 2001, Michigan commits to protecting Water-dependent Natural Resources from the effects of withdrawals. Protecting Water-dependent Natural Resources in streams brings to mind both water quality and water quantity. Protecting water quality is recognized by the Council to be as important as protecting water quantity. The Council also recognizes, however, that water quality protection is not specifically included in the Council's charge in 2006 PA 34, and that much of the water law and regulation in Michigan is designed to improve stream water quality and protect it from degradation. The principle relation between water quality and the Council's work is that flow reduction can become a water quality issue in two ways. First, reduced flow can result in detrimental physical changes to aquatic and riparian habitats, such as shallower streams or warmer streams. Second, reduced flow can result in detrimental chemical changes to aquatic and riparian habitats, such as too little flow for dilution and transport of permitted point discharges to streams.

The general relationship of Water-dependent Natural Resources in streams to water quantity is clear and intuitive. Considering only the ends of a water-use spectrum, one can be assured that removing no water from a stream will have no effect and that removing all the water from a stream will kill much of the flora and fauna dependent on water in that stream. Across the remainder of the spectrum, understanding this relationship is more complex. In fact, explicitly quantifying the exact effect of a specific withdrawal amount on all flora and fauna associated with all streams cannot be done with the current level of scientific knowledge. Realistically, such knowledge may never be available.

Michigan is fortunate, however, to have a significant database on fish abundances and streamflows throughout the state. The relationship between fish abundances and streamflows has been the subject of much research at MDNR and UM. The Council sees this relationship as instructive in informing Michigan about how its water withdrawals—individually and cumulatively—may impact Water-dependent Natural Resources. That is, if withdrawals negatively affect fish abundances, then the amount of change in streamflow is believed to be sufficient to negatively affect many other Water-dependent Natural Resources in streams and nearby floodplains. Fish are often used as environmental indicators for streams because: 1) they are high in the stream food web and thus considered "integrators" of habitat and food web quality; and 2) they are of interest to many people.

The Water Withdrawal Assessment Process described herein is seen by the Council to explicitly address the issues of Annex 2001 regarding causing adverse impacts to the Water-dependent Natural Resources of the Great Lakes Basin. It does so by protecting flow in streams. Although there is a perception that this process is about protecting only trout, this perception is inaccurate because it is incomplete. By protecting the flow regime of Michigan's rivers, using fish abundance as a surrogate, the Water Withdrawal Assessment Process will protect Michigan's Waters and Water-dependent Natural Resources, including trout and trout streams.

The Council is also aware of the broader national context for the Annex and recent Michigan legislation. The news media are constantly reporting on current and projected water shortages in the western United States. More recently, and perhaps surprisingly, are reports of water availability concerns on the East Coast, a region which has precipitation more similar to Michigan than does the drier West. Consequently, many midwestern and eastern states are now considering how to manage water withdrawals in a sustainable fashion.

Michigan's water resources are abundant and conflicts of water availability have been uncommon. The Council recognizes that, in the near term, a great majority of water withdrawals in Michigan will not adversely affect other withdrawals or aquatic ecosystems. However, as the population of the Great Lakes basin grows, there will be increased pressure from these competing uses for water resources. The state's economy is strongly dependent upon its water resources and future economic opportunities will likely be tied to water being available for industrial, municipal, domestic, recreational, aesthetic, and other uses. The Council recognizes that some types and amounts of water withdrawals in Michigan will not affect other withdrawals or aquatic ecosystems. Large withdrawals, or groups of withdrawals, however can have significant impacts on aquatic ecosystems in some parts of the state, depending on the size of the withdrawal, local geology, and streamflow. The Water Withdrawal Assessment Process is designed to assess potential impacts and determine which may be unlikely or likely to cause an adverse impact on streamflow and aquatic ecosystems.

The goals of the Water Withdrawal Assessment Process are to provide a better understanding of withdrawal impacts, to minimize conflicts over water use, to facilitate water planning and conservation among stakeholders, and to assess the long-term sustainability of water use. Education is critical for water users to understand their responsibilities with respect to water conservation and efficient use. Both the Screening Tool within the Impact Assessment Model and the water-users committee envisioned in 2006 PA 36 can serve as powerful educational tools. Local, voluntary, problem-solving approaches for resolving water-use disputes and

withdrawal impacts are the desirable starting point for conflict resolution, and legal action should be seen as a last option. Education will need to be an integral element of any water-users committee process.

Conceptual Framework

The purpose of the Water Withdrawal Assessment Process and its Impact Assessment Model is to assist a large quantity user or the state in determining if a withdrawal may cause an Adverse Resource Impact. Specifically, the process evaluates whether or not a withdrawal may impair the ability of a surface-water body to support "Characteristic Fish Populations." The Water Withdrawal Assessment Process designed by the Council addresses only the first of the two definitions of an Adverse Resource Impact stated in 2006 PA 33. That is, it does not address the potential impact of a withdrawal on the "level of a body of surface-water." How this statute interacts with other statutes that regulate the determination and maintenance of lake levels and subsequent impacts on streamflows should be a topic of future consideration by the legislature.

The Impact Assessment Model does address the definition of an Adverse Resource Impact associated with "decreasing the flow of a stream by part of the index flow" and whether or not a withdrawal is likely to functionally impair the ability of a stream to support Characteristic Fish Populations. To determine Adverse Resource Impact, the Impact Assessment Model relies on three distinct types of information and analysis—streamflow, streamflow reduction caused by a withdrawal, and changes in fish populations caused by streamflow reduction. In being used to assess the impact of water withdrawals, this information is analyzed in a tiered fashion. When efficiency is desired, the Impact Assessment Model uses an automated screening mechanism, the Screening Tool, to compute streamflow and streamflow reduction caused by a withdrawal, and assess resource impact. In cases requiring the most accurate information, the Water Withdrawal Assessment Process instead relies on site-specific information.

The Screening Tool makes use of statewide data, is simple, provides consistent and predictable results, and is efficient in the sense that it does not require site-specific information or analysis by a potential user or MDEQ. All of these characteristics are desirable in such a screening tool. Because the Screening Tool uses statewide data and models, it is less certain than Site-specific Analysis. Therefore the Screening Tool is only intended to "screen in" (say "yes") to those proposed withdrawals that are highly certain not to cause Adverse Resource Impacts. Because of Michigan's abundant water resources, the Council anticipates that a high percentage of proposed withdrawals in the near term will be "screened in" by the Screening Tool.

The Council believes it is important to emphasize that a potential water user has a number of avenues of proceeding if a withdrawal is not initially "screened in." These options may include changing the size, location, or depth of the proposed withdrawal. The next step an applicant may take could be a review of site-specific data or conducting site-specific measurements that could lead to a more accurate estimate of available flow and potentially a different decision. The applicant could also engage other users in the watershed to determine if efficiency improvements could lead to greater water availability. In any specific case one,

or a combination of these actions, or others potentially established by the legislature, may result in authorization of a withdrawal that initially was not "screened in."

Description of Screening Tool

The Screening Tool, within the Impact Assessment Model, relies upon three distinct models. None of these models are unusual; similar ones exist for other places. The linkage of the models into a screening tool for assessing the impact of water withdrawals on aquatic ecosystems, however, is unique.

Scientific models are conceptual and/or mathematical constructs that, based on data and experience, represent the real world or a convenient way to think about the real world. Models are used by all scientists for all of their thinking about, experimenting with, and predicting of the natural world. Good models are based on sound data, include appropriate simplifications and assumptions that allow proper use of the models, and are always assumed to be imperfect. No models are always correct. Models always include uncertainty. We cannot think about, nor evaluate, the potential impacts of human actions on natural systems without models. Natural resource legislation and decision-making should be based upon scientific models, and therefore policy must account for the associated uncertainty.

The three models that comprise the Screening Tool are the "Streamflow Model," the "Withdrawal Model," and the "Fish Community Model." The Streamflow Model describes how much flow is in Michigan streams. The Withdrawal Model describes how much a withdrawal will reduce streamflow in nearby streams. The Fish Community Model describes how reduced streamflow will affect Characteristic Fish Populations in affected streams. The three models are linked though a geographic information system (GIS) which associates information about streamflow, withdrawals, and fish communities with specific stream segments in Michigan. Stream segments are contiguous stream reaches that share common geographic, geologic, and hydrologic characteristics. The Impact Assessment Model, the Screening Tool, and Site-specific Analysis all rely on information associated with about 11,000 Michigan stream segments.

The Streamflow Model is based upon long-term streamflow information at 132 streamflow gages in Michigan or adjacent states. For each streamflow gage, an Index Flow was calculated consistent with 2006 PA 33; specifically, an Index Flow means the 50% exceedence flow for the lowest flow month of the flow regime at a site. In other words, it is the median flow for that month. If all the daily flows for that month, from all the years of record, are ranked, the median flow is the one where half of the flows are greater than that value and half are less. In Michigan, the lowest flow month of the flow regime is August or September in most of the state, but in some areas it is January or February. The design team used August or September, because this is the time of greatest stress on the ecosystem from low flows and high temperatures, and a large amount of information on fish populations has been collected during these months. Aquatic ecologists consider this a critical time period for streams, because stream characteristics that limit fish abundance can approach marginal ranges. The Index Flow, then, can be thought of as an average low flow during the summer months, which typically have the least precipitation. An example Index Flow for the Looking Glass River is shown in Figure 1. Under natural conditions, water in streams during low flow periods is groundwater flowing into the stream. To develop the Streamflow Model,

hydrologists compared calculated Index Flows at streamflow gages to watershed characteristics (such as surficial geology, land cover, precipitation, and other factors) upstream of the gages. This comparison, which was done statistically, was then used to estimate Index Flows for ungaged streams in Michigan. This approach is consistent with the requirement of 2006 PA 33, which calls for Index Flows to be either calculated over the period of record at a streamflow gage or "extrapolated from analyses of the United States geological survey gauges" [sic] in Michigan. The result is a Streamflow Model that has a calculated Index Flow for every stream segment in Michigan.

The Withdrawal Model assumes that surface-water withdrawals come from the stream segment associated with the same subwatershed that the withdrawal is in. For groundwater withdrawals, the model is more complicated. Effects of groundwater withdrawals on streams are not instantaneous; it may take weeks, years, or decades for a groundwater withdrawal to affect streamflow. Groundwater withdrawals may affect only the closest stream segment, or their effect may be distributed among nearby stream segments. Intermittent groundwater withdrawals may have substantially less impact on streams than continuous withdrawals. The impact on a stream of a groundwater withdrawal from a sand-and-gravel aquifer will be substantially different than one from a confined limestone aquifer. Therefore the Withdrawal Model must take into account the following factors: for surface water or groundwater—the type of withdrawal, and the amount and continuity of the withdrawal; for groundwater only—the depth of the well, the distance of the well from the stream, and aquifer properties. The first four factors are entered into the Screening Tool by a person proposing to make a withdrawal and the last two factors are calculated by the Withdrawal Model. The result of the Withdrawal Model is a reduction in streamflow that can be calculated for every stream segment in Michigan, given the specific characteristics of a proposed withdrawal.

The Fish Community Model relies upon a long-term MDNR, UM, and U.S. Forest Service data set that describes abundance of fishes at about 1,700 stream locations in Michigan and upon an MDNR grouping of stream types in Michigan based upon watershed size and stream temperature. The grouping of stream types results in 11 stream types that classify all Michigan streams. Examples of stream types are cold streams, warm streams, and warm small rivers. Each stream type has associated with it a characteristic relationship between fish abundance and streamflow. The fish abundance data were directly related to the Index Flows calculated by the Streamflow Model for all stream segments in Michigan. The Fish Community Model describes, for each stream type, the decline in fish populations caused by a series of increasing reductions in streamflow.

The Screening Tool is designed to be used via the internet. The internet interface is map-based, intuitive, and simple. Essentially the interface asks the proposed user for information about the withdrawal, then either informs the person that the proposed withdrawal is not likely to have an Adverse Resource Impact on any stream's fish populations or that the proposed withdrawal may have an Adverse Resource Impact and suggests alternatives with respect to modifying characteristics of the withdrawal or indicates that the person should contact MDEQ.

The Council notes that the Screening Tool is state-of-the-art. It could not have been developed until very recently. In 1997 MDNR and UM pioneered the concept of stream segments as a model for understanding the linkages of hydrology and stream ecology. The

geographic framework and the information associated with stream reaches became available in 2007, after years of work by federal and state scientists. The analytical solution used in the Withdrawal Model was published in 2003. The hydrogeologic information used to predict effects of groundwater withdrawals was completed in 2005 in response to 2003 PA 148. And the Fish Community Models are a new (2007) interpretation and synthesis of decades of research by MDNR and UM. Thus the information used to design and develop the Screening Tool is very recent, and much of it was developed in and for Michigan.

The models that comprise the Screening Tool include numerous simplifications and assumptions, as do all models. They also have uncertainty, in some cases an amount that cannot be quantified. To account for uncertainty in the streamflow estimates of the Screening Tool, the Council has applied a safety factor to the calculated Index Flows. We applied a percentage safety factor to the modeled streamflow estimates in order to adequately reduce the number of cases where the Index Flows would be overpredicted. This also will result in many cases where the Screening Tool will underpredict the true amount of available water. The safety factor in this case relates to the estimates of streamflow extrapolated from data provided by existing stream gages on Michigan streams. The more accurate these estimates can be, the less restrictive the safety factor needs to be. The Council did not reach a consensus on the precise safety factor to be applied in all cases. The streamflow safety factor is not to be applied in a Site-specific Analysis, as flow data will be more accurate.

Description of Site-specific Analysis

Analysis of a proposed withdrawal may be performed by MDEQ using data and information that are more site-specific, and generally more accurate, to supplement that from the three models described above. Applicable site-specific data and information replace or supplement the Streamflow Model, the Withdrawal Model, the Fish Community Model, or some combination of the three. In most cases, because of availability and cost, the site-specific data will be streamflow measurements that are already available or can be collected relatively efficiently. As a streamflow safety factor is used in the Screening Tool, this provides additional motivation for a Site-specific Analysis, because flow data will be more accurate and thus the safety factor can be removed.

In cases involving groundwater withdrawals, the site-specific data may be from local aquifer tests or geologic logs that allow for more accurate estimation of a withdrawal's effects on streamflow. And there may be cases where a person wishes to collect fish abundance data to develop a site-specific fish community description to supplement information from the Screening Tool.

The Impact Assessment Model

Regardless of whether Screening Tool or Site-specific Analysis inputs are used, aspects of the three models are combined in a consistent manner to provide an assessment of the potential impact of a proposed water withdrawal on one or more specific stream segments. This section describes the scientific basis and policy considerations underlying the Council's development of the Impact Assessment Model. In describing the assessment model we also provide definitions for the terms "Functional Impairment" and "Characteristic Fish Populations," used in 2006 PA 33. Detailed technical descriptions of the science underlying each of the three

models, and the Impact Assessment Model, can be found at http://www.michigan.gov/deqgwcac and will be published in peer-reviewed technical reports.

Flow-fish functional response curves

As described above, relationships between flow reduction and change in fish populations were defined for all 11 Michigan stream types. Each relationship is shown as a set of response curve, which show how fish population abundances change as flow is incrementally reduced. These curves define the Functional Impairment of the fish populations, as stated in 2006 PA 33. For each stream type we used two response curves that tell us about different aspects of fish abundance response to streamflow reduction (Figure 2). Curve A is the response curve for an abundance metric which is the proportion of initially "thriving species" that still remain classified as “thriving” at increasing levels of flow reduction. Thriving species are those that do very, very well at sites of the given stream type; the flows and temperatures are well matched with needs of these species. Curve A depicts changes in density of the best fish populations and is fairly sensitive to flow reductions, typically showing initial rapid response to modest flow reductions. Curve B is an averaging of two response curves that describe different aspects of how “characteristic species” at a site respond to flow reduction. Characteristic species include thriving species and also species that do fairly well in the given stream type, but not as well as the thriving species. This serves as the definition of Characteristic Fish Populations, as stated in 2006 PA 33 (Figure 3). While the two metrics described by Curve B (proportion of characteristic species that remain at "characteristic" abundance levels and the overall abundance of characteristic species) measure different aspects of the fish populations, they showed very similar responses to flow reduction, so they were combined into one line. Curve B responds more slowly to flow reductions than Curve A, but indicates the most serious population changes, where both total abundance and species presence decline. When Curve B declines to a proportion of zero, characteristic populations are no longer found at that site.

Recent scientific literature provides some insight into acceptable levels of streamflow reduction, indicating a gradient from some initial changes in density of fish, to some replacement of sensitive species, to various degrees of alteration of ecological function and replacement of sensitive species entirely by highly tolerant species (Figure 4). About midway along this gradient is “notable replacement by tolerant species.” The Council is in agreement that “notable replacement” is unacceptable because it does not provide sufficient protection for the aquatic resources. Most Council members consider this level of change to be an Adverse Resource Impact. Near the initial or baseline condition is minor change, perhaps not even measurable, in fish abundances. The Council is in agreement that this amount of change is acceptable for all stream types and is the amount of change most appropriately addressed by the Screening Tool. Between what the Council views as minor change and unacceptable change, lies a zone of increasing risk of Adverse Resource Impact. The Council has considered various actions that might be appropriate to implement as the risk level increases; these are discussed later in this report.

Interpreting curves

In some stream types, fish abundances are highly sensitive to fairly small flow reductions. However in other stream types, fish abundances show fairly gradual changes in response to much larger flow reductions. Determination of the degree of "acceptable" streamflow reduction for these various types requires agreement on a consistent set of rules that include both an acceptable level of fish population change, and a degree of caution (i.e., some safety factor) that recognizes the uncertainties inherent in our simplified Water Withdrawal Assessment Process. Once these elements are agreed upon, then the rules can be applied to the response curves for each stream type to determine how much flow can be removed without causing an unacceptable change in fish populations, i.e., Adverse Resource Impact.

The Council studied how to interpret the curves in terms of ecological risk and chose to use two horizontal lines as a tool; one at 90% of the initial fish population metric and one at 80% (Figure 5). The points where these horizontal lines intersected fish response curves A and B were used to draw several vertical lines to the bottom axis, indicating proportional flow removals associated with each threshold risk point. We felt that this approach allowed us to select risk threshold points that satisfied several objectives: 1) to keep ecological impacts to a minimum, primarily 10% or less of the initial fish population metrics; 2) to correspond with the levels of ecological degradation equating to "Some density changes" and "Some replacement of sensitive species," while staying clear of "Notable replacement of sensitive species"; and 3) to stay on the upper portion of the curves, away from the inflection point that leads to steeper slopes and riskier decisions.

Our approach created three vertical lines that indicated key proportions of flow removal associated with these threshold risk levels: the left line showing the theoretical edge of minor impact, the right line showing the theoretical start of Adverse Resource Impact, and a center line (Figure 6). These three lines divide the index-flow reduction axis into four zones, labeled Zones A, B, C, and D (Figure 7).

The Council finds that flow reductions that leave 90% or more of the "thriving species still thriving" represent minimal measurable impact on fish populations. This is the point on Curve A straight across from the 90 on the left axis. The proportion that the Index Flow can be reduced associated with this is found by drawing a line straight downward from the point just described to the bottom axis. This line denotes the edge of Zone A and the beginning of Zone B (Figures 6 and 7).

Flow reductions that cause fewer than 90% of characteristic species to remain, or reduce overall abundance of characteristic species to less than 90% of the initial value, constitute "notable replacement," and are an unacceptable level of change indicating an Adverse Resource Impact. This is the point on Curve B straight across from the 90 on the left axis. The edge of Zone C and the beginning of Zone D is found by drawing a line straight downward from the point just described to the bottom axis (Figures 6 and 7).

Finally, flow reductions that leave less than 80% "thriving species still thriving" constitute a significant decline in fish population density and movement toward "notable replacement" for characteristic species, and thus mark a questionable level of fish population change. This is the point on Curve A straight across from the 80 on the left axis. The delineation between

zones B and C is found by drawing a line straight downward from the point just described on Curve A to the bottom axis (Figures 6 and 7).

We feel that our assessment model, incorporating variable stream types and fish populations, along with the response curves and resulting four zones is an appropriate and powerful framework for developing state water withdrawal policy. It incorporates the variable natures of water resources and water uses, and acknowledges that impact assessment is a matter of increasing risk (illustrated by the four zones), rather than a yes/no situation. The following recommendations reflect the majority view of the Council. However, some council members believe, due to the new nature of the science and the uncertainties involved, that a more conservative approach is warranted.

Determining policy based on four zones

The Council agrees that Zone A is a level of reduction that describes minor impact. Ample water appears to be available for the proposed use, with little impact to aquatic resources. Zone A is appropriate for the Screening Tool to "screen in." Large quantity water users should be required to register their use and encouraged to follow generally accepted water conservation practices for their use sector.

The Council also agrees that Zone D clearly represents an Adverse Resource Impact, with the proposed use very likely to seriously impact aquatic resources. The proposed use should be denied.

We do not have clear recommendations for interpretation and actions within zones B and C. These are clearly zones of increasing risk of Adverse Resource Impact, and therefore present opportunities to develop a series of required program actions that educate, engage, restrict, and hold accountable users seeking withdrawals that fall in these zones. In Zone B the proposed water use will likely begin to impact "thriving" fish populations and, at a minimum, steps need to be taken to better understand water uses in the area and concerns regarding specific aquatic resources and to educate users. In Zone C we see a greater impact on "thriving" fishes and an initial reduction to the "characteristic" fishes. General goals for this zone would be to stay away from the boundary of Zone D, and to implement conservation measures and other actions that potentially increase Index Flows back towards Zone B.

The Council decided that mitigation may be appropriate for some withdrawal scenarios. Mitigation should not be allowed as a trade-off for reducing Index Flow into Zone D.

The Council recommends that further work be undertaken to more fully define and clarify the full scope of appropriate program actions across the range of zones A-D, with special attention to the transitional zones B and C. We feel that the process should include an increasing degree of user engagement and responsibility, as the risk of an Adverse Resource Impact also increases. Additional policy determinations need to build in consideration of ecological and social attributes that vary across the 11 stream types.

The three models, the functional response curves, and the four risk zones comprise the Impact Assessment Model (Figure 8). The Impact Assessment Model is used within the

Water Withdrawal Assessment Process both in cases where the Screening Tool is applicable and in cases where a Site-specific Analysis is applicable. The difference in applying the Impact Assessment Model in these two cases is merely the source of the information—either statewide data or site-specific data. **The Council recommends that the Impact Assessment Model be adopted as the legal standard for determination of an Adverse Resource Impact. The Council believes such a standard is based on sound science and meets the intent of 2006 PA 33 and 34.**

The Impact Assessment Model involves integration of several complex analyses; however, its application on a statewide basis is deceptively simple. Individual flow-fish functional response curves are calculated for each of the 11 stream types in Michigan (Figure 9). Each of Michigan's 11,000 stream segments has been assigned to one of these stream types. Thus, determining the impact of an Index Flow reduction on any given segment is straightforward, whether using the Screening Tool or a Site-specific Analysis.

Additionally, because of the broad, gentle shape of response curves for some stream types, such as those coldwater streams and rivers shown in the upper left panels in Figure 9, the amount of flow reduction allowed prior to an Adverse Resource Impact (Zone D) can be very substantial, in the range of 40-50% of Index Flow. This occurs because many Michigan coldwater streams have extremely high Index Flows, fed by some of the highest rates of groundwater influx in North America. These Index Flows are well above the Index Flows required to support good populations of trout and other coldwater fishes. In contrast, other stream types such as "Cold Transitional" streams display such steep response curves that Zones B and C are so narrow that they are nearly indistinguishable. The Council recognizes that levels of 40-50% allowable flow reduction may not be reasonable or desirable for certain stream types, and that other factors like regional rarity, or high or unique social values (e.g., recreation, aesthetics, or designated use) will need to be considered in further development of the water withdrawal program.

APPLYING THE PROCESS

This section describes Council recommendations for how the Impact Assessment Model is to be used, with inputs from either the Screening Tool or Site-specific Analysis, in an overall decision-making process on a proposed withdrawal (Figure 10). It also describes how that decision-making process relates to other legal issues associated with a proposed water withdrawal. Note that the decision-making process does not require use of the Screening Tool. Any person may request a site-specific determination from MDEQ in lieu of using the Screening Tool. A more complete discussion, as well as a detailed flow chart illustrating these concepts, is included at http://www.michigan.gov/deqgwcac.

Screening Tool Determinations

According to 2006 PA 33 a person considering a new or increased Large Quantity Withdrawal is not allowed to cause an Adverse Resource Impact. The Screening Tool provides an initial evaluation of whether this legal obligation is met. Basic information about a proposed new or increased Large Quantity Withdrawal is entered into the Screening Tool by the person proposing a withdrawal. The Screening Tool calculates the amount of flow

reduction for the appropriate stream segment and makes a determination of impact. This determination will be either: (1) the proposed withdrawal is not likely to cause an Adverse Resource Impact and is authorized: (2) the proposed withdrawal is likely to cause an Adverse Resource Impact and may not be authorized; the user can modify the proposal and try the Screening Tool again or the user can pursue an alternative, Site-specific Analysis of the withdrawal in conjunction with MDEQ.

Not likely to cause an Adverse Resource Impact

If the Screening Tool calculates that the proposed withdrawal would result in an impact assessment falling in Zone A, then this withdrawal would be considered as not likely to cause an Adverse Resource Impact. The user would then simply register the proposed withdrawal with MDEQ and receive subsequent authorization to proceed (certification). The Screening Tool is designed to automate registration and certification. The person could immediately begin the withdrawal.

The Council did not reach final consensus on whether or not a withdrawal in Zone B also should be considered as "not likely to cause an Adverse Resource Impact," either by the Screening Tool or following a site-specific determination. We recognize that this area required discussion beyond the time afforded the Council for deliberations.

A withdrawal that initially does not pass the Screening Tool might do so if reconfigured. For instance, a proposed groundwater withdrawal might have a different effect on streamflow if it were at a different depth or location. Entering different information into the Screening Tool— changing the specific characteristics of the proposed withdrawal—might result in withdrawal that passes the Screening Tool. A person is always free to try different withdrawal configurations in the Screening Tool.

Site-specific analysis is necessary

Since the Screening Tool incorporates estimates in both the Streamflow and Withdrawal models, and includes a safety factor, it is possible that a proposed withdrawal that does not pass the Screening Tool may still only cause a level of flow reduction associated with Zone A if site-specific data are used (along with no safety factor). Therefore if a person chooses not to reconfigure a withdrawal, or possible reconfigurations are not "screened in," then MDEQ can be asked to make a site-specific determination of the impact of the proposed withdrawal on streamflow. Site-specific information will have more certainty associated with it than the estimates used by the Screening Tool. Site-specific information that is available to MDEQ may be supplemented by the person proposing the withdrawal. Such additional data collection must be in accordance with MDEQ guidelines. The site-specific calculation of streamflow reduction would then be applied to the Fish Community Model for the relevant stream segment to determine if the reduction is in Zone A.

As previously discussed, the Council has recommended a legal standard that incorporates four zones corresponding to increasing levels of reductions in streamflow. As previously stated, the Council agrees on policy recommendations for the end zones, A and D; however further work is required to determine exactly what program actions would be required in the

transitional zones B and C. A Site-specific Analysis that provides the most accurate estimate, and thus the least risk, of potential impact should be considered as one such requirement. The legislature will need to determine from a procedural standpoint how these site-specific decisions are made within the Water Withdrawal Assessment Process.

Legal Aspects of an Administrative Decision

An administrative decision by MDEQ to approve or deny a withdrawal has three aspects that must be recognized. First, it is based on data and information that exist when the decision is made. Second, the decision can be administratively or legally challenged. Third, the decision is made within Michigan's system of riparian water rights. Each of these aspects of an administrative decision is discussed below.

Existing information

MDEQ's administrative decision is based on the best data, information, and estimates that exist when the decision is made. This means that if any of these change, so might the decision. Most notably, MDEQ's decision is based on what is known about current levels of flow in a stream based on current withdrawals from that stream. Therefore a person denied a withdrawal has the opportunity to take steps which may, in effect, make more streamflow available. For example, a person proposing a withdrawal may initiate the convening of the water-users committee for the watershed. This committee may provide a solution that allows for existing and proposed water uses by reducing one or more of the existing uses through actions, such as adoption of conservation measures. If the results of this process can be sufficiently documented and assured, then MDEQ could recalculate the effect of a proposed withdrawal. This could result in the withdrawal being authorized.

Legal challenges

MDEQ's administrative decision can be legally challenged either by the person proposing the withdrawal (if the withdrawal is denied) or by another party (if the withdrawal is authorized). The legal challenge would begin with a petition for a contested case filed under the Administrative Procedures Act. The Council recommends that the petitioner for the contested case be required to notify other registered water users within a defined geographic area of the proposed withdrawal. MDEQ's final administrative decision, after the contested case, could be challenged in circuit court. MDEQ's decision could be overturned either through the contested-case process or through judicial appeal.

The Council and legal subcommittee discussed the range of legal presumptions used in Michigan law (see http://www.michigan.gov/deqgwcac). Much discussion focused on whether or not decisions based on the Screening Tool should have the same presumption as an MDEQ administrative decision.

The Council discussed the policy issue of what legal presumption should be afforded MDEQ's decision. In general, based on the Michigan Constitution and Administrative Procedures Act, courts provide deference to an administrative agency determination. In pertinent terms, such a determination will not be overturned if it is "supported by competent, material, and substantial

evidence" unless it is "arbitrary and capricious or clearly an abuse or unwarranted exercise of discretion." The Council discussed, but did not reach consensus on, whether a different legal presumption should be applied to a DEQ determination on a water withdrawal.

The Council also discussed, but did not reach consensus on, whether a different legal presumption should be afforded to a result derived from use of the Screening Tool. Specifically, what presumption should be afforded to a Screening Tool result indicating that a withdrawal is in Zone A (and perhaps Zone B) and therefore is not likely to cause an Adverse Resource Impact. 2006 PA 33 currently provides a legal presumption that a withdrawal will not cause an Adverse Resource Impact, if it is a certain distance from a trout stream or more than a certain depth. That presumption can be overcome by "a preponderance of the evidence." 2006 PA 33 also requires MDEQ to use "clear and convincing scientific evidence" to revoke a water use permit.

Riparian water rights

The Council recommends only implementing a Water Withdrawal Assessment Process that does not change Michigan's system of riparian water rights. Riparian law is a means of allotting available water among potential users. By establishing a system that maintains flows protecting Characteristic Fish Populations, the legislature would be specifying how much water is available to be allotted through the riparian system.

Therefore, even if a proposed withdrawal is initially denied because it would cause an Adverse Resource Impact, the person proposing the withdrawal still has recourse. That recourse is to assert common-law riparian rights to a reasonable use of water. These rights would be asserted in a common-law water rights adjudication against other users in the watershed. In effect, the person proposing the new withdrawal would assert that existing uses are not reasonable, thereby depriving him or her of the ability to make a reasonable use of the water without causing an Adverse Resource Impact. At the same time, other riparians have the right to challenge that the new or increased withdrawal is affecting their existing riparian water rights.

CONSIDERATIONS WITH RESPECT TO THE PROCESS

There are several significant issues surrounding the Water Withdrawal Assessment Process that have been discussed by the Council. Some are fully resolved; some are not fully resolved. The purpose of this section of the report is to identify these issues and describe Council considerations with respect to each. These issues include cumulative withdrawals, mitigation, return flow, uncertainty, social values, and water-users committees.

The sequence of the Council's work needs to be recognized. Prior to considering many of the issues discussed in this section, the Council first needed to have the Screening Tool designed and the Impact Assessment Model framed. Work on these consumed most of the Council's time. Consequently, the full Council did not have sufficient opportunity to adequately consider and discuss some significant issues raised by subcommittees. Therefore, lack of consensus on some issues may reflect more a lack of available time to reach consensus than issue complexity and disparate views. Given sufficient time, the Council believes that it may have reached agreement on more or all of these issues.

Implications of Cumulative Withdrawals

The zones of index-flow reduction should not be thought of as zones caused solely by individual withdrawals, but rather as zones caused by a cumulative set of withdrawals. The Council believes that many cases of a single new or increased Large Quantity Withdrawal indicating a flow reduction associated with zones B, C or D will be cases where one or more authorized withdrawals already exist.

Because impacts are cumulative, it is clear that in many cases collective actions may be required of a group of several users, that includes the proposed new user and existing users. This is consistent with reasonable-use doctrine. Design of a water use program needs to account for cumulative withdrawals that do not favor one person over another based on sequence of authorization of withdrawals.

Likewise, water-users committees that form because a proposed withdrawal is calculated to cause an index-flow reduction in zones B, C, or D are not formed solely because of the most recent proposed withdrawal. Water-users committees need to consider existing and proposed withdrawals without favoring one person over another based on sequence of authorization of withdrawals

Additionally, the outcome from a water-users committee is likely to mean either a group of users mitigate or a group of users reduce withdrawals. For the latter case, existing withdrawals authorized through the Water Withdrawal Assessment Process may have to be reauthorized at new rates of withdrawal.

Finally, it should be noted that new withdrawals less than 100,000 gallons per day will not be captured in water-use database and thus not necessarily explicitly considered in cumulative withdrawals. There are areas in Michigan where clusters of homes on individual wells could exceed a combined capacity of 100,000 gallons per day, because the typical capacity of a domestic well is about 14,000 gallons per day.

Considerations with Respect to Mitigation

The Council has not reached consensus on whether mitigation should be allowed or under what circumstances. Discussion has centered on mitigation being required for ranges of flow reduction associated with Zone C. This is not mitigation of a flow reduction in Zone D that would bring the amount of flow reduction back to Zone C. At this time, the Council considers Zone D off limits to individual and cumulative withdrawals. Instead mitigation in Zone C is viewed as protective in light of model uncertainty—to ensure flow reductions do not cause an Adverse Resource Impact and to allow for future development. The goal of such actions should be to move water use impacts back toward Zone B.

Criteria that mitigation would have to meet have not been discussed at length by the full Council. Brief discussions and comments indicate, not surprisingly, disparate views of where in a watershed mitigation should occur, what types of activities or measures might constitute meaningful mitigation, how to ensure the planned effects of mitigation actually occur, and how to ensure these effects are sustained into the future or as long as the withdrawal(s) last.

There are three clear areas of Council agreement with respect to mitigation. First, mitigation is applicable only to a select set of withdrawals, not all withdrawals. Second, there are stream segments of special ecological integrity or sensitivity that should be protected, and thus not considered for mitigation. We recommend that further work be done to identify such sensitive areas. Third, for mitigation to be effective there needs to be institutional practices that ensure the planned effects of mitigation actually occur that these effects are sustained into the future or as long as the withdrawal(s) or their effect(s) last. Finally, draft language regarding mitigation has been suggested by some subcommittee members, but not fully discussed by the entire Council. This language is at http://www.michigan.gov/deqgwcac.

Considerations with Respect to Return Flow

The Council discussed and agreed to a number of issues related to return flow. Return flow is returning all or part of a withdrawal to a stream, either directly via surface discharge or indirectly via groundwater discharge. There is consensus that if the return flow is in the same vicinity as the withdrawal, is of similar quality, especially with respect to temperature, and is of essentially the same timing as the withdrawal, then return flow should be an explicit part of the process. At this time, the Council agrees that return flow cannot be automated as a part of the Screening Tool, although future improvements to the Screening Tool should allow for incorporation of return flow.

Consideration of return flow should be part of a MDEQ site-specific evaluation in determining what zone of index-flow reduction a withdrawal might be associated with. This puts an additional burden on MDEQ. Additionally, all return flows, even those associated with withdrawals authorized via the Screening Tool, should be accounted for in the ongoing tracking of Index Flows in the Streamflow Model. In many situations, a return flow can be viewed to reduce the net withdrawal. The Council also recognizes that current statutes address aspects of many potential return flows.

Water Withdrawal Capacity versus Actual Water Use

The Water Withdrawal Assessment Process uses the capacity of a proposed new or increased withdrawal to assess the likelihood that it may cause an Adverse Resource Impact. Capacity is used for several reasons, including: capacity is added in increments that can be tracked and accounted for; use may vary significantly from year-to-year, especially in those sectors where weather is an important variable; and capacity establishes a maximum level and allows for planned increases in use over time.

The actual water use, however, is what affects streamflow. Most water withdrawals facilities do not use their capacity continuously. Intermittent uses, seasonal uses, and standby uses are common in Michigan.

If the Water Withdrawal Assessment Process relies solely on capacity, there may be unnecessary restrictions placed upon withdrawals in areas that can sustain greater uses. This issue requires further study.

Considerations with Respect to Uncertainty

Sources of error within each of the modeling steps include: measurement error, sampling error, model assumption error, and model prediction error. In some cases, errors may lead to over-predicting the effects of a withdrawal; in other cases errors may lead to under-predicting the effects of a withdrawal. Therefore, as policy considerations are incorporated into application of the process, uncertainty and its implications need to be explicitly considered. Scientific literature and related policy guidance documents typically recommend some caution in applying scientific models and processes in a resource-management and regulatory context. An appropriate amount of caution can avoid undue risk of adversely impacting natural resources. A considerable amount of Council discussion addressed the concept of "acceptable risk" or "unacceptable risk" of Adverse Resource Impacts underlying the specific issue being considered.

The Council has incorporated caution into design of the Water Withdrawal Assessment Process. Although explicit discussion of how this was done requires technical presentation of the various models, it is worth pointing out that caution is incorporated into the Impact Assessment Model and the Screening Tool in decisions on the size of stream segments, the distribution of groundwater withdrawals among stream segments, the use of a safety factor for Index Flows, and in the approach to calculating response curves. Use of four zones, rather than only two zones, in the Impact Assessment Model also incorporates caution and the concept of risk. The addition of two intermediate zones creates a gradient of increasing risk of an Adverse Resource Impact and provides a framework for actions and policy that appropriately address this risk.

Despite these cautionary elements, the process still contains a number of factors that may lead to underestimating resource impacts. These include the simplified model of aquatic ecosystem health, limited understanding of the impacts of flow reduction on stream temperature, the use of median low flow, and the time frame for predicting impacts into the future. The current process uses "median" low flow. That means that one half of the years will have a lower low flow and result in impacts greater than predicted by the tool. Therefore, the use of "median" low flow will overpredict the amount of water during low flow half the time, and actual flows could be a little as 10% of what the tool predicted. While the fish population response models incorporate natural variation about the median flow, our allowance of additional flow removals could result in the over commitment of resources, a lack of drought planning, and significant impacts to aquatic resources, especially during the driest years.

Considerations with Respect to Stream Types and Values

People value some stream and river resources more highly than others and these social valuations of streamflow are typically diverse. Council discussions demonstrated this diversity with respect to thinking about different types of streams in Michigan. While some members maintained that all streams should be equally valued, other members clearly valued certain types of streams differently. The Council did not reach consensus on how to value streams in the Water Withdrawal Assessment Process. **We do however view this as a much needed step towards final definition of the process and recommend that an open and**

collaborative process be developed for consideration of variable social values related to streams and rivers.

Role of Water-users Committees

A guiding principle of the Council is that individuals, local groups, local government, and state government all have roles to play in water management. Furthermore, in the Council's 2006 report in response to 2003 PS 148, the Council stated that, "local, voluntary problem-solving approaches for resolving groundwater disputes and withdrawal impacts are the desirable starting point for conflict resolution." The 2006 PA 36 states, "all persons making Large Quantity Withdrawals within a watershed are encouraged to establish a water-users committee to evaluate the status of current water resources, water use, and trends in water use within the watershed and to assist in long-term water resources planning." A water-users committee may be composed of all registrants, water withdrawal permit holders, local government officials, and other interested parties within the watershed. The Council only briefly discussed the role of these water-users committees within the Water Withdrawal Assessment Process. The Council agreed that the burden of forming these committees should not necessarily fall on the person proposing an increased or new Large Quantity Withdrawal. MDEQ should have a role in forming, informing, and educating a water-users committee about a water withdrawal issue. The Council recommends that a water-users committee be formed in response to proposed individual or cumulative withdrawals that cause a flow reduction in Zone C. Some Council members also think a committee should be formed in response to flow reductions in Zone B.

UPDATING IMPACT ASSESSMENT MODELS

In 2006 PA 34, the Council is directed to recommend an appropriate timetable for periodic updates or changes to the water withdrawal assessment tool or to the water withdrawal assessment tool's parameters or variables. Updates are needed to account for new data, refined or redefined models, and future changes in the process. Some updates are necessary for the Impact Assessment Model and the Screening Tool to continue to function as part of the Water Withdrawal Assessment Process. For instance, new authorized withdrawals need to be accounted for in the calculation of available streamflow for that stream segment. Such updates need to be relatively frequent and ongoing. Other updates may improve the accuracy of Screening Tool calculations over time, but are not necessary for ongoing use of the model. For instance, as new geological information becomes available over a period of many years, the Withdrawal Model can be updated with newer aquifer properties that will improve the accuracy of Screening Tool calculations.

Many of the Impact Assessment Model components that need updating can only be described in fairly technical terms. Therefore the Council has detailed these updates in a separate document, Recommended Updates to the Impact Assessment Model, available at http://www.michigan.gov/deqgwcac. **The Council recommends that MDEQ ensures updates are made consistent with this document. A brief summary follows.**

Streamflow Model

- Update and revise statistical models and Index Flow estimates every 5 years.
- Design a sampling scheme for placement of additional long-term stream gages and for collecting miscellaneous flow measurements to improve flow estimates.

Withdrawal Model

- Update groundwater/surface water depletion models every 5 years.
- Define a strategic research program aimed at more accurately representing the groundwater/ surface water interaction.
- Develop and maintain a comprehensive suite of databases and internet-based delivery tools incorporating the PA 148 (GWIM) work, water withdrawal reporting databases, and the water withdrawal Screening Tool.
- Design and implement a statewide groundwater monitoring network to assess changes over time.
- Follow recommendations from Council's 2006 report regarding updating GWIM

Fish Community Model

- Update fish population models and flow-response curves every 5 years.
- Improve approach to modeling physical habitat responses to flow removals.
- Consider impacts of flow reduction on other riverine biota.
- Describe variation (uncertainty) in fish population response by rivers within a given type.

MEASURING THE PROCESS— Indicators of Groundwater Sustainability

The results of programs to manage and regulate new or increased withdrawals (as committed to in Annex 2001) should be measurable. Michigan in 2003 PA 148 and 2006 PA 34 directed the Council to consider groundwater sustainability as a goal of a water management program and to develop indicators of groundwater sustainability. To meet the requirement of 2006 PA 34, the Council, with the assistance of the Institute of Water Research at MSU, submitted a proposal to the USEPA to develop a comprehensive statewide Groundwater Sustainability Indicator System Model. The proposal, however, was declined for funding.

In lieu of this more comprehensive approach, the Council designed and held a 1-day workshop. The Groundwater Sustainability Workshop brought together recognized experts in the sectors of environmental integrity, economic development, and social equity to identify, review, and vet a short working list of indicators and criteria for each sector. A full report to the Michigan Legislature was published on the Council's internet site on May 5, 2007 and is entitled: "Recommended Criteria and Indicators of Groundwater Sustainability for the State of Michigan." The report summarizes the findings of the March 26, 2007, workshop and provides 6 major recommendations to the Michigan Legislature for the development of 11 groundwater sustainability indicators and 16 measurements with associated criteria to guide

the sustainable management of groundwater resources in Michigan. A brief summary of the workshop findings follows.

The use of science-based criteria and indicators is expected to be one of the principal tools in supporting the sustainable management of groundwater and related natural resources in Michigan. Criteria are defined as standards or points of reference that help in choosing indicators; they are more general and less detailed than indicators. Indicators are defined here as measures that give relevant information on trends in a readily understandable way. Good indicators should be measurable, consistent, based on readily available or obtainable information, and comparable among various geographic regions. Workshop participants were instructed to identify those indicators they believed were most appropriate, irrespective of whether or not relevant data were currently available. For each indicator, a set of specific measurements is selected to provide explicit quantitative information about that indicator. Comparing measurements over time for specific indicators results in trends, which can be used to assess the sustainability of Michigan's groundwater resources.

Five indicators were developed for the environmental sector, three for the economic sector, and three for the social sector. Measurements and criteria were identified for most, but not all, indicators. Each indicator provides some information regarding the sustainability of groundwater resources in Michigan. The set of indicators provides a framework to support a holistic assessment of the sustainability of Michigan's groundwater resources. As emphasized in the Council's 2006 report, however, the identification of sustainability indicators must be a dynamic and ongoing process that requires periodic review and re-evaluation. The Council's workshop initiated this process, but did not complete it.

Finally the workshop report includes six recommendations that are included here, without the accompanying explanatory text.

- Adopt the recommended set of sustainability indicators described in the workshop report in conjunction with an implementation program to determine the current status of these indicators
- Create/appoint a groundwater sustainability indicators working group to refine the indicators and measures identified in the workshop report and to consider additional indicators not identified in the report.
- Require the working group to meet annually to review the sustainability indicators, assess data trends, and modify or add indicators, as needed, based on sound science research and knowledge.
- Refine the criteria for groundwater sustainability indicators, where appropriate.
- Aggregate the key indicators from the environmental, social, economic sectors into a composite set of comparative metrics to determine the overall status of groundwater sustainability.
- Collect, generate, and analyze relevant data to assist the evaluation and effective management of state groundwater resources for use by future generations.

SUMMARY AND FINAL RECOMMENDATION

The Michigan Groundwater Conservation Advisory Council has met the intent and requirements of our charge, as set forth in 2006 PA 34. The Council has worked earnestly to frame a science-based, state Water Withdrawal Assessment Process that incorporates an Impact Assessment Model including an automated Screening Tool. The development of the Impact Assessment Model represents considerable progress in linking water use and water withdrawal to the maintenance of ecological integrity for stream systems. This process will support sound management across the entire scope of Michigan's flowing waters (sizes and types of streams and rivers) and their related natural resources. We have used considerable scientific evidence within an open, collaborative council process to define several terms from 2006 PA 34: "Characteristics Fish Populations" for specific stream segments; and the "Functional Impairment" response of Characteristic Fish Populations as successively more water is withdrawn from a stream segment. A council majority also has agreed upon the degree of Functional Impairment that should be considered an "Adverse Resource Impact" to Characteristic Fish Populations, that is, the degree that should not be allowable by law.

The recommended Water Withdrawal Assessment Process must be viewed as a work in progress. We believe we have in hand a solid process framework based on a good science foundation; however the Council unanimously believes that both the process and the imbedded tool will require further development and testing prior to any implementation. We likewise believe that even after it is implemented, this work must be made adaptable and allowed to continuously develop through time; we need to keep learning about both our management processes and the ecosystems we manage. Any implementation must include a plan for ongoing, periodic field testing and review and revision of the process and tool. The underlying science will continue to develop and the process and Impact Assessment Model should likewise develop in a defined manner. Finally we recognize that parallel work remains to be done with respect to surface water ecosystems.

The Council also began to explore the broader, socio-economic processes and contexts within which the Water Withdrawal Management Process would be used. As with the science aspects, we agreed on a number of policy constructs, however many aspects related to balancing social values and identifying acceptable sets of societal outcomes for various regional settings remain far from settled, and will require substantial attention in coming months prior to the process being implemented. This initial product represents our attempts at finding some balance, but there are several aspects we did not discuss completely and significant levels of discomfort and disagreement regarding social balance still persist with Council members. Some topics still in need of development are:

- The appropriate degree of caution to build into the process, in response to various points of scientific uncertainty.
- Application of differential levels of acceptable risk to various stream or landscape types.
- When and how local water-users committees fit into the process, and how they might go about considering allocation questions.
- Aspects of a possible mitigation framework for increased risks due to a withdrawal.
- The degree of legal presumption(s) afforded at various stages in the Water Withdrawal Assessment Process.

The Council recommends most strongly, that Michigan's water policy deliberations continue to move forward in an entirely inclusive and collaborative manner, similar to that we have modeled over the past five years. We have worked diligently for the entire period of the Council to reach consensus, and to recognize where such consensus has not been possible without rancor but rather in amity. Such a process, founded upon well developed and robust scientific evidence, best serves the long-term interests of all of the stakeholders and citizens of the state.

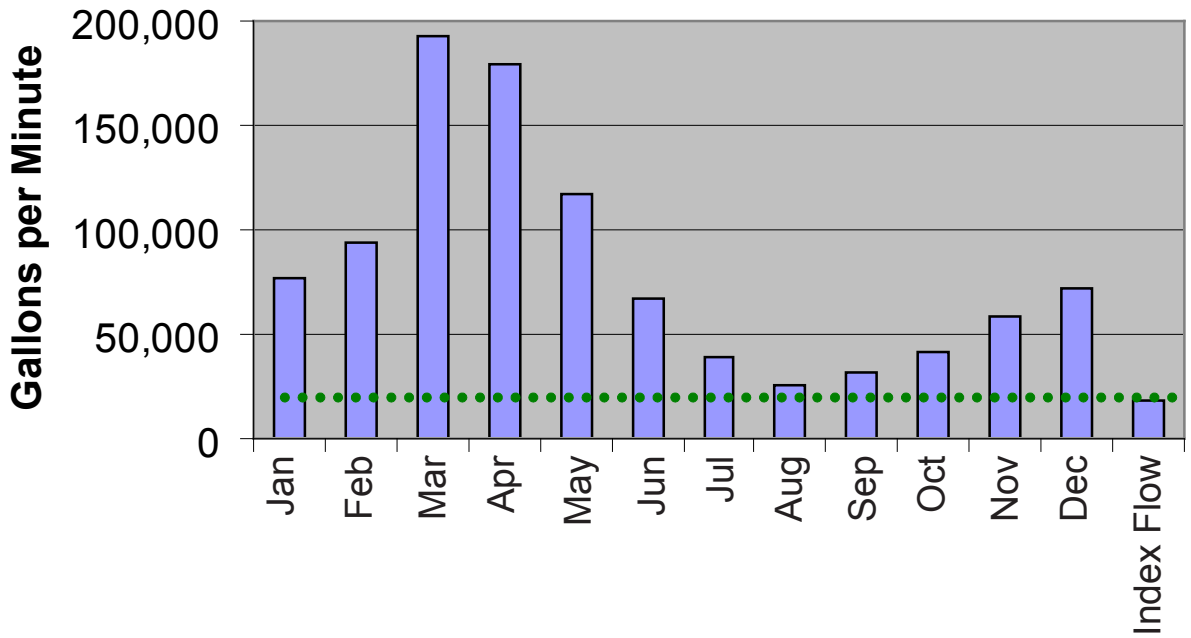

Figure 1.–Mean monthly flows for the Looking Glass River near Eagle, Michigan, showing: 1) a typical seasonal pattern in monthly flows and 2) an Index Flow (horizontal dotted line; the median flow for the lowest month) calculated for August.

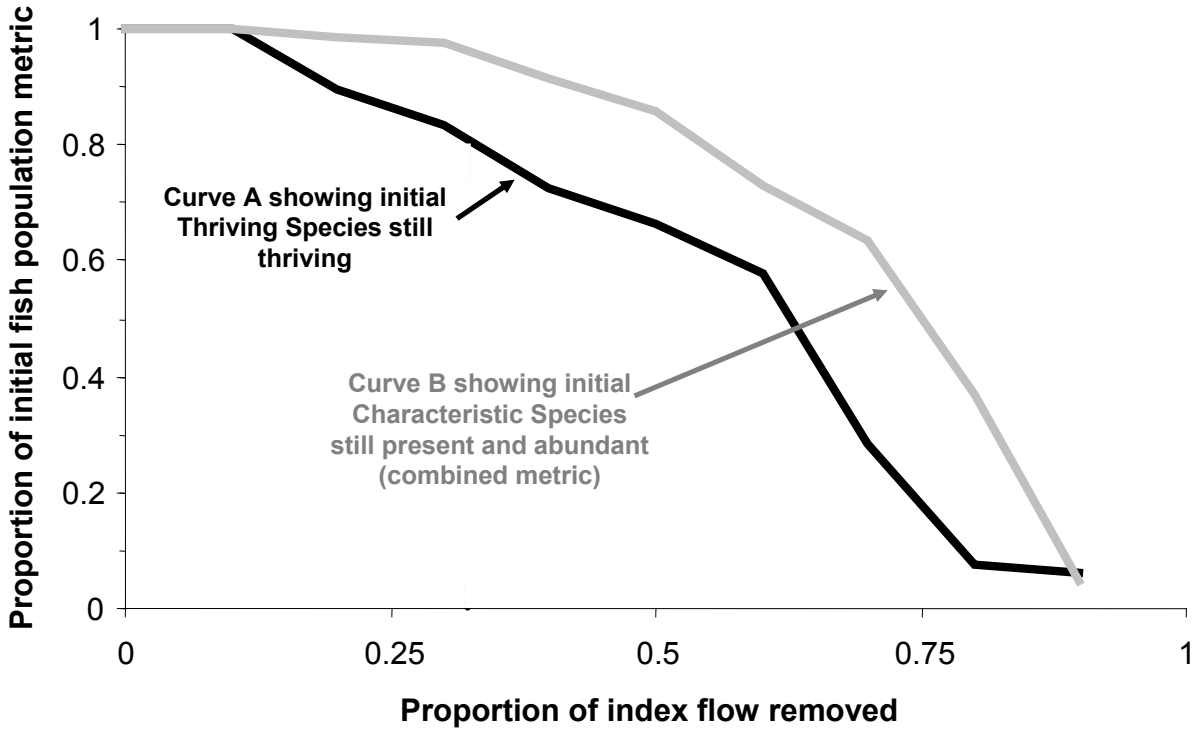

Figure 2.–The two curves showing different aspects of the functional responses of fish populations to increasing water withdrawals from Michigan streams. Curve A represents an initial, rapid response in densities of the initially most abundant fish species. Curve B represents a combination of two metrics describing the slower but more serious losses in both population abundance and species presence for characteristic fish species; when Curve B reaches zero all of the characteristic fishes have been lost.

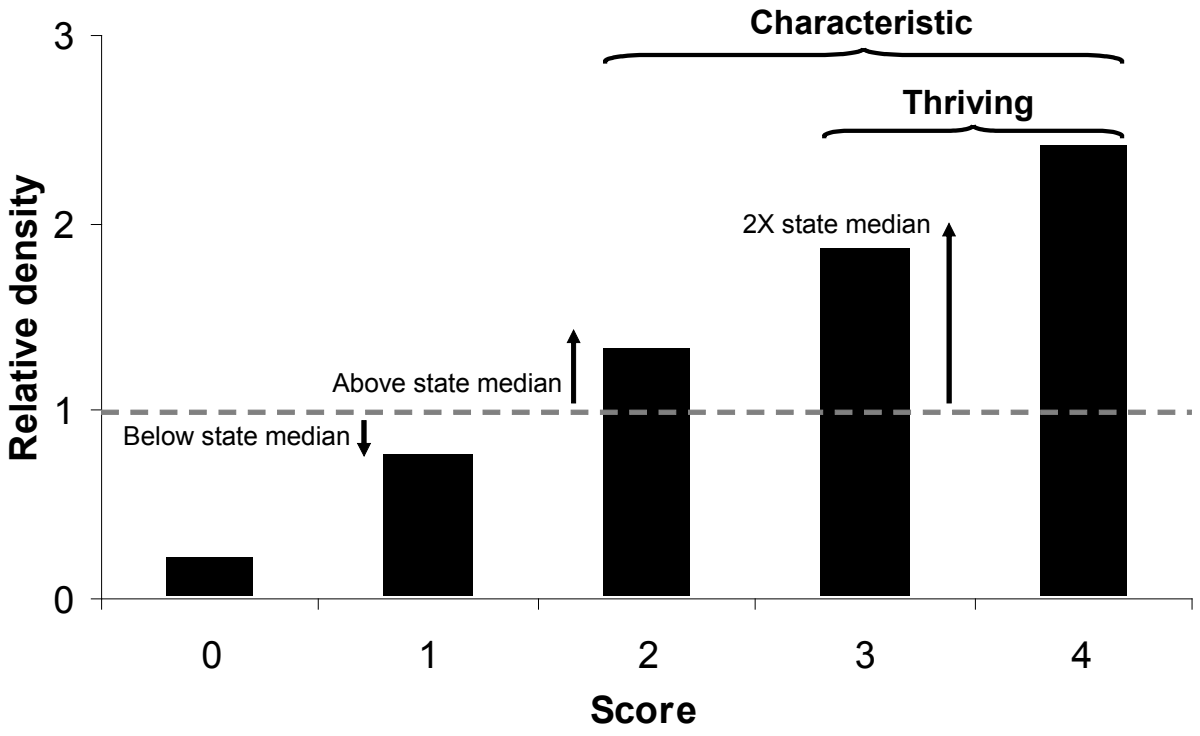

Figure 3.–Measured relative density for stream fish species shown by score categories used in the Fish Community Model. "Thriving species" scored 3 or 4, and averaged 2x the state median density. "Characteristic species" scored 2, 3, or 4 and averaged nearly that. This analysis was based on an extensive fish survey database for Michigan streams.

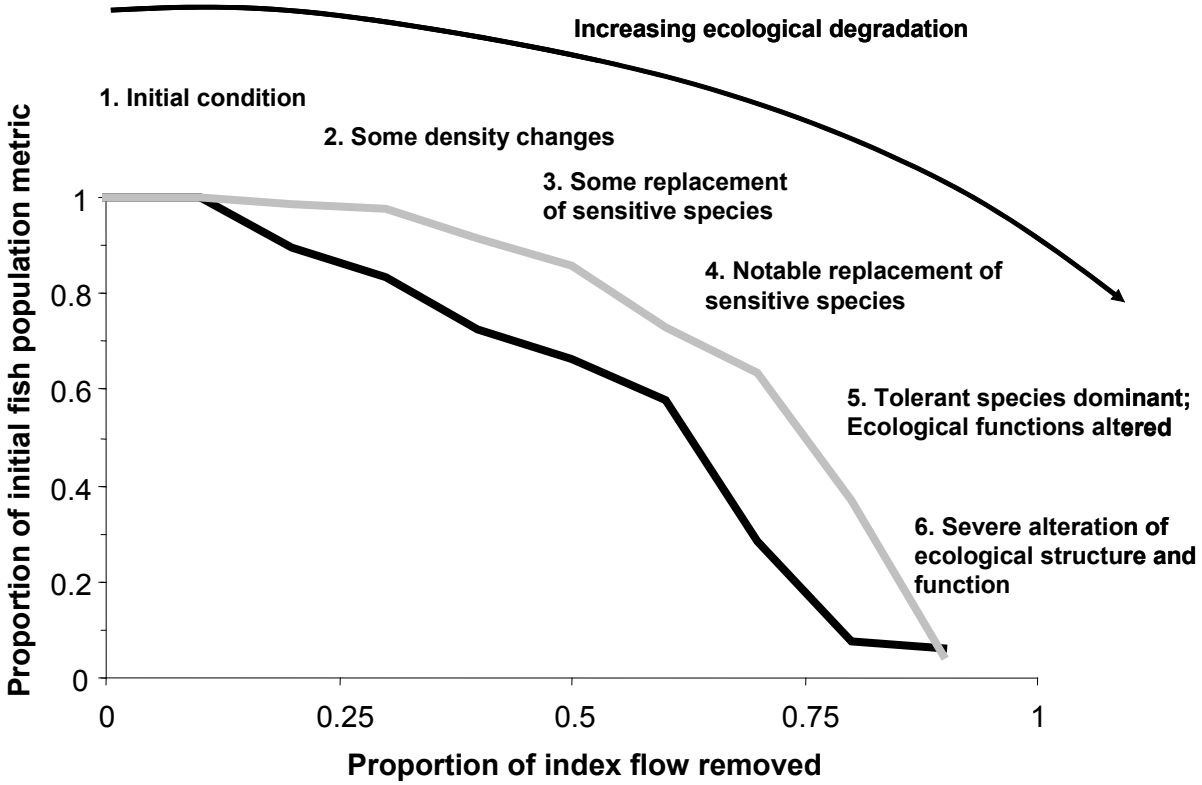

Figure 4.–Steps in ecological degradation expected as Index Flow is increasingly removed. The Council agreed that "Notable replacement of sensitive species" would clearly be an Adverse Resource Impact and that flow removals to this point should not be authorized.

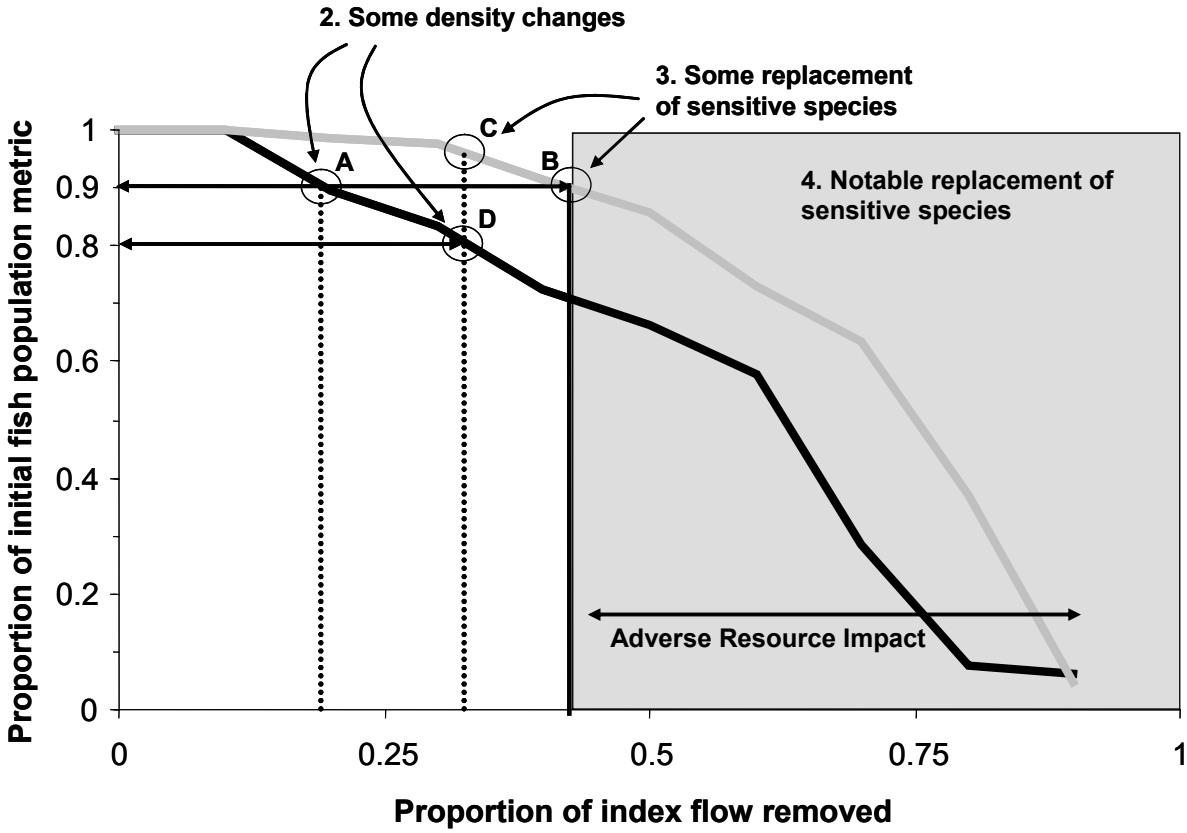

Figure 5.–The two functional response curves were interpreted using horizontal lines representing preservation of 0.8 and 0.9 of the initial fish population metrics. At points where these lines intersected the two curves (with one exception), a vertical line was dropped to indicate the proportion of Index Flow removed associated with that point on the curves. Selected points were chosen to reflect the Council's interpretation of degrees of impairment, with the intent of keeping within the range of "some density changes" (points A and D) and "some replacement of sensitive species" (points B and C). Points were also chosen prior to the point downward inflection of the curves, to stay off the 'slippery slope'. To the right of point D indicates the range of Adverse Resource Impact.

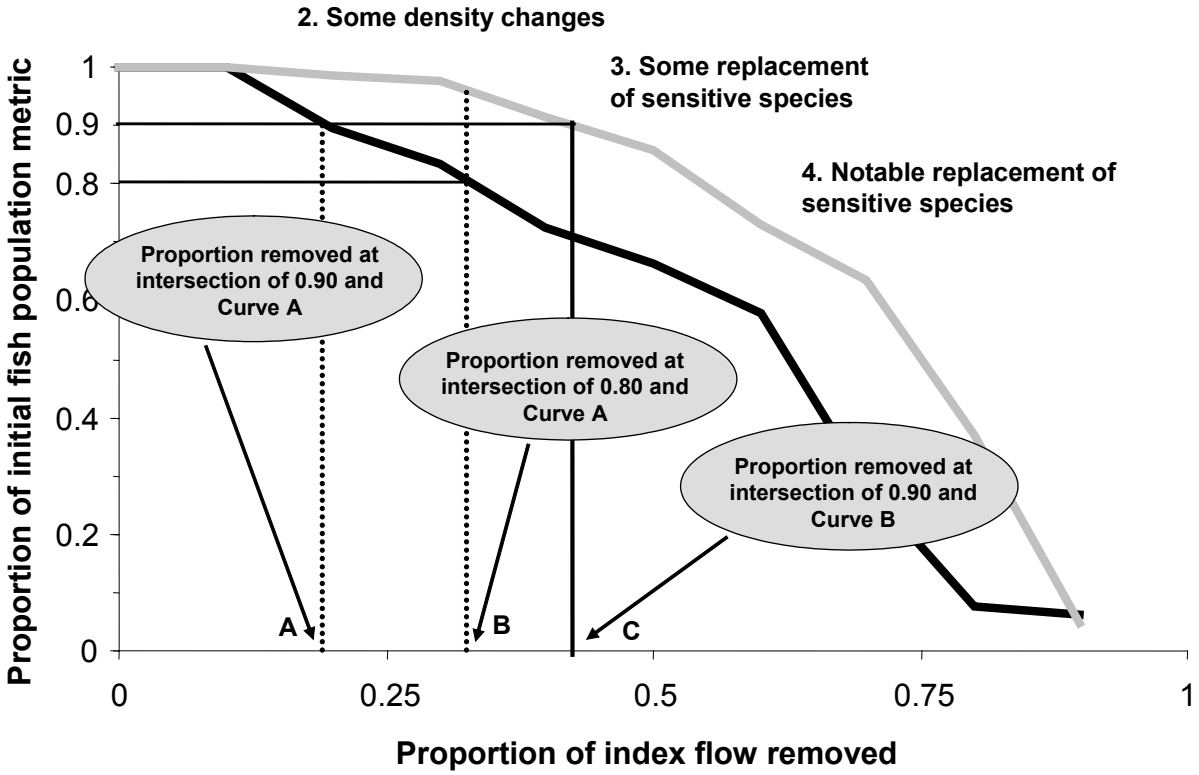

Figure 6.–Analysis of the functional response curves yielded three 'proportions of index flow removed' (A, B, and C), each identifying a threshold of ecological risk and a point of potential policy distinctions.

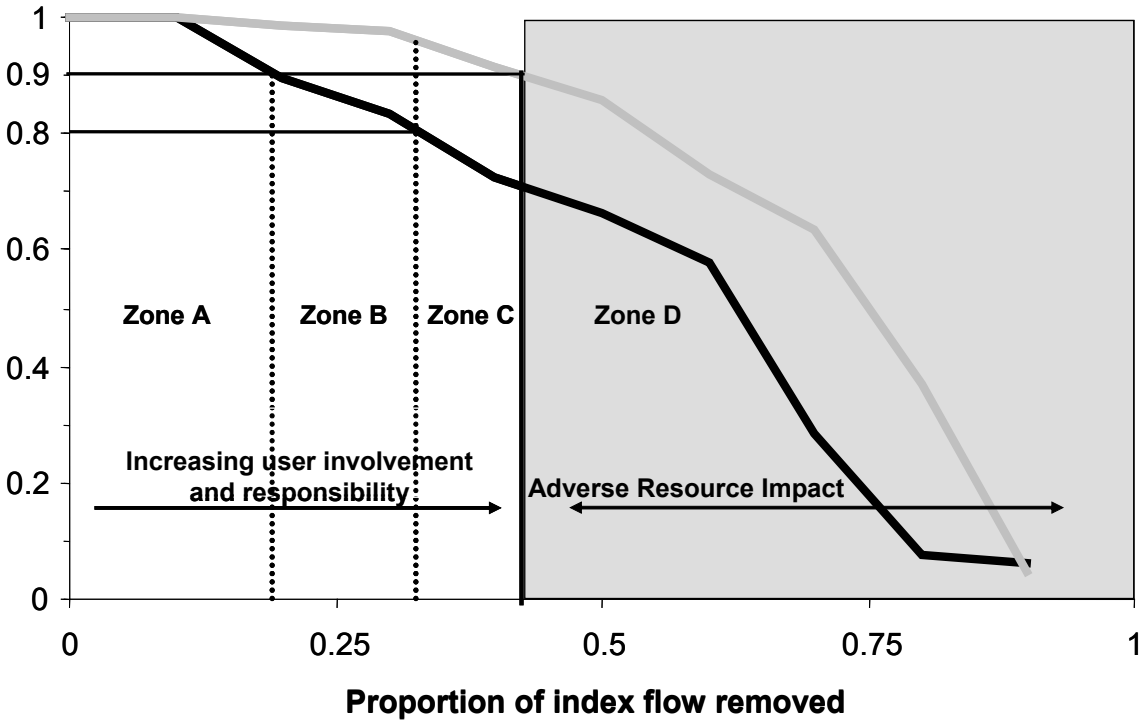

Figure 7.–The four policy zones demarcated by increasing levels of index flow removal. The Council's intent is that a series of water management program actions are implemented that matches increasing degrees of user involvement and responsibility, with increasing risk of Adverse Resource Impact.

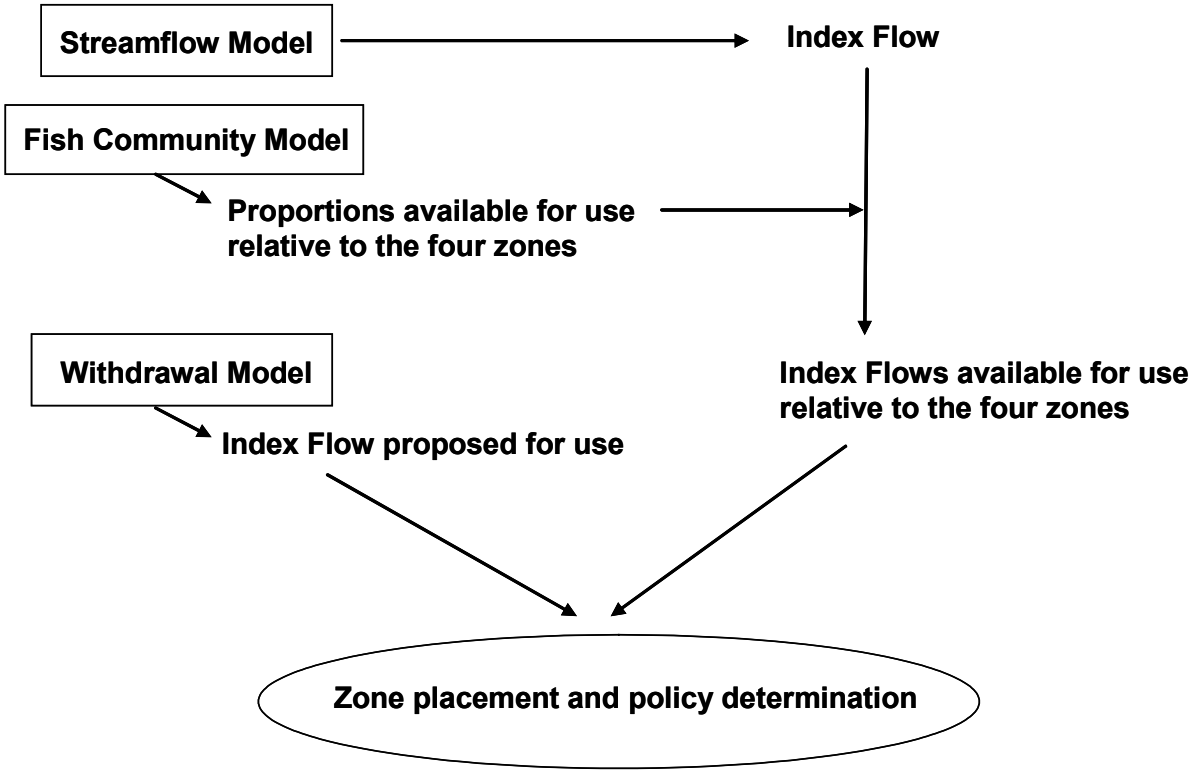

Figure 8.–Diagram of the components and flow pathways within the Impact Assessment Model.

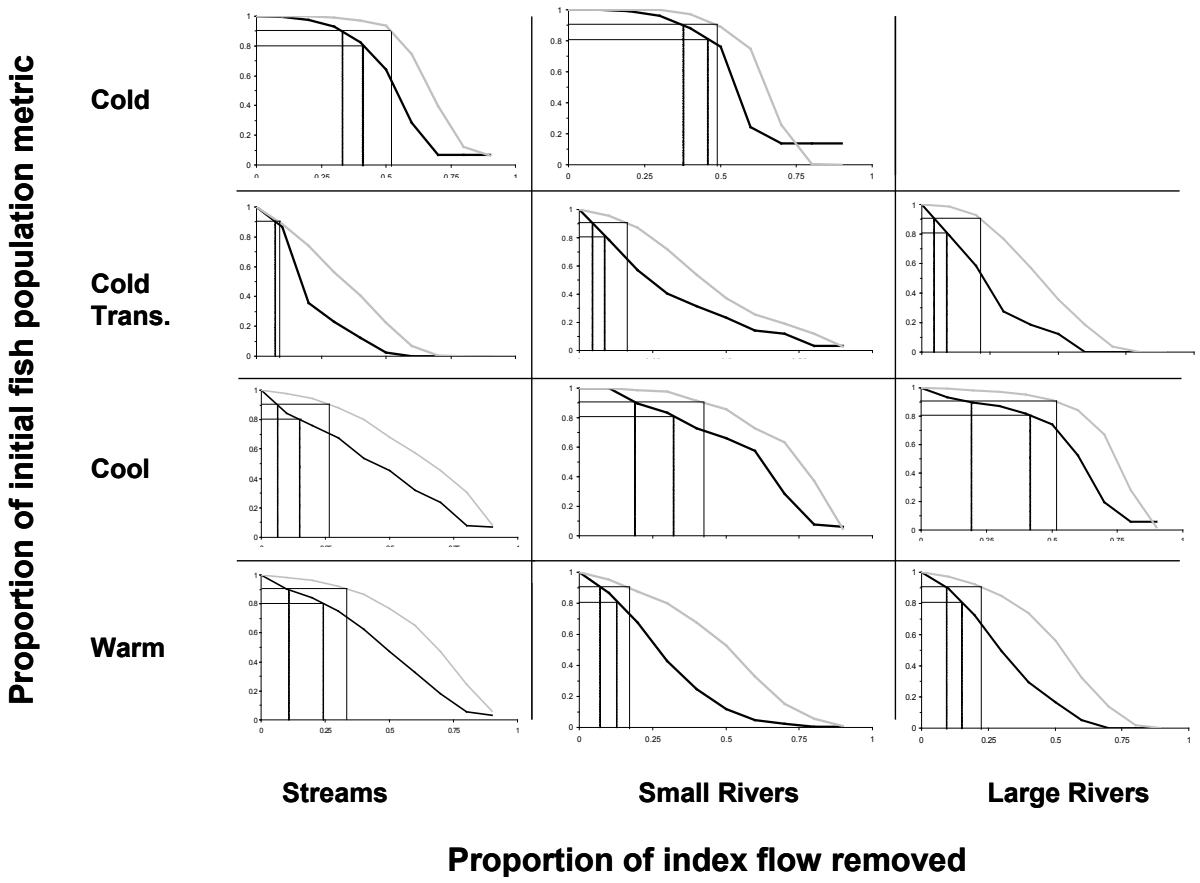

Figure 9.–Chart of the eleven stream types found in Michigan, showing the unique Impact Assessment Model developed for each type. Note the fairly strong patterns seen across the size categories for each temperature category. Cold Trans. = Cold Transitional.

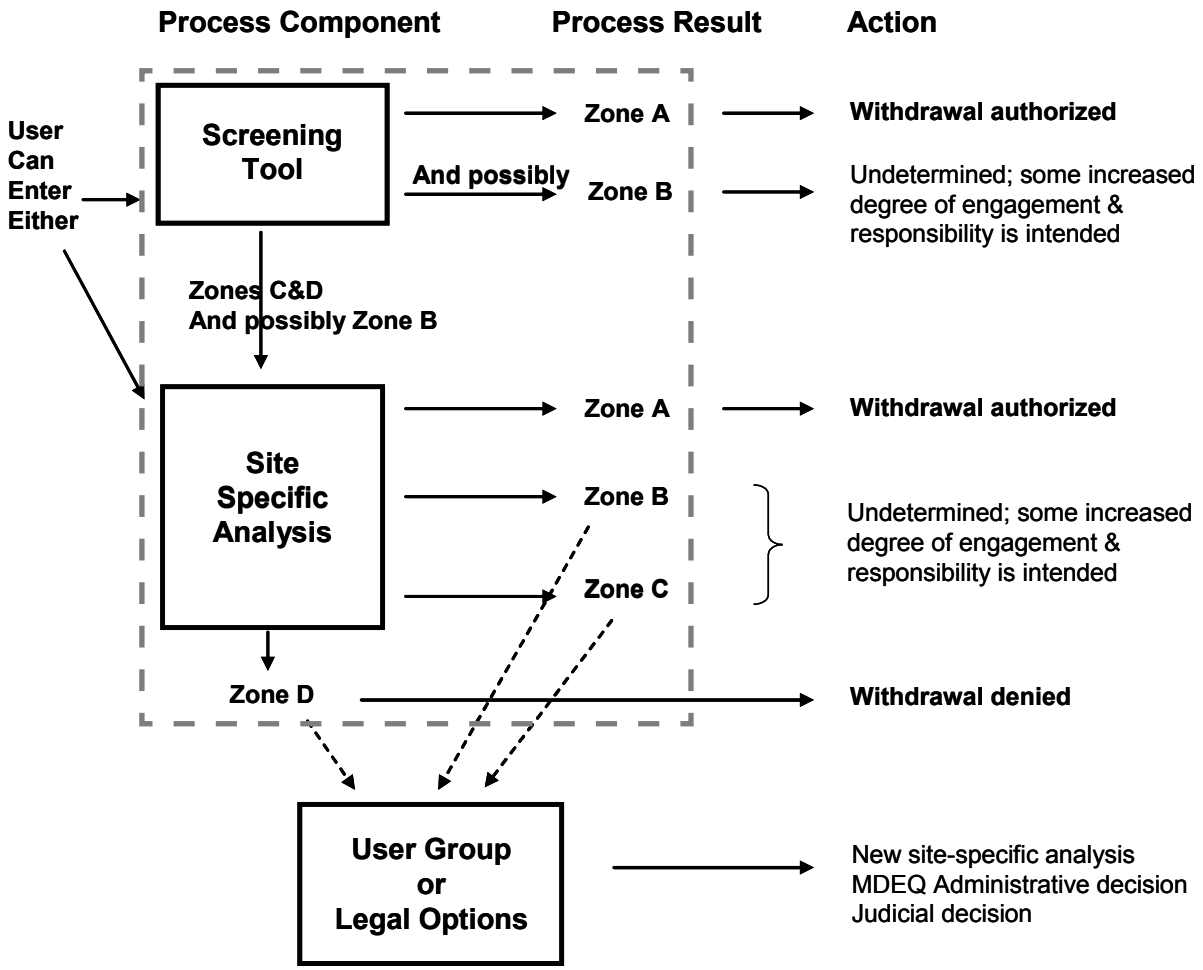

Figure 10.–Diagram of the components, results, and resulting actions within the proposed Water Withdrawal Assessment Process. The realm of the Impact Assessment Model is enclosed with a dashed line.

Appendix A

Council Membership

As set forth by 2003 PA 148 there are 17 voting members of the Council appointed by the Director of the Michigan Department of Agriculture (MDA), the Director of the Michigan Department of Environmental Quality (MDEQ), the Director of the Michigan Department of Natural Resources (MDNR), the Governor, and the State Legislature. At its second meeting, the Council agreed to be led by three co-chairs. Council membership is as follows:

Jon Allan (co-chair)
Consumers Energy Company
Appointed by the Senate Majority Leader
Representing Utilities

Sumedh Bahl
City of Ann Arbor Manager Water Treatment Services
Appointed by the Governor
Representing Municipal Water Suppliers

Rich Bowman
Director of Government Relations
The Nature Conservancy Michigan Chapter
Appointed by the Governor
Representing Conservation Organizations

Jim Cleland
Lansing Operations Division, Water Bureau
Appointed by the Director, MDEQ
Representing MDEQ

James Clift
Michigan Environmental Council
Appointed by the Director, MDEQ
Representing Environmental Organizations

Jon Coleman
Tri-County Regional Planning Commission
Appointed by the Director, MDEQ
Representing General Public

Michael R. Gregg
Water Resource Program
Appointed by the Director, MDA
Representing MDA

Kurt L. Heise (co-chair)
Wayne County Dept of Environment
Appointed by the Speaker of The House
Representing Local Units of Government

Fred Henningsen
District Agriculture and Irrigation Agent Emeritus
Appointed by the Speaker of The House
Representing Agricultural Interests

Craig Hoffman
The Rock on Drummond Island
Appointed by the Director, MDEQ
Representing Nonagricultural Irrigators

Rod Mersino
Mersino Dewatering Inc.
Appointed by the Speaker of The House
Representing Well Drilling Contractors

Thomas Newhof
Prein & Newhof
Appointed by the Senate Majority Leader
Representing Business and Manufacturing Interests

Michael Newman
Michigan Aggregates Association
Appointed by the Director, MDEQ
Representing Aggregate Industry

William F. Pearson
Pearson Drilling Company
Appointed by the Speaker of The House
Representing Well Drilling Contractors

Scott D. Piggott
Michigan Farm Bureau
Appointed by the Senate Majority Leader
Representing Agricultural Organizations

Dr. Paul Seelbach (co-chair)
Institute for Fisheries Research
Appointed by the Director, MDNR
Representing MDNR

Dr. Alan Steinman
Annis Water Resources Institute
Grand Valley State University
Appointed by the Senate Majority Leader
Representing Conservation Organizations