HYDRAULIC FRACTURING IN MICHIGAN

INTEGRATED ASSESSMENT

DRAFT FINAL REPORT

EXECUTIVE SUMMARY

FEBRUARY 2015

UNIVERSITY OF MICHIGAN

Participating University of Michigan Units
Graham Sustainability Institute
Energy Institute
Erb Institute for Global Sustainable Enterprise
Risk Science Center

For more information on this project and to submit comments on this draft report, please go to:
http://graham.umich.edu/knowledge/ia/hydraulic-fracturing

You may also contact John Callewaert, Graham Sustainability Institute Integrated Assessment Center Director, (734) 615-3752, jcallew@umich.edu.

ABOUT THIS DRAFT REPORT

This draft report is part of the Hydraulic Fracturing in Michigan Integrated Assessment (IA) which has been underway since 2012. The guiding question of the IA is, "What are the best environmental, economic, social and technological approaches for managing hydraulic fracturing in the State of Michigan." The purpose of the IA is to present information that expands and clarifies the scope of policy options to address that question in a way that allows a wide range of decision makers to make choices based on their preferences and values. As a result, the IA does not advocate for recommended courses of action. Rather, it presents information about the likely strengths, weaknesses, and outcomes of various options to support informed decision making.

The project's first phase involved preparation of technical reports on key topics related to hydraulic fracturing in Michigan which were released by the University of Michigan's Graham Sustainability Institute (Graham Institute) in September 2013. This document is a draft version of the final report for the IA and is a work in progress. Because it is a work in progress, it is incomplete and subject to revision. The content does not reflect a consensus position and is not intended to limit on-going discussions, revisions, or preclude new options from being considered. This is not an official document and as such, this document is not to be quoted, cited in any reference, or used by anyone for any purpose other than as a draft document.

Topics covered in this report have been informed by the technical reports, input from an advisory committee with representatives from corporate, governmental, and non-governmental organizations, and a review of numerous public comments received throughout this process. However, the draft report does not necessarily reflect the views of the advisory committee or of all public comments received to date. In addition, this draft document does not yet reflect detailed input from a peer review panel, the advisory committee, or the general public. Those reviews and public comment processes are currently underway and will be fully considered as the Graham Institute prepares the final version of the report. As with preparation of the technical reports, all decisions regarding content of project analyses and reports will be determined by the IA Report and Integration Teams.

While the IA has attempted to provide a comprehensive review of the current status and trends of high volume hydraulic fracturing (HVHF) in Michigan (the technical reports) and an analysis of policy options (this report) there are certain limitations which must be recognized. First, the assessment does not and was not intended to provide a quantitative assessment (human health or environmental) of the potential risks associated with HVHF. Completing such assessments is currently a key point of national discussion related to HVHF despite the challenges of uncertainty and limited available data–particularly baseline data. Second, the assessment does not provide economic analysis or a cost-benefit analysis of the presented policy options. While economic strengths and/or weaknesses were identified for many of the options, these should not be viewed as full economic analyses. Additional study would be needed to fully assess the economic impact of various policy actions, including no change of current policy.

EXECUTIVE SUMMARY

OVERVIEW

There is significant momentum behind natural gas extraction efforts in the United States, with many individual states embracing it as an opportunity to create jobs and foster economic strength. Natural gas extraction has also been championed as a way to move toward domestic energy independence and a cleaner energy supply. First demonstrated in the 1940s, hydraulic fracturing—injecting fracturing fluids into the target formation at a force exceeding the parting pressure of the rock (shale) thus inducing a network of fractures through which oil or natural gas can flow to the wellbore—is now the predominant method used to extract natural gas in the United States.[1] As domestic natural gas production has accelerated in recent years, however, the hydraulic fracturing process and associated shale gas activities have come under increased public scrutiny – particularly with respect to high volume hydraulic fracturing (HVHF), which uses substantially more water and materials to complete the process. Concerns include perceived lack of transparency, chemical contamination from fracturing fluids, water availability, wastewater disposal, and impacts on ecosystems, human health, and surrounding communities. Consequently, numerous hydraulic fracturing studies are being undertaken by government agencies, industry, environmental and other non-governmental organizations, and academia, yet none have a particular focus on Michigan.

The idea for conducting an Integrated Assessment on HVHF in Michigan was developed by the University of Michigan (U-M) Graham Sustainability Institute over a one year time frame (June 2011-June 2012) and involved conversations with several other U-M institutes, the Graham Institute's External Advisory Board, U-M faculty, researchers at other institutions, regulatory entities, industry contacts, and a wide range of non-governmental organizations.

Integrated Assessment (IA) is one of the ways the Graham Institute addresses real-world sustainability problems. This methodology begins with a structured dialog among scientists and decision makers to establish a key question around which the assessment will be developed. Researchers then gather and assess natural and social science information to better prepare decision makers in addressing the question. The purpose of this IA is to present information that expands and clarifies the scope of policy options in a way that allows a wide range of decision makers to make choices based on their preferences and values. As a result, the Integrated Assessment does not advocate for recommended courses of action. Rather, it presents information about the likely strengths, weaknesses, and outcomes of various options to support informed decision making.

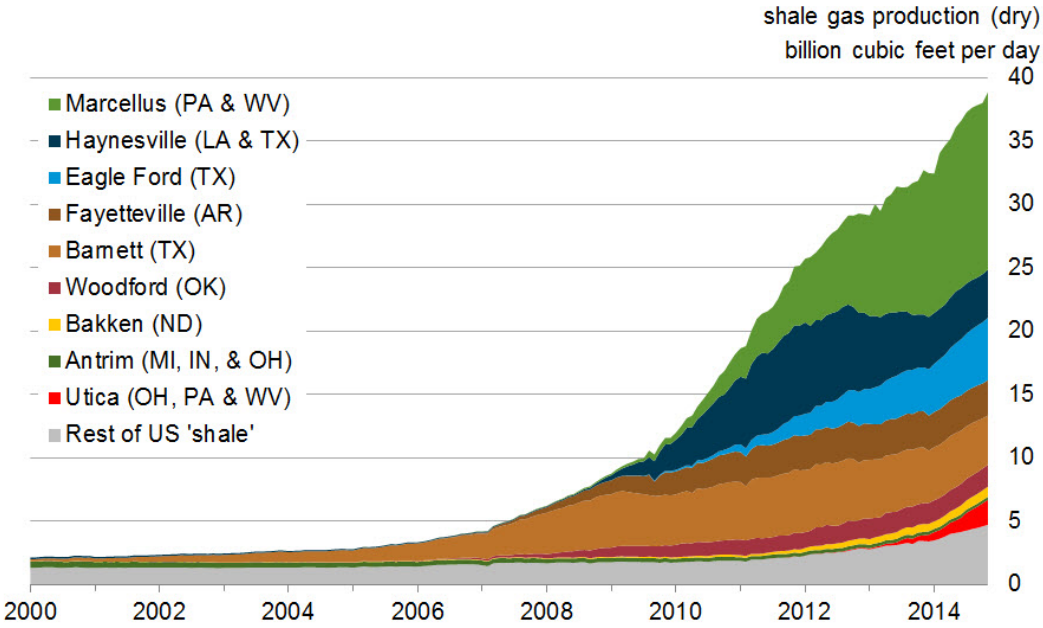
High volume hydraulic fracturing intersects many issues that are important to Michigan residents—drinking water, air quality, water supply, local land use, energy security, economic growth, tourism, and natural resource protection, including the Great Lakes. The project does not seek to predict a specific future for HVHF in Michigan, but it posits that natural gas extraction pressures will likely increase in Michigan if the following trends persist: desire for job creation, economic strength, energy independence, and decreased use of coal.

The guiding question—*What are the best environmental, economic, social, and technological approaches for managing hydraulic fracturing in the State of Michigan?*—bounds the scope of the IA. While the IA focuses on Michigan it also incorporates the experience of other locations that are relevant to Michigan's geology, regulations, and practices. Additionally, the IA primarily concentrates on HVHF (defined by the Michigan Department of Environmental Quality guidelines as well completions that intend to use a total of more than 100,000 gallons of hydraulic fracturing fluid), but the analysis of options may also consider implications for other practices or include options for different subsets of wells.

Recent interest from energy developers, lease sales, and permitting activities suggest increasing activity around deep shale gas extraction in Michigan. Below are some key points regarding hydraulic fracturing in Michigan.

- According to the Michigan Department of Environmental Quality (DEQ), over the past several decades more than 12,000 oil and gas wells have been fractured in the state and regulators report no instances of adverse environmental impacts.[2] Most of these are Antrim Shale vertical wells drilled and completed in the late 1980s and early 1990s. Some new activity will still take place, and a very small number of the old wells may be hydraulically fractured in the future, but this is a "mature" play and is unlikely to be repeated.
- The hydrocarbon resources in the Utica and Collingwood Shales in Michigan will likely require high volume hydraulic fracturing and horizontal drilling (a drilling procedure in which the wellbore is drilled vertically to a kickoff depth above the target formation and then angled through a wide 90 degree arc such that the producing portion of the well extends horizontally through the target formation).
- A vertical well that is hydraulically fractured in Michigan may typically use about 50,000 to 100,000 gallons of water while a high volume, horizontally drilled well may use up to 20,000,000 gallons of water or more.[3]
- A May 2010 auction of state mineral leases brought in a record $178 million—nearly as much as the state had earned in the previous 82 years of lease sales combined. Most of this money was spent for leases of state-owned mineral holdings with the Utica and Collingwood Shales as the probable primary targets.[4,5] However, there has been limited production activity in response to these leases.
- As of December 22, 2014, there were 13 producing HVHF completed wells in Michigan, 2 active applications, 28 active permit holders, 5 locations with complete plugging, and 11 locations with completed drilling.[6]
- Shale gas production in Michigan is much lower than production in other states (see U.S. Energy Information Administration shale gas production information in Figure 1.1).
- Several bills have been proposed in Michigan to further regulate or study hydraulic fracturing,[7] state officials are proceeding with promulgation of additional rules on high volume hydraulic fracturing,[8] and a ballot question committee has been working to prohibit the use of horizontal hydraulic fracturing in the state.[9]

Figure 1.1: U.S. dry shale gas production[10]



Terminology is important to any discussion of shale gas and hydraulic fracturing. Below are key terms which will be used throughout the report. Additional terminology and definitions can be found in the glossary in Appendix A of the full report.

- **Conventional and Unconventional Natural Gas:** Natural gas comes from both "conventional" (easier to produce) and "unconventional" (more difficult to produce) geological formations. The key difference between "conventional" and "unconventional" natural gas is the manner, ease, and cost associated with extracting the resource. Conventional gas is typically "free gas" trapped in multiple, relatively small, porous zones in various naturally occurring rock formations such as carbonates, sandstones, and siltstones.[11] However, most of the growth in supply from today's recoverable gas resources is found in unconventional formations. Unconventional gas reservoirs include tight gas, coal bed methane, gas hydrates, and shale gas. The technological breakthroughs in horizontal drilling and fracturing are making shale and other unconventional gas supplies commercially viable.[12]
- **Shale Gas:** Natural gas produced from low permeability shale formations.[13]
- **Hydraulic Fracturing:** Injecting fracturing fluids into the target formation at a force exceeding the parting pressure of the rock thus inducing a network of fractures through which oil or natural gas can flow to the wellbore.
- **High Volume Hydraulic Fracturing:** High volume hydraulic fracturing well completion is defined by State of Michigan regulations as a "well completion operation that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid."[14,15]

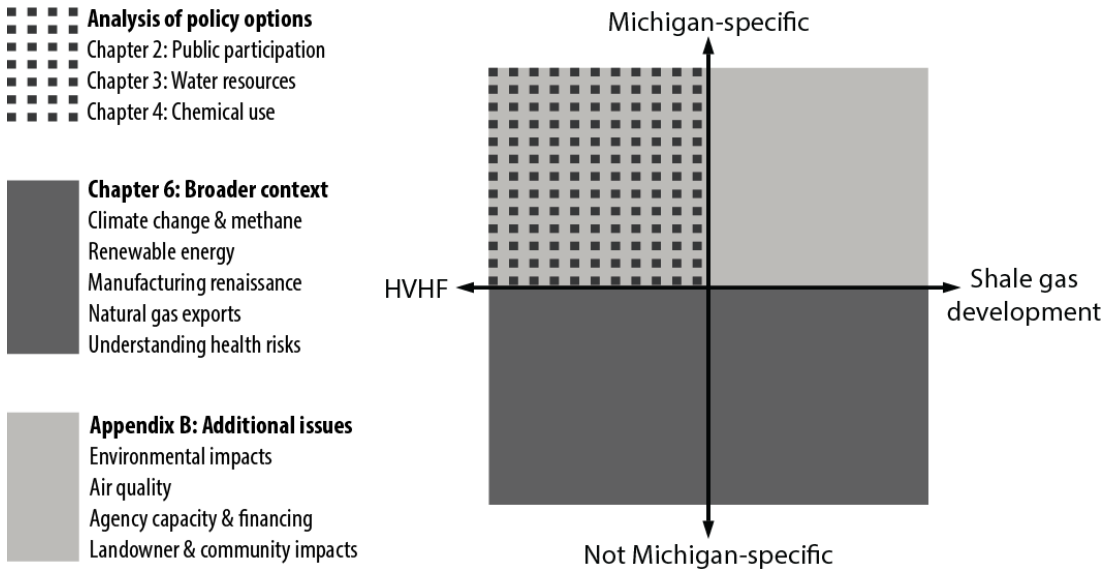
Chapter 1 of the full report provides an overview of the purpose, scope, and process used for this assessment including contributors, participants, previously released technical reports, and other

stages of the project. Chapters 2, 3, and 4 represent the central part of the report and focus on an analysis of primarily HVHF policy options specific for Michigan in the areas of public participation, water resources, and chemical use. Chapter 5 provides a frame for analyzing all the new policy options presented in Chapter 2 (public participation), Chapter 3 (water resources) and Chapter 4 (chemical use). Using adaptive and precautionary policy frames, this chapter categorizes policy options by their approach to uncertainty in order to help identify options appropriate for several plausible futures or conditions with respect to high volume hydraulic fracturing in Michigan. Chapter 6 provides an overview of key points of discussion within the broader context of shale gas development that are not specific to Michigan. Chapter 7 identifies the limits of this report and knowledge gaps. Appendix B offers a review of additional shale gas development issues that are relevant to Michigan but not specific to HVHF.

The key contribution of this report is the analysis of HVHF options specific for Michigan in the areas of public participation, water resources, and chemical use (Chapters 2 – 4). These topics were identified based on review of key issues presented in the technical reports from the first phase of the IA, numerous public comments, and the expert judgment of Report Team members based on a review of current policy in Michigan, other states, and best practices.

The technical reports and public comments also include other issues related, but not specific, to HVHF activity in Michigan. While these issues are beyond the focus of this IA, they are important at geographic scales beyond Michigan and for unconventional shale gas development more generally. Therefore, a concise summary of key topics in the broader context and national discourse related to expanded natural gas production and use is provided in Chapter 6, and information about additional issues related to shale gas development but not HVHF-specifically is included in Appendix B. Figure 1.2 illustrates the organization of the full report around its focus on HVHF in Michigan.

Figure 1.2: Report organization



ANALYSIS OF POLICY OPTIONS

Chapters 2 through 4 present an analysis of HVHF options specific for Michigan in the areas of public participation, water resources, and chemical use. Within each chapter an overview of the topic is provided along with a description of current policy in Michigan, new HVHF rules proposed by the state, and a range of approaches from other states and novel approaches. Each of these chapters also provides an analysis of the strengths and weaknesses of the policy options. There is some variation in approach for each chapter given the range of policies and related conditions which are addressed.

Public Participation

"Public participation" has been interpreted in many ways. In the context of public policy, it often takes the form of public comment periods and hearings, where the public might be described as having a consultative role. Other forms of public participation such as moderated workshops and deliberative polling may allow for more interactive discussions that encourage collaborative decision making. Although no unified theory of public participation exists, scholars generally agree that good public participation should:

(1) Lead to higher-quality decisions by appropriately incorporating stakeholder information and values,
(2) Be legitimate and perceived as fair,
(3) Reduce conflict and build trust in institutions,
(4) Lead to a shared understanding of the issues, and
(5) Improve the capacity of all parties to engage in the policy-making.

Scholars and industry alike are beginning to reconsider how the public might be more involved in shaping HVHF-related policies, in particular, and oil and gas policy, in general. By contrast, only a few states have made efforts to engage the public in more deliberative discussions about unconventional shale gas development. Instead, most states have relied on existing oil and gas regulations to govern their public participation practices. In some states this means the public may be notified of proposed oil and gas wells and possibly given an opportunity to submit comments; in other states, only surface owners are given such an opportunity.

The public participation chapter examines options for improving how public values and concerns are incorporated into HVHF-related policy. The first subsection explores this question broadly by looking at how public values inform unconventional shale gas policies, in general, and what opportunities exist for improvement. The remaining two subsections examine how public interests are represented in state land leasing decisions and well permitting as both affect a question of primary importance to the public: where will HVHF occur?

To date, Michigan has largely treated HVHF as an extension of other types of oil and gas activities. As a result, the public has had few opportunities to weigh in on whether and where HVHF occurs. Beyond changing regulations specific to state land leasing and well permitting practices (which will be discussed in the next two sections), the state could consider

implementing a number of options to better represent public values in unconventional shale gas policies. As a first step toward building the public's trust and signaling that public concerns have been heard, the state could revise the content and usability of the DEQ website as well as require risk communication training for DEQ and DNR staff. DEQ could augment these efforts by providing interactive listening sessions, moderated by a skilled facilitator, where the public can engage in genuine dialogue about their concerns related to deep shale gas development. Information generated during these discussions may help ease some of the public's concerns as well as inform state decision making.

To help ensure that potential impacts to human health, the environment, and local communities are adequately considered in HVHF policies, the state could increase stakeholder representation on the Oil and Gas Advisory Committee as well as appoint a multi-stakeholder advisory commission to further study the potential impacts of HVHF in Michigan. Finally, to ease tensions around HVHF and provide an opportunity to engage the public in more analytic-deliberative discussions about unconventional shale gas development, the state could impose a moratorium or ban on HVHF permitting.

Michigan's existing policy of requiring public notice and comment before auctioning state mineral rights has been reasonably responsive to public concerns. The existing policy could be strengthened, however, by increasing public notice to targeted stakeholders (e.g., nearby landowners and users of state lands), providing moderated workshops where the public can engage in dialogue with the state about proposed leases, and/or requiring public notice and comment when well operators request modifications of existing state land leases. Each of these steps could enhance transparency about state land leasing as well as increase the likelihood that the DNR's decisions will be informed by relevant environmental, health, and community considerations.

Michigan's existing policy for involving the public in well permitting decisions is more inclusive that many states but less inclusive than others. By only notifying surface owners and local units of government, the current policy hinders transparency about HVHF operations in the state and reduces the ability of affected community members to voice concerns that should be legitimately considered in DEQ's decision making. Increasing public notice, requiring a public comment period, and allowing adversely affected parties to petition for a public hearing are all options that can help address these concerns. To be most effective, these options should be implemented together.

The policy options addressed in Chapter 2 – Public Participation are listed in Table 1.1. The descriptions are not complete; refer to the chapter section for additional detail.

Table 1.1: Policy options for public participation and incorporating public values into shale gas development policy

Incorporating public values in unconventional shale gas development policy	
2.2.3.1	Keep existing Michigan policy for public engagement
	No mandatory public notice and comment on well applications; public comments on proposed rules and testimony at rule promulgation public hearings; DEQ informs residents about HVHF through website and participates in public meetings/events
2.2.3.2	Revise the DEQ website to improve transparency and usability
2.2.3.3	Require risk communication training for DEQ and DNR employees
2.2.3.4	Conduct public workshops to engage Michigan residents in HVHF decision-making
2.2.3.5	Impose a state-wide moratorium on HVHF
2.2.3.6	Ban HVHF
2.2.3.7	Appoint a multi-stakeholder advisory commission to study HVHF impacts and identify best practices for mitigating them
2.2.3.8	Increase stakeholder representation on Oil and Gas Advisory Committee
Public input in state land leasing	
2.3.3.1	Keep Michigan's existing state land leasing policy
	NRC and DNR manage state-owned lands and mineral resources; oil and gas rights leased for qualified lands via public auction, auction lists made publically available, public comment is allowed and, in practice, DNR prepares response although not required to do so; notification of public auctions via newspapers in leasing regions, on DNR website, and to DNR mailing list
2.3.3.2	Increase public notice
	Expand notification to all landowners adjacent to or within ¼ mile of parcel; notification at parcel itself if near a recreational area
2.3.3.3	Require DNR to prepare a responsiveness summary
2.3.3.4	Require public workshops prior to state land auctions
2.3.3.5	Increase public notice and comment when lessees submit an application to revise or reclassify a lease
Public participation and well permitting	
2.4.3.1	Keep existing Michigan well permitting policy
	DEQ is required to give notice of permit applications to surface owner, county, and city/village/township if the population >70,000, but, in practice, provides notice regardless of population size; is required to consider written comments from any city, village, township, or county with a proposed well; informally accepts any public comments on permit applications; voluntarily posts map of HVHF activity and notices of weekly permit activity on website
2.4.3.2	Increase notification of permit applications
	Remove population threshold; public notice in local newspapers and nearby property—potentially done by permit applicant

2.4.3.3	Require a public comment period with mandatory DEQ response
2.4.3.4	Allow adversely affected parties to request a public hearing before a HVHF well permit is approved

Water Resources

High volume hydraulic fracturing requires large quantities of water for its operation and these numbers are often a source of concern for many citizens when it comes to thinking about the potential impacts caused by HFHV. The State of Michigan has a well-developed system for the management of water withdrawals, the (Water Withdrawal Assessment Process) WWAP, which was developed as part of the Great Lakes Compact, and instituted in 2009. The WWAP offers a unified mechanism of managing HVHF operations, by managing the water resources of the State. The management of water resources as a central means of managing HVHF operations is currently utilized by both the DRBC and the SRBC. In the same vein, the WWAP provides a singular mechanism for managing HVHF operations by recognizing that their water needs can also fall under the purview of the WWAP, just like all other large-scale water uses in the state.

The water resources chapter is organized into two major sections. The first explores the various methods in which improvements to the WWAP may provide mechanisms to govern water withdrawals associated with HVHF. Many of these improvements have been raised in public comment as well as in public meetings of the Water Use Advisory Council. The second section explores regulatory rules changes concerning waste management of water used in HVHF.

As sophisticated as the WWAP is in governing water withdrawals, it was not designed to address the specific issues of water withdrawals associated with HVHF, which means that—in order to effectively use the state's core mechanism for water conservation—the various parts of the WWAP need to be updated and modified in order to address the unique technical, physical, and social challenges presented by HVHF. The different parts of WWAP address different issues associated with water quantity governance, and this section presented different policy options to deal with each of them. Two general means of addressing water quantity governance were provided: enacting changes to the WWAP that would specifically include HVHF and treat it no differently from other water withdrawals or putting policies in place that specifically address only HVHF water withdrawals, specifically to assuage public concerns over the water volumes associated with HVHF operations. The thresholds for regulation could be altered to ensure the inclusion of HVHF water withdrawal operations. These changes could have negative consequences on certain types of water users, but they will also have the benefits of increasing the strength and quality of water conservation throughout the state. The scientific models underlying the central piece of the WWAP—the water withdrawal assessment tool—can be improved in various ways in order to broaden the types of water withdrawals for which it can predict associated impacts as well as to expand its capacity to model impacts to inland lakes, ponds, and wetlands (hydric systems that are not currently included the models). While these improvements will require additional public investments, the long-term benefits of these investments will be a far more predictive, automated, and equitable water governance structure. Furthermore, improvements to the existing public engagement structures outlined in the

WWAP—specifically WUCs and Water Resources Education Advisory Committees—can help develop local water use governance, especially in cases where water resources approach an adverse resource impact (ARI) designation.

In addition to modifying and updating the existing WWAP structure, a number of additions to the WWAP are presented in this section. Options such as fee schedules, like those used by the Susquehanna and Delaware River Basin Commissions could be implemented to fund and improve water governance mechanisms and structures within the state. In addition, providing opportunities for the public to provide monitoring information to the DEQ allows for civic engagement at little additional governmental cost. Finally, discussion of implementation of a water-use market is presented, which could provide options for minimizing additional water withdrawals by HVHF operations through financial agreements with existing water-withdrawal registrants over the use of a portion of their registered water withdrawals.

The future of water uses in the State of Michigan will undoubtedly become more complex, and the process of governing the state's water resources to ensure they align with the requirements of the Great Lakes Compact will simultaneously require modification. The WWAP provides a unique mechanism for addressing most water conservation decisions through an automated, scientifically based, free online tool as well as a system of human-based reviews for areas with heightened scrutiny in addition to a system of local decision making over water uses. It is necessary to recognize that the current WWAP was meant as only an initial version of an increasingly sophisticated water governance framework. High-volume hydraulic fracturing presents a challenge for the current version of the WWAP, but it is one that can – with sufficient applications of policy options – be addressed effectively without the need of building a completely new water conservation structure.

Presently, the wastewater management and water quality policies of the State of Michigan have been mostly adequate in dealing with most of the issues surrounding the historic generation of wastewaters associated with hydraulic fracturing. However, with the intensity of wastewater generation associated with high volume hydraulic fracturing, it is not clear whether the laws and regulations written at a time of small-scale, shallow hydraulic fracturing options will be adequate. Where there once were thousands of gallons of wastewater per well to handle from historic small-scale fracturing operations, a future with high-volume hydraulic fracturing will create hundreds-of-thousands (and possibly millions) of gallons of wastewater; one hundred to one thousand times more than historic wells.

A future with high volume hydraulic fracturing in the State of Michigan should be met with the understanding of the vastly different implications associated with high volume hydraulic fracturing. Providing additional safeguards will provide better protection of public drinking water supplies and the sources of water for many of the state's prime fishing rivers. Furthermore, providing additional options for managing wastewater use and alternative sources for water acquisition will provide well operators with a means of minimizing the local negative impacts of water withdrawals as well as providing potential economic savings in the operations of the well.

The current process for managing hydraulic fracturing wastewater fluids in the State of Michigan is deep well injection. The Underground Injection Control program, which is the national governing framework for deep well injection, is managed by the U.S. Environmental Protection Agency (EPA), and, together with Michigan State Law, it requires the disposal of hydraulic fracturing fluids into Class II wells.

In addition to deep well injection, another way to manage wastewater and water quality is to promote alternative sources of hydraulic fracturing fluids, including recycled wastewater and treated municipal water. Currently, the State of Michigan provide only a single defined regulatory option for recycling hydraulic fracturing wastewater (i.e., ice and dust control, but only if the wastewater meets specific quality conditions), even though recycling technologies are actively being developed. The State of Michigan also does not allow for the use of treated municipal wastewater as the water source for hydraulic fracturing operations, even though this can be used an alternative water source. Providing opportunities for recycling wastewater and using alternative water resources both hold potential benefits of improved water quality, through diminished demands for groundwater resources. However, neither of these are a total panacea, as they both carry associated environmental risks and costs.

The policy options addressed in Chapter 3 – Water Resources are listed in Table 1.2. Refer to the chapter section for a complete description of each policy option.

Table 1.2: Policy options for water resources

Regulating HVHF by modifying the WWAP	
Requirements for water withdrawal approval	
3.2.1.3.1	Keep existing Michigan policy for water withdrawal approval
	No cumulative water withdrawals in subwatershed units may cause an adverse resource impact (ARI)
3.2.1.3.2	Remove the HVHF exemption from the WWAP
3.2.1.3.3	Disallow HVHF operation approaching an ARI (Michigan proposed rule)
3.2.1.3.4	Adopt additional rules for proposed water withdrawals (Michigan proposed rule)
	Requires provision of well logs of recorded and reasonably identifiable fresh water wells within a certain distance; permit applicants required to show the locations of proposed withdrawal wells along with recorded wells, reasonably identifiable wells, and proposed fresh water pit impoundment and containment facilities; must also provide a contingency plan if deemed necessary
3.2.1.3.5	Disallow any HVHF operations within a cold-transitional system
3.2.1.3.6	Overestimate proposed HVHF water withdrawals
Water withdrawal regulation thresholds	
3.2.2.3.1	Keep existing Michigan policy for water withdrawal regulation
	Registration required for all water withdrawals >70 gpm for any 30-day period; permit required for withdrawals > 1,388 gpm (with some exceptions)

3.2.2.3.2	Lower thresholds for regulation
3.2.2.3.3	Increase water use reporting frequency
	Require reporting and $200 reporting fee every 30 days for HVHF withdrawals (currently required annually)
3.2.2.3.4	Set a total volumetric water withdrawal limit
Improvements to the WWAT	
3.2.3.1.1	Keep existing Michigan WWAT
	The current WWAT reflects water quantity measures, regulatory subwatersheds, and Policy Zone determinations from 2008
3.2.3.1.2	Update the scientific models of WWAT
	Increase data collection; use mechanistic models; include lakes and wetlands
3.2.3.1.3	Implement a mechanism for updating the models underlying WWAT
Water withdrawal fee schedules	
3.2.4.3.1	Keep existing Michigan water withdrawal fees
	HVHF operators are exempted from the WWAP and pay no water withdrawl fees
3.2.4.3.2	Modify water withdrawal fee schedules
	Fee schedule could take into account site- and project-specific factors; project planning fees could be levied against projects in vulnerable areas; large-scale projects could be subject to a withdrawal fee based on the total project cost
Water withdrawal permitting	
3.2.5.3.1	Keep existing Michigan policy for water withdrawal permitting
	Permits only available for withdrawals >1,388 gpm (694 gpm in a Policy Zone C area; 70 gpm for intrabasin water transfers)
3.2.5.3.2	Open option to obtain a large-scale water withdrawal permit
3.2.5.4.1	Prohibit HVHF operations from obtaining a water withdrawal permit
	HVHF operations would need to keep water withdrawal rates below 1,388 gpm and register the rate through the WWAT
Transfer/sale/lease of water withdrawals	
3.2.6.3.1	Keep existing Michigan policy for transfer/sale/lease of water withdrawals
	Ambiguity regarding whether registered or permitted water withdrawals can be used by someone other than the registrant
3.2.6.3.2	Provide a mechanism to transfer, sell, lease registered/permitted water withdrawals
3.2.6.4.1	Prohibit transfer or use of registered water withdrawals to HVHF operations
Additional monitoring	
3.2.7.2.1	Keep existing Michigan policy for monitoring
	Site-specific review may be conducted when adverse resource impact is suspected, in a Policy Zone C subwatershed unit, or proposed withdrawal would cause a Policy Zone C or D
3.2.7.2.2	Install additional monitoring wells in the presence of other water withdrawal wells (Michigan proposed rule)
	If one or more fresh water wells are within 1,320 feet of a proposed large

	volume water withdrawal, permittee must install a monitoring well and record the water level daily during withdrawal and weekly afterwards until the water level stabilizes
3.2.7.2.3	Collect baseline groundwater data (Michigan proposed rule)
	HVHF permittees and applicants required to collect baseline samples from all available water sources (up to 10), within a ¼-mile radius
3.2.7.2.4	Require site specific reviews for all HVHF water withdrawal proposals
3.2.7.2.5	Provide a mechanism to use private monitoring
Public engagement on new water withdrawals	
3.2.8.3.1	Keep existing Michigan policy for public engagement on new water withdrawals
	Notification for withdrawal permits but not registrations
3.2.8.3.2	Organize water users committees
3.2.8.3.3	Organize water resources assessment and education committees
3.2.8.3.4	Require public notice on new high-capacity wells
3.2.8.4.1	Report to the Supervisor of Wells (Michigan proposed rule)
	Requires approval from Supervisor of Wells before withdrawing a large volume of water for HVHF
Wastewater management and water quality	
Deep well injection	
3.3.5.2.1	Keep existing Michigan policy for deep well injection
	DEQ and USEPA responsible for management of Class II disposal wells for the disposal of flowback fluids
3.3.5.2.2	Increase monitoring and reporting requirements
3.3.5.2.3	Require use of Class I hazardous industrial waste disposal wells
Wastewater recycling	
3.3.6.3.1	Keep existing Michigan policy for wastewater recycling
	Deep-well injection of all flowback fluids is the sole defined regulatory option for wastewater management
3.3.6.3.2	Provide options for wastewater recycling
3.3.6.3.3	Use alternative water sources for HVHF

Chemical Use

The chemical substances associated with HVHF activities are numerous and may be found at every point in the process. For example, between 2005 and 2011, the EPA identified over 1,000 different chemicals that were either used in fracturing fluids or found in associated wastewaters. A number of these chemicals *may* interact with receptors (e.g., humans, animals and/or plants) at the HVHF worksite, and in the ecological and community environments situated near these worksites via air, water, and/or soil. The presence and use of these chemicals in HVHF has engendered much debate and concern among stakeholders in the U.S. generally, as well as in other jurisdictions currently engaging in HVHF.

When faced with scientific uncertainty about the risks of an activity to human health and the environment, policymakers can take three general approaches. The first is to adopt a precautionary approach. Particularly when there are threats of irreversible damage or catastrophic consequences, policymakers may decide to regulate the activity to prevent harm. In its strongest form, the precautionary approach would counsel banning an activity that could result in severe harm. The second is to adopt an adaptive approach. Based on the principles of adaptive management, policymakers may choose to take some regulatory action at the outset, and continually refine the response as further information becomes available. The third is to adopt a remedial—or post-hoc—approach. Policymakers may decide to allow the activity, and rely on containment measures and private and public liability actions to address any harm.

The chemical use chapter examines three types of policy tools that states have used to address chemical use in HVHF activities: information policy, prescriptive policy, and response policy. Information policies gather data about HVHF for decision makers and the general public; prescriptive policies mandate a specific action or set a performance standard; and response policies manage any contamination through emergency planning, cleanup, and liability requirements. For each type of tool, Michigan's existing policies are described and a range of policies adopted by other states are presented. Building on the three approaches to uncertainty, combinations of policy options are offered and compared to the proposed rules.

U.S. states have focused much of their policy attention on gathering information about chemical use in hydraulic fracturing through reporting and monitoring requirements. While the focus may be on increasing transparency between the operator and the state (through such mechanisms as chemical disclosure websites and/or Material Safety Data Sheets (MSDS)), information policies may also increase transparency between all relevant stakeholders, including the public at large. In doing so, they may enhance public participation in the decision-making process.

State information policies primarily focus on three types of technical information:

(1) information on the chemical additives in the hydraulic fracturing fluid;
(2) information on the integrity of the well, the barrier between the chemicals and the environment; and
(3) information on movement of chemicals in water resources around the well.

Information policy responds to scientific uncertainty about risk by gathering information on chemical hazards and the potential for human and ecological exposure. State objectives for collecting information depend on the policy approach. Under a precautionary approach, states collect information on threats prior to HVHF to set preventative limits on the location, construction, and operation of the HVHF well or to decide whether to allow HVHF at all. Under an adaptive approach, states continually collect information so that over time they can better understand risk and refine their HVHF policies. Under a remedial approach, states collect information after HVHF to respond to contamination and to ensure HVHF well operators are held liable for any damage.

Information policy also may respond to public uncertainty about risk by helping members of the public both participate in the democratic process and make individual decisions about property and health. Under a precautionary approach, members of the public use information to participate in setting preventative limits and also to take actions prior to HVHF to reduce the potential for individual exposure. Under an adaptive approach, members of the public use information to participate in the refinement of policies and also to change their behavior over time, such as determining whether to continue to drink water from wells. Under a remedial approach, members of the public use information to take actions to minimize their exposure to contamination and also to decide whether to seek compensation from a well operator.

Michigan's current information policy, as in several other states, responds to uncertainty through a remedial approach. Information on hazardous chemicals, when combined with well pressure records, are primarily useful in helping the state to identify the source of any contamination. Broad trade secret protection and lack of monitoring data on water quality make it difficult for the state to use the information in an adaptive way to refine policies. Members of the public are also unlikely to use the information to change their behavior. While the MSDSs provide more information on the hazards of chemicals than does a list of chemical constituents of additives, the sheets are written for trained employees and focus on the risks to workers.

The state has traditionally used prescriptive approaches-or 'command and control' regulation-as a mechanism to influence and shape behavior. Unlike information policy, states have not been uniform in their attention to prescriptive requirements that restrict or control aspects of hydraulic fracturing. As the chapter on chemical use illustrates, legislation and regulation can lag behind technological advances. As such, the opportunity to craft a suite of prescriptive regulatory requirements tailored specifically for various activities associated with HVHF currently exist in Michigan, as well as a number of other states.

State prescriptive policies primarily focus on four areas:

(1) Restrictions on the chemicals used in HVHF;
(2) Limitations on siting an HVHF well;
(3) Controls focused on minimizing risks to groundwater; and
(4) Controls focused on minimizing risks to surface waters.

Prescriptive policy responds to scientific uncertainty about risk by requiring private actors to take an action, such as install a specified technology, or to attain a level of performance. Under a precautionary approach, prescriptive policies use preventative mandates that restrict the activity causing the threat of harm or ban the activity altogether. Under an adaptive approach, prescriptive policies use flexible mandates that can be altered over time as more is learned about risk. Under a remedial approach, prescriptive policies use corrective mandates that minimize the harm from any incident and assist in identifying the source of harm.

Like most states, Michigan has adopted all three approaches in its prescriptive policies. Michigan's well integrity requirements and surface controls are primarily adaptive, made more flexible by the discretion given to permitting staff to set conditions for well construction and

surface pad construction under state rules. Yet Michigan also uses both a precautionary approach in its area-of-review analysis and in requiring tanks for flowback, and a remedial approach in mandating secondary containment measures for storage tank areas. Finally, Michigan has adopted precautionary setback requirements for groundwater drinking sources.

Spills, or accidental release, of chemicals used in HVHF activities, and the implications of exposure to these chemicals on humans and the environment, have engendered significant debate and concern among stakeholders and the public generally. Such concern has been, arguably, fueled by a lack of comprehensive policies addressing emergency planning for dealing with chemical discharge, liability for contamination, and public transparency. As with all other facets of HVHF activities, the state has the ability to introduce policies specifically tailored to address emergency planning, and operator response, in the event that spills and/or release occur.

State spill response policies primarily focus on three areas:

(1) Planning for emergencies;
(2) Cleanup of spills and releases; and
(3) Imposing liability for contamination.

Response policy responds to scientific uncertainty about risk by requiring private actors to prepare for possible incidents, clean up contamination, and take responsibility for environmental and human health harm. Under a precautionary approach, response policies focus on incidents, but their underlying purpose is to deter actors from engaging in activities that could cause significant harm. Under an adaptive approach, response policies seek to protect the most sensitive areas from harm while using information on incidents to adjust requirements over time. Under a remedial approach, response policies acknowledge that incidents happen, and seek to minimize harm and hold actors responsible.

Most states, including Michigan, have adopted a remedial approach. The primary response policy is to require oil or gas well operators to promptly report and clean up after incidents. Bonds ensure that the state can recover at least some costs if an operator refuses or is not able to pay for remediation. And in some of the states, operators are also liable to private surface owners for damage to the surface environment, including damage from spills and releases. While Michigan does not have a statute on surface damages, operators are liable under common law.

Table 1.3 presents a list of the policy options addressed in Chapter 4 – Chemical Use. Note that the policy options considered in this chapter contain a combination of multiple policy elements. Refer to the chapter section for a more detailed description.

Table 1.3: Policy options for chemical use

Information policy		
4.2.2	Existing Michigan policy	
	Chemical use	Subject of disclosure: hazardous constituents
		Means of disclosure: MSDS on state website
		Timing of disclosure: within 60 days
		Trade secret claim review: none
	Well construction	Pressure monitoring: monitored and reported within 60 days
		Mechanical integrity test: none
	Water quality	Water source: none
		Area around well: none
		Number of sources tested: none
		Frequency of testing: none
		Test results: none
4.2.4.1	Option A: Michigan's proposed rules	
	Chemical use	Subject of disclosure: all constituents
		Means of disclosure: permit application; FracFocus
		Timing of disclosure: before HVHF and within 30 days after HVHF
		Trade secret claim review: statement of claim; must use family name or other description
	Well construction	Pressure monitoring: monitored and reported immediately to state if problem; HVHF ceases until plan of action implemented
		Mechanical integrity test: when monitoring indicates problem
	Water quality	Water source: groundwater
		Area around well: ¼-mile radius around well
		Number of sources tested: up to 10
		Frequency of testing: once, >7 days but <6 months prior to drilling of new well or HVHF of existing well
		Test results: within 45 days; immediate notification of contaminants of concern; to state and owner
4.2.4.2	Option B: Adaptive approach	
	Chemical use	Subject of disclosure: all constituents; plain-language description
		Means of disclosure: master list; state website; FracFocus
		Timing of disclosure: before and within 30 days after HVHF
		Trade secret claim review: narrow exception for trade secrets
	Well construction	Pressure monitoring: monitored and reported immediately to state and nearby landowners if problem; status on website; HVHF ceases until plan of action implemented
		Mechanical integrity test: when monitoring indicates a problem
	Water quality	Water source: groundwater and surface water
		Area around well: based on characteristics of aquifer/watershed
		Number of sources tested: part of larger monitoring system in area

	Water quality	Frequency of testing: baseline test; long-term regular monitoring
		Test results: within 10 days; immediate notification of contaminants of concern; to state, owner, and public (through website)
4.2.4.3	Option C: Precautionary approach	
	Chemical use	Subject of disclosure: all constituents; plain-language description of risks and alternatives; studies
		Means of disclosure: permit application; state website
		Timing of disclosure: before HVHF
		Trade secret claim review: full information provided to state
	Well construction	Pressure monitoring: monitored and reported immediately to state and nearby landowners if problem; status on website; HVHF ceases until operator demonstrates integrity
		Mechanical integrity test: prior to approval of HVHF; when monitoring indicates a problem
	Water quality	Water source: groundwater and surface water
		Area around well: based on characteristics of aquifer/watershed
		Number of sources tested: variable, based on importance of sources
		Frequency of testing: baseline test; long-term regular monitoring
		Test results: prior to approval of well and within 10 days; immediate notification of contaminants of concern; to state and owner
Prescriptive policy		
4.3.2	Existing Michigan policy	
	Restrictions on chemical use	None
	Limitations on siting	Siting: oil or gas well; storage tanks at surface facility
		Feature: freshwater wells; public water supply wells
		Distance: 300 feet; 800-2000 feet
	Controls on groundwater risk	Construction requirements: casing and cementing requirements
		Area of review analysis: wells within 1,320 feet; must relocated well, demonstrate no contamination, or take other actions
	Controls on surface risk	Flowback and chemical additives: “brine” (including flowback) stored in tanks
		Secondary containment: storage tanks at surface facility
4.3.4.1	Option A: Michigan's proposed rules	
	Restrictions on chemical use	None
	Limitations on siting	Siting: no change
		Feature: no change
		Distance: no change
	Controls on groundwater risk	Construction requirements: no change
		Area of review analysis: no change

	Controls on surface risk	Flowback and chemical additives: clarification that flowback stored in tanks
		Secondary containment: no change
4.3.4.2	Option B: Adaptive approach	
	Restrictions on chemical use	List of prohibited chemicals, amended over time
	Limitations on siting	Siting: oil or gas well site; storage tanks
		Feature: particularly sensitive features
		Distance: change over time based on new findings/best practices
	Controls on groundwater risk	Construction requirements: change over time based on new findings/best practices
		Area of review analysis: within area affected by HVHF; corrective action or monitoring of conduits
	Controls on surface risk	Flowback and chemical additives: flowback stored in tanks; monitor well site for leaks and spills
		Secondary containment: storage tanks at well site and surface facility
4.3.4.3	Option C: Precautionary approach	
	Restrictions on chemical use	Approval of chemicals only if reduced toxicity
	Limitations on siting	Siting: all related facilities
		Feature: all potentially affected water resources
		Distance: larger setback; protected areas
	Controls on groundwater risk	Construction requirements: strict requirements for several levels of safety
		Area of review analysis: within area affected by HVHF; relocate well unless no risk from conduits
	Controls on surface risk	Flowback and chemical additives: closed loop system for chemical additives, flowback; additive handling requirements
		Secondary containment: entire well site and surface facility
Planning, response, and liability policy		
4.4.2	Existing Michigan policy	
	Emergency Planning	Emergency response plan: hydrogen sulfide wells
	Cleanup	Notification: all losses or spills of chemical additives and "brine," which includes flowback; larger spills reported within 8 hours; to state
		Standard: not specified; other cleanup standards could apply
		Bonds and insurance: $30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance
	Liability	Type of contamination: losses and spills of brine, which includes flowback
		Presumption: none
		Remedy: clean up

4.4.4.1	Option A: Michigan's proposed rules	
	Emergency Planning	Emergency response plan: no change
	Cleanup	Notification: no change
		Standard: no change
		Bonds and insurance: no change
	Liability	Type of contamination: no change
		Presumption: no change
		Remedy: no change
4.4.4.2	Option B: Adaptive approach	
	Emergency Planning	Emergency response plan: HVHF wells in sensitive areas; adapt plans over time
	Cleanup	Notification: all losses or spills; larger spills reported immediately; to state and public
		Standard: remediation and long-term monitoring
		Bonds and insurance: eliminate blanket bonds
	Liability	Type of contamination: spills of chemical additives and flowback into groundwater
		Presumption: for liability if do not monitor environment around well
		Remedy: remediation and long-term monitoring
4.4.4.3	Option C: Precautionary approach	
	Emergency Planning	Emergency response plan: all HVHF wells
	Cleanup	Notification: immediate reporting of all losses or spills to state and public
		Standard: restoration of environment
		Bonds and insurance: increase individual well bond to $250,000; liability insurance
	Liability	Type of contamination: all spills of chemical additives and flowback
		Presumption: strict, joint and several liability
		Remedy: restoration of environment

Policy Framing Analysis

As noted in the section on chemical use, when there is scientific uncertainty about the risks of an activity, two common responses are to adopt an adaptive approach whereby some regulatory action is taken at the outset which can be refined as more information becomes available or a precautionary approach which seeks to control or prohibit activity which may cause harm. Using that adaptive/precautionary frame, policy options from the public participation, water resources, and chemical use sections are organized into four adaptive policy categories: no regrets, automatic adjustment, complex systems principles, and formal review. This should not be

perceived as an absolute categorization but is meant to provide a useful approach for identifying and integrating policy options which might best fit different conditions or scenarios.

Adaptive Policy Options

- No Regrets*:* With respect to HVHF in Michigan, this includes policy options which deserve consideration regardless of the level of future conditions such as the price of natural gas, the level of activity in Michigan, new technological innovations, or new understandings of risks. A no regret policy does not imply no cost or administrative burden. No regrets options were identified across all three of the main policy areas – public participation, water resources, and chemical use.
- Automatic Adjustment: In reviewing the policy options regarding public participation, water resources, and chemical use, potential automatic adjustment policy options can be identified for all three major categories – public participation, water resources, and chemical use. These are options which are already developed but are not activated until a particular threshold is reached or activity takes place. Examples of relevant HVHF policy options include allowing permits to be challenged when there is evidence of adverse impacts, additional regulations based on levels of water withdrawals, the formation of a user committee once a particular water withdraw zone status is established, responding to monitoring results, and adjustments to siting based on proximity to sensitive features.
- Complex Systems Principles: A third category of adaptive policy are those policies which involve complex systems principles – or conditions which require examining multiple factors. For the options presented in this report there are only a few within the Water Resources chapter which can be categorized as adaptive policies employing complex systems principles such as developing a system for the transfer, sale or lease of water withdrawals by water users and novel approaches for wastewater recycling – both of which would require substantial review given the potential to increase surface contamination risks, water quality impacts, and additional truck traffic.
- Formal Review: A fourth category of adaptive policy is formal review. It is similar to automatic adjustment, in that it acknowledges that monitoring and remedial measures are integral to complex adaptive systems and that it is necessary to constantly refine interventions through a continual process of variation and selection. However, it is different from automatic adjustment in that automatic adjustment can anticipate what signposts to use and what actions might need to be triggered to keep the policy effective. Formal review is a mechanism for identifying and dealing with unanticipated circumstances and emerging issues. Policies which can be categorized as formal review options include updating the models which are used for the Water Withdrawal Assessment Tool (WWAT) and establishing a mechanism for scheduling updates as well as reviewing and amending any list of prohibited chemicals and well integrity monitoring systems to ensure the application of best practices.

Precautionary Policy Options

A second overall approach is precautionary policy which can be employed to prevent harm when there are threats of irreversible damage or catastrophic consequences. In this situation, policymakers may decide to regulate the activity to prevent harm. Precautionary policy options exist across all three major categories – public participation, water resources, and chemical use. They range from a complete ban and moratorium on high volume hydraulic fracturing in Michigan to prohibitions, restrictions, or requirements on a range of activities. The objectives of these policies are to avoid harm, ensure additional safety precautions or monitoring, or provide full information on activities in advance. The recent decisions to ban HVHF in New York and Quebec based in part on potential health and environmental impacts can be viewed as a precautionary approach.

BROADER CONTEXT

In response to numerous public comments received over the course of the project, the report includes an overview of the broader context and national discourse of issues (not specific to Michigan) related to expanded natural gas production and use: climate change and methane leakage, natural gas as a bridge fuel to a cleaner energy future, the potential for a U.S. manufacturing renaissance based on expanded natural gas production, the potential impacts in the event U.S. policy is changed to expand exports, and methodological approaches to understanding and managing human health risks.

LIMITATIONS AND KNOWLEDGE GAPS

While the integrated assessment has attempted to provide a comprehensive review of the current status and trends of HVHF in Michigan (the technical reports) and an analysis of policy options (this report) there are certain limitations which must be recognized. First, the assessment does not provide a quantitative assessment (human health or environmental) of the risks associated with HVHF. This was not the intent of the assessment but it is a question we have often received regarding the scope of the project. Second, the assessment does not provide economic analysis or a cost-benefit analysis of the policy options presented in the preceding chapters. While economic strengths and/or weaknesses were identified for many of the options, these should not be viewed as full economic analyses. Additional study would be needed to fully assess the economic impact of various policy actions, including no change of current policy. Additional areas of investigation and knowledge gaps were identified through the technical reports. Those items are listed in the last chapter of the report along with other emerging research questions.