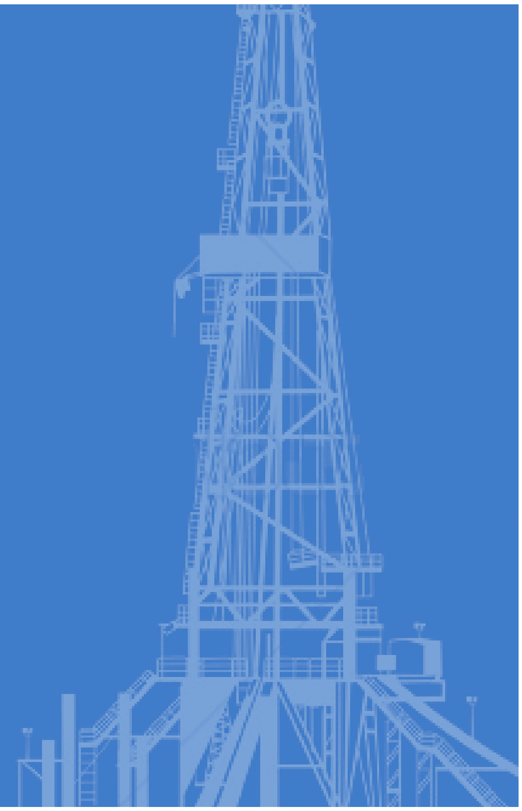

GRAHAM
SUSTAINABILITY INSTITUTE
UNIVERSITY OF MICHIGAN

High Volume Hydraulic Fracturing in Michigan

INTEGRATED ASSESSMENT FINAL REPORT

SEPTEMBER 2015

About this Report

This 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, and
- 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 the 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 in September 2013. This document is the final report for the IA.

The IA report has been informed by the technical reports, input from an Advisory Committee with representatives from corporate, governmental, and non-governmental organizations, a peer review panel, and numerous public comments received throughout this process. However, the report does not necessarily reflect the views of the Advisory Committee or any other group which has provided input. As with preparation of the technical reports, all decisions regarding content of project analyses and reports have been 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), specifically, in Michigan (the technical reports) and an analysis of policy options (this report) there are certain limitations which must be recognized:

- 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.
- The assessment does not provide an 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.

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, please go to:
http://graham.umich.edu/knowledge/ia/hydraulic-fracturing

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LIST OF ACRONYMS/ABBREVIATIONS

API	American Petroleum Institute
ARI	Adverse Resource Impact
CAS	Chemical Abstracts Service
CBM/CBNG	Coal Bed Methane / Natural Gas
CDP	Comprehensive Development Plans
CLOSUP	University of Michigan Center for Local, State and Urban Policy
CGDP	Comprehensive Gas Drilling Plan
CNG	Compressed Natural Gas
CO	Carbon Monoxide
COGCC	Colorado Oil and Gas Conservation Commission
CO_2	Carbon Dioxide
CSSD	Center for Sustainable Shale Development
CWA	U.S. Clean Water Act
DCH	Michigan Department of Community Health
DEP	Pennsylvania Department of Environmental Protection
DEQ	Michigan Department of Environmental Quality
DMRM	Ohio Division of Mineral Resources Management
DNR	Michigan Department of Natural Resources
DOGGR	California Division of Oil, Gas, and Geothermal Resources
DOH	New York State Department of Health
DRBC	Delaware River Basin Commission
EPA	U.S. Environmental Protection Agency
EUR	Estimated Ultimate Recovery
FERC	U.S. Federal Energy Regulatory Commission
GDP	Gross Domestic Product
GEIS	Generic Environmental Impact Statement
GHG	Greenhouse Gas
GPD	Gallons per Day
GPM	Gallons per Minute
HF	Hydraulic Fracturing
HIA	Health Impact Assessment
HVHF	High Volume Hydraulic Fracturing
H_2S	Hydrogen Sulfide
IA	Integrated Assessment
IOGCC	Interstate Oil and Gas Compact Commission
ISSD	International Institute for Sustainable Development
LCA	Life Cycle Assessment
MCL	Michigan Compiled Laws
MLP	Master Leasing Plans
MSDS	Material Safety Data Sheets
NMEAC	Northern Michigan Environmental Action Council
NORM	Naturally Occurring Radioactive Materials
NO_x	Nitrogen Oxides
NPDES	U.S. Environmental Protection Agency National Pollutant Discharge Elimination System
NRC	Michigan Department of Natural Resources Natural Resource Commission
OOGM	Michigan Department of Environmental Quality Office of Oil, Gas, and Minerals
PM	Particulate Matter
POTW	Publicly Owned Treatment Works
PSE	Physicians, Scientists, and Engineers
PwC	PricewaterhouseCoopers
RDSC	Royal Dutch Shell
RFF	Resources for the Future
SCA	Stipulation and Consent Agreement
SDWA	U.S. Safe Drinking Water Act
SO_2	Sulfur Dioxide
SRBC	Susquehanna River Basin Commission
SSR	Site-Specific Review
STRONGER	State Review of Oil and Natural Gas Environmental Regulations, Inc.
TDS	Total Dissolved Solids
TERI	The Energy and Resources Institute
TSA	Transfer Settlement Agreement
U-M	University of Michigan
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
USGS	United States Geological Survey
VOC	Volatile Organic Compounds
WRAEC	Water Resources Assessment and Education Committee
WUC	Water Users Committees
WWAP	Water Withdrawal Assessment Process
WWAT	Water Withdrawal Assessment Tool

EXECUTIVE SUMMARY

PURPOSE AND SCOPE OF THE ASSESSMENT

There is significant momentum behind natural gas extraction efforts in the United States, with many states viewing it as an opportunity to create jobs and foster economic growth. Natural gas extraction has also been championed as a way to move toward domestic energy security 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 the past 10 years, however, the hydraulic fracturing process and associated shale gas development activities have come under increased public scrutiny particularly with respect to high volume hydraulic fracturing (HVHF). Key concerns include, for example, a perceived lack of information transparency, potential chemical contamination from fracturing fluids, water use, wastewater disposal, and possible 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 Graham Sustainability Institute over a one-year time frame (June 2011-June 2012) and involved conversations with several other University of Michigan (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 dialogue 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 help inform decision makers. For more about the IA research framework, please visit: http://graham.umich.edu/knowledge/ia.

The assessment does not seek to predict a specific future for HVHF activity in Michigan. Rather, it posits that natural gas extraction pressures will likely increase in Michigan if the following trends persist: desire for job creation, economic strength, energy security, and decreased use of coal. Given that HVHF intersects many issues that are important to Michigan residents—drinking water, air quality, water supply, land use, energy security, economic growth, tourism, and natural resource protection—the assessment asks:

What are the best environmental, economic, social, and technological approaches for managing hydraulic fracturing in the State of Michigan?

This guiding question bounds the scope of the IA. The assessment focuses on Michigan, but 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 State of Michigan regulations as well completion operations that intend to use a total volume of more than 100,000 gallons of primary carrier fluid),[2,3] but the analysis of options also considers implications for other practices and includes options for different subsets of wells.

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 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.

OVERVIEW OF ACTIVITY IN MICHIGAN

Background

While recent interest from energy developers, lease sales, and permitting activities suggest the potential for increasing activity around HVHF in Michigan, consistently low gas prices for the past two years[10] has been identified as a key contributor to limited HVHF activity in Michigan at present.[11] Below are some key points regarding hydraulic fracturing in Michigan.

- According to the Michigan Department of Environmental Quality (DEQ), since 1952 more than 12,000 oil and gas wells have been fractured in the state, and regulators report no instances of adverse environmental impacts from the process.[12] The distribution of wells throughout Michigan's Lower Peninsula is illustrated by Figure 1. Most of these are relatively shallow (1,000 to 2,000 feet deep) Antrim Shale[13] vertical wells drilled and completed in the late 1980s and early 1990s in the northern part of Michigan's Lower Peninsula. Some new activity will continue to take place in the Antrim in the short term, and a very small number of the old wells may be hydraulically fractured in the future. This appears, however, to be a "mature" play and is unlikely to be repeated and will not involve HVHF.
- The hydrocarbon resources in the Utica and Collingwood Shales in Michigan (4,000 to 10,000 feet below ground) will likely require HVHF and below-surface 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 [generally] horizontally through the target formation) up to two miles.[14]
- A May 2010 Department of Natural Resources (DNR) auction of state mineral leases brought in a record $178 million—nearly as much as

Box 1: Key Terms

Terminology is important to any discussion of 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.

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.[4] 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.[5]

Shale Gas: Natural gas produced from low permeability shale formations[6]

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: HVHF well completion is defined by State of Michigan regulations as a "well completion operation that is intended to use a total volume of more than 100,000 gallons of primary carrier fluid."[7,8]

Experts and the public often use terminology differently, and often interchangeably. In some instances, for example, the public tends to view hydraulic fracturing—including lower and high volume completions—as the entirety of the natural gas development process from leasing and permitting, to drilling and well completion, to transporting and storing wastewater and chemicals. Industry and regulatory agencies hold a much narrower definition that is limited to the process of injecting hydraulic fracturing fluids into a well.[9]

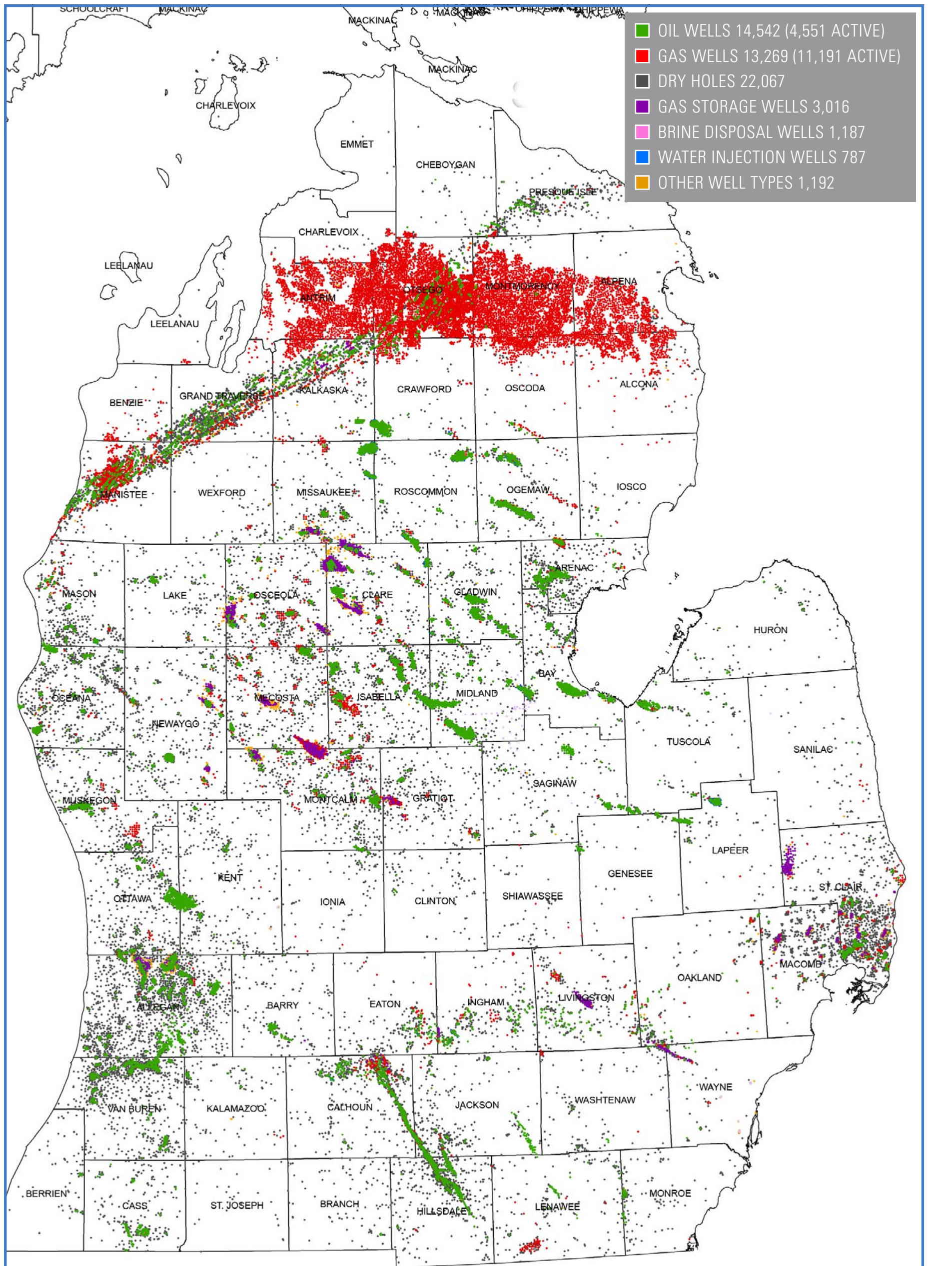

FIGURE 1a[i]: Activity in Michigan: oil and gas wells in 2005[22]

[i] Full size, zoomable map available at: http://www.michigan.gov/documents/deq/MICHIGAN_OIL_GAS_MAP_LP_411599_7.pdf

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.[15,16] However, there has been limited production activity thus far under these leases.

- As of May 28, 2015, there were 14 producing HVHF-completed oil and gas wells in Michigan, 2 active applications, 16 active permit holders, 6 locations with completed plugging, and 13 locations with completed drilling.[17] Figure 1 provides a map of these locations.
- 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 2).
- Given the limited activity to date, is it very difficult to predict the scale of future HVHF activity in Michigan, but there is agreement that further development of the Utica and Collingwood Shales is likely years away given that current low gas prices make development less feasible economically.[18]
- Over the past few years, several bills have been proposed in Michigan to further regulate or study hydraulic fracturing,[19] state officials implemented new rules for HVHF in March 2015,[20] and a ballot question committee has been working to prohibit the use of horizontal hydraulic fracturing in the state.[21]

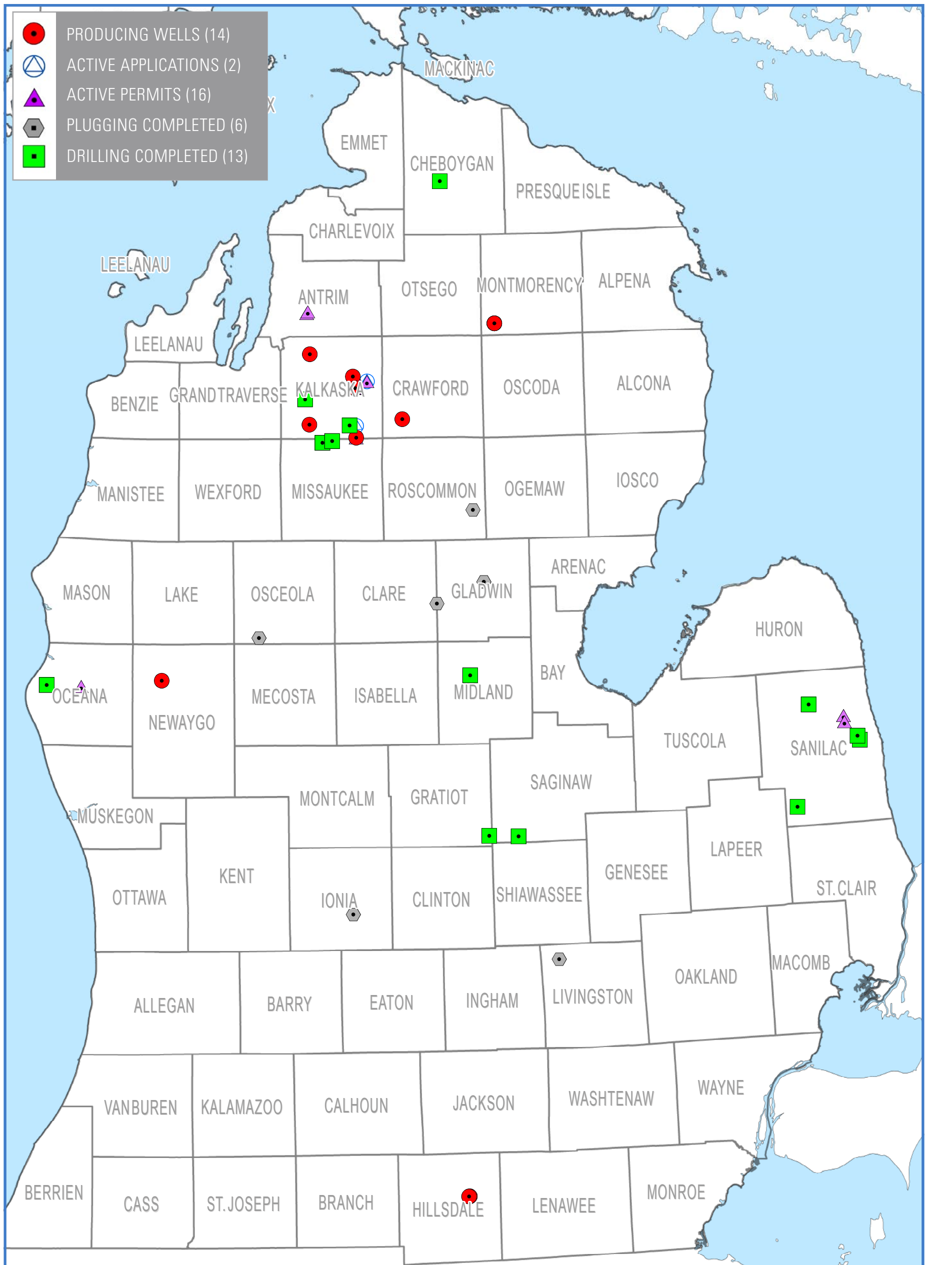

FIGURE 1b[i, ii]: Activity in Michigan: HVHF wells as of May 28, 2015.[23]

[i] Full size zoomable map available at: http://michigan.gov/documents/deq/hvhfwc_activity_map_new_symbols-jjv_483124_7.pdf

[ii] The source map contains the following disclaimer: "High volume hydraulically fractured well completions are defined in Supervisor of Well Instruction 1-2011 as a 'well completion operation that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid.' We made all efforts to trace back the well completion records thru 2008 to compile [sic] this map and list. This information provided here in is accurate to the best of our knowledge and is subject to change on a regular basis, without notice. While the Department of Environmental Quality - Office of Oil, Gas, And Minerals (DEQ-OOGM) makes every effort to provide useful and accurate information, we do not warrant the information to be authoritative, complete, factual, or timely. It is suggested that this information be combined with secondary sources as a means of verification. Information is provided 'as is' and an 'as available' basis. The State of Michigan disclaims any liability, loss, injury, or damage incurred as a consequence, directly or indirectly, resulting from the use, interpretation, and application of any of this information."

Technical Reports

The first phase of the IA (2012-2013) involved preparation of seven technical reports on key topics related to hydraulic fracturing in Michigan (technology, geology/hydrogeology, environment/ecology, public health, policy/law, economics, and public perceptions). Each report includes an overview of the topic, a discussion of status and trends, a review of challenges and opportunities, and suggestions for additional analysis. The reports provide decision makers and stakeholders with a solid foundation of information on the topic based primarily on an analysis of existing data. Following a peer review process, the reports were made public in September 2013. Selected highlights from each report follow.[i]

Technology

Hydraulic fracturing originated in 1947–1949, initially in Kansas, Oklahoma, and Texas as a means of stimulating production from uneconomic gas and (mostly) oil wells, and was quickly successful at increasing production rates by 50% or more, typically using hydrocarbon fluids (not water) as the carrier. To date in the United States, an estimated more than 1.25 million vertical or directional oil/gas wells have been hydraulically fractured, with approximately 12,000 fractured wells located in Michigan.[26] Fracturing of deep and/or directional wells is most often done with several hundred thousand to several million gallons of high-pressure water that contains about 10-20% of sharp sand or an equivalent ceramic with controlled mesh size and about 0.5% of five to ten chemicals that are used to promote flow both into and subsequently out of the fractured formation. To facilitate fracturing, the steel casing that is inserted into the well is typically penetrated with pre-placed explosive charges. As illustrated by Figure 3, the fracturing mixture flows into the formation through the resulting holes, and these holes subsequently provide a route for product flow back into the production tubing.

Geology and Hydrogeology

One of the most widely cited issues regarding the environmental consequences of hydraulic fracturing operations is groundwater contamination, and water quality issues more broadly. One study, conducted by Osborn et al., concluded that water wells located near natural gas production sites in Pennsylvania had higher contribution of thermogenic methane than wells farther away from such operations, suggesting a possible (not definite) link between hydraulic fracturing and increased methane in drinking water.[27] Other studies, such as one by Molofsky et al., suggest that methane leakage occurs naturally, and may have more to do with land topography than hydraulic fracturing.[28] Another key concern about possible impacts from shale gas development includes the quantity of water used. Typically, HVHF will use over 100,000 gallons of fracturing fluid per well, the overwhelming majority of which is water, but some wells have used over 21 million gallons.[29] Of the total volume of hydraulic fracturing fluids injected into a well, amounts varying from 10 to 70% may return to the surface along with additional produced native formation brines. Disposal of flowback and produced brine fluids in Michigan occurs via deep well injection into brine disposal wells. This method for disposal of produced oilfield brines

[i] As it is not possible to include all of the information from the technical reports here, readers are encouraged to review the complete set of technical reports, available at: http://graham.umich.edu/knowledge/ia/hydraulic-fracturing.

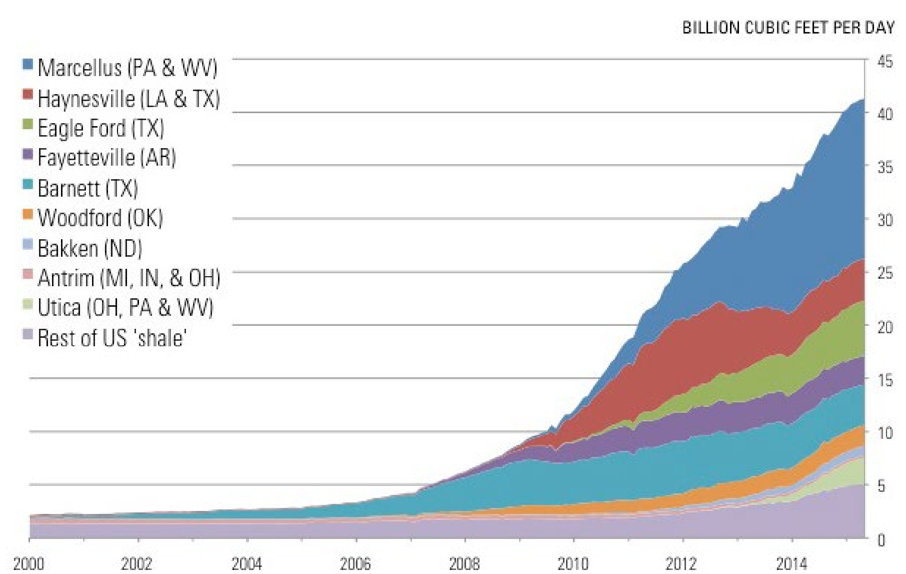

FIGURE 2: U.S. dry shale gas production[24]

is very common throughout the U.S.[30] HVHF flowback waters currently make up less than 1% of the annual brine disposal volumes in Michigan (compared to 2011 cumulative disposal volumes).

Environment and Ecology

There are numerous potential ecological consequences of all shale gas and oil development. Building the necessary roads, product transportation lines, power grid, and water extraction systems, together with the siting of drilling equipment and increased truck traffic, produces varying site-specific environmental impacts. Potential effects include: increased erosion and sedimentation, increased risk of aquatic contamination from chemical spills or equipment runoff, habitat fragmentation and resulting impacts on aquatic and terrestrial organisms, loss of stream riparian zones, altered biogeochemical cycling, and reduction of surface and hyporheic waters available to aquatic communities due to lowering groundwater levels.

Public Health

As with many of the areas that shale gas development could impact, possible impacts on public health have yet to undergo a rigorous assessment, owing primarily to substantial gaps in data availability, both in Michigan and beyond. It is important that public policy and regulations around shale gas development be grounded in strong, objective peer-reviewed science (as opposed to anecdotes). Nonetheless, the health related concerns expressed by community members, especially those that are scientifically plausible or those that are recurring, need to be seriously evaluated. While not all potential hazards have evidence to support their presence in or relevance for Michigan, certain ones, such as noise and odor, were identified as such. Noise pollution has been associated with negative health outcomes such as annoyance, stress, irritation, unease, fatigue, headaches, and adverse visual effects. Since some hydraulic fracturing operations occur around-the-clock (over roughly one to three weeks), the noise generated could also potentially interfere with the sleep quality of area residents. Silica exposure is another potential hazard identified, primarily impacting workers, who may be exposed to respirable crystalline silica. Silica sand is often used as a proppant during operations. Inhalation of silica can lead to the lung disease silicosis, which can include symptoms ranging from reduced lung function, shortness of breath, massive fibrosis, and respiratory failure.

Policy and Law

As HVHF and public concern have grown in the last few years, governments have begun to make policies specifically addressing hydraulic fracturing, and in some cases HVHF. The details of these policies may be presented in informal statements of policy or guidance, or may be made binding in law through legislative action or agency rulemaking. Courts have also been called upon to resolve disputes, creating an additional source of law. Michigan's DEQ is responsible for governing gas exploration, development, and production waste. With this authority, the DEQ issues specific rules and guidance, setting permitting conditions and enforcing requirements on the location, construction, completion, operation, plugging, and abandonment of wells. Michigan's DNR, which is the largest owner of mineral interests in the state, operates the program for leasing state owned mineral interests.

Economics

In Michigan, the shale gas industry generates employment and income for the state, but the employment effects are modest when compared with other industries. With regard to employment, there are two broad types of jobs to be found in the natural gas extraction industry: jobs directly involved in production and jobs that provide services to producers. While there tend to be fewer production jobs, they generally pay higher salaries and are less sensitive to well development than servicing jobs. It has been estimated that the number of production jobs in Michigan has ranged from 394 (in 2002) to 474 (in 2010), and the number of service industry jobs has ranged from 1,191 (in 2002) to 1,566 (in 2008).[31] Taxes paid to the State of Michigan from revenues earned by private landowners in 2010 were $32.6 million. These monies support the state general fund. In addition, the State of Michigan earns revenue from gas extracted from

Box 2: Hydraulic Fracturing and High Volume Hydraulic Fracturing

A vertical well that is hydraulically fractured in Michigan may use about 50,000 to 100,000 gallons of water while a high volume, horizontally drilled well may use 20,000,000 gallons of water or more.

While HVHF completions use significantly more water per completion than shallower, vertical completions, there is disagreement regarding the two completion techniques' relative overall use of water and efficiency of water use (the amount of water used standardized by the size of the reserves or amount of gas produced). Some argue that fewer large wells could produce more gas per volume of water used or size of production unit. Similar arguments are made regarding surface impact: that the development of multiple HVHF wells per site, rather than many individual wells and well pads, reduces the area of land disturbed.

However, HVHF activity is currently too limited in Michigan to draw any conclusions regarding these types of comparisons due to uncertainties such as, but not limited to, average production rates, decline curves, productive lifetimes, the extent of future development, and water use in the Utica and Collingwood. Additionally, some contend that comparisons between different shale resources are inherently problematic because different completion techniques and economic considerations are involved. Depending on the metric and assumptions used in these comparisons, one may reach different conclusions about the relative impacts.

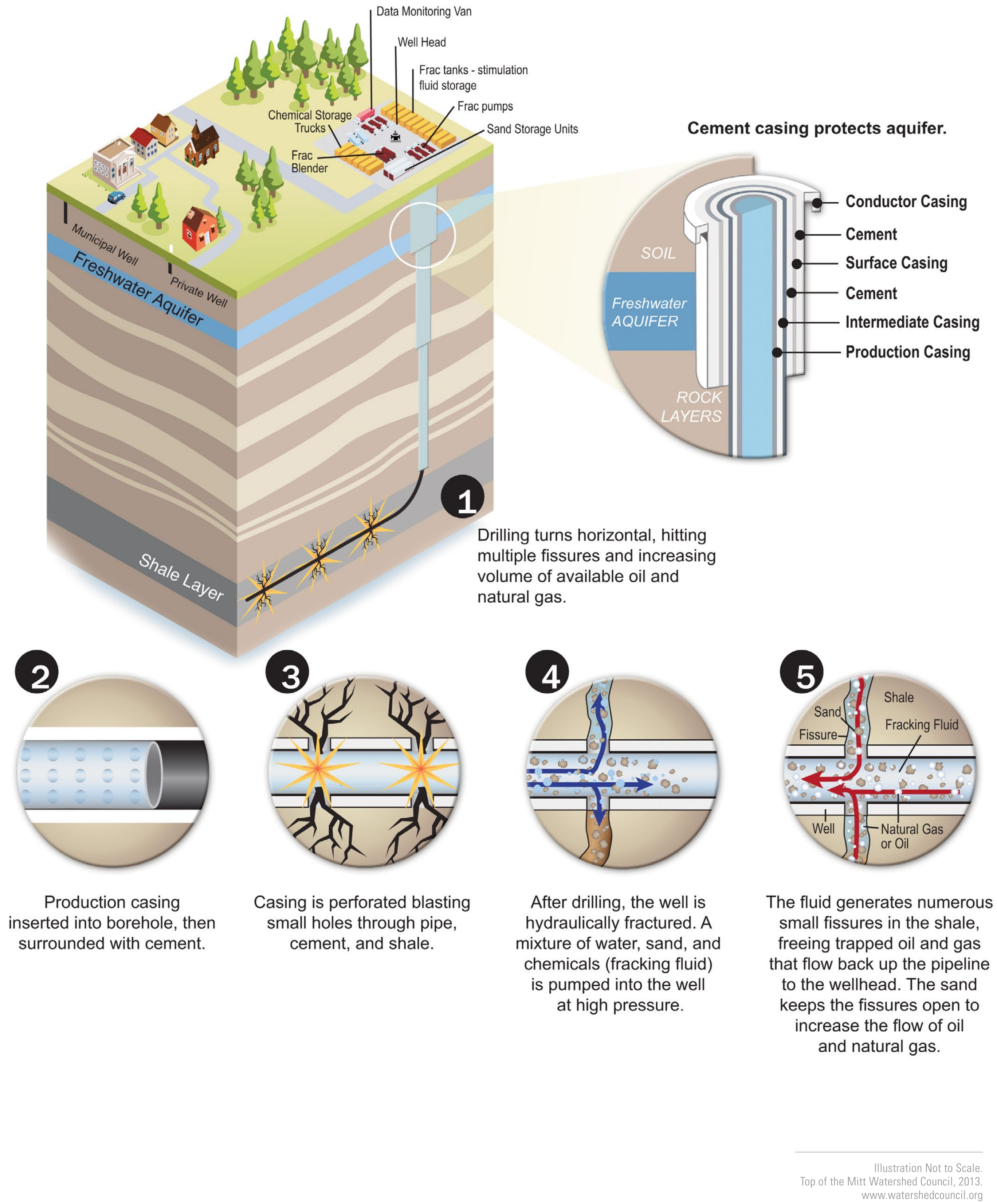

FIGURE 3: Hydraulic fracturing process[25]

OPTIONS ANALYSIS

The report focuses on an analysis of options for three issues relevant to the State of Michigan and specific to HVHF. Topics were identified as prioritized pathways in the technical report and in public comments.

- PUBLIC PARTICIPATION (Chapter 2)
- WATER RESOURCES (Chapter 3)
- CHEMICAL USE (Chapter 4)

STATE-SPECIFIC — **NATIONAL & GLOBAL**

HVHF — **UNCONVENTIONAL GAS DEVELOPMENT**

ADDITIONAL ISSUES

Other topics relevant to Michigan and HVHF, but not exclusive to HVHF, identified in the technical reports and public comments are included in Appendix C:

- Environmental impacts
- Air quality
- Landowner & community impacts
- Agency capacity & financing

BROADER CONTEXT

Issues related to unconventional shale gas more generally and relevant at scales larger than Michigan are included in Appendix B:

- Climate change & methane leakage
- Renewable energy
- Manufacturing renaissance
- Natural gas exports
- Understanding health risks

FIGURE 4: IA report organization

state property. In 2012, the DNR received $18.4 million in royalties, $7.7 million in bonuses and rent, and a $0.1 million in storage fees. Nearly all the revenue from gas extracted on state property is used to improve state land and game areas.[ii]

Public Perceptions

Among the general public, roughly 50-60% of Americans are at least somewhat aware of hydraulic fracturing, and awareness seems to be on the rise. In Michigan, a 2012 poll found that a majority (82%) of residents have heard at least "a little" about fracking and nearly half report that they follow debates about fracking in the state "somewhat" to "very closely." Consistent with other national and state-level polls, a slight majority of Michigan residents (52%) believes that the benefits of fracking outweigh the risks, but concerns remain about potential impacts on water quality and health. Fifty-two percent of respondents from the same poll agreed that the State of Michigan should impose a moratorium on hydraulic fracturing until its risks are better known. In Michigan and elsewhere, most people support tighter regulation of the oil and gas industry, including requiring disclosure of the chemicals used in hydraulic fracturing fluids.

[ii] In 2014, $40 million was collected for lease revenues (J. Goodheart, DEQ, personal communication, July 15, 2015)

STRUCTURE OF THE REPORT

Chapter 1 of this 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 HVHF policy options specific for Michigan in the areas of public participation, water resources, and chemical use. Chapter 5 provides a framework for reviewing policy options presented in Chapter 2 (public participation), Chapter 3 (water resources) and Chapter 4 (chemical use) using adaptive and precautionary policy categories. Chapter 6 identifies the limits of this report and knowledge gaps. Several appendices are also included. Appendix A is a glossary of terminology used throughout the report and HVHF discussions. Appendix B provides an overview of broader issues related to expanded shale gas development that are not specific to Michigan. Appendix C offers a review of additional shale gas development issues that are relevant to Michigan but not specific to HVHF. Appendix D provides a description of the peer review process along with the review summary developed by the panel and a response document indicating how the panel's input was utilized. Appendix E provides a summary and response for public comments received following the release of the final draft IA report.

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. Each chapter provides an overview of the topic, a description of current policy in Michigan (including new HVHF rules implemented by the state in March 2015), and a range of approaches, including 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 conditions which are addressed. A complete list of all the policy options can be found at the end of this summary.

Figure 4 illustrates the organization of the report around its focus on HVHF in Michigan.

ANALYSIS OF POLICY OPTIONS

Public Participation

Governing HVHF and related activities in a manner that is socially acceptable can be challenging, especially given the different and often conflicting viewpoints held by different stakeholder groups. Similar dilemmas have been provoked by technologies such as nuclear power plants and hazardous waste facilities. In these settings, a large body of research has argued that to arrive at sound public policies that reflect democratic decision making and address stakeholder concerns, the public must have a significant participatory role.[32–36]

There are numerous ways in which the public could inform deep shale gas development. These might include, for example, sharing knowledge about local conditions, identifying key concerns and risks, and helping decision makers prioritize needed regulations. How the public weighs in on these issues can take many forms. In the context of public policy, public participation is often construed as public comment periods and hearings, where the public might be described as having a consultative role.[37,38] Other forms of public participation such as moderated workshops and deliberative polling may allow for more interactive discussions that encourage collaborative decision 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. For example, the National Research Council, which serves as the working arm of the National Academy of Sciences, hosted two workshops in 2013 to examine risk management and governance issues in shale gas development.[39] One of the papers to emerge from this workshop argues that public participation efforts must go beyond simply informing the public about HVHF or allowing them to submit comments on proposed activities; instead, stakeholders should be engaged in analytic-deliberative processes where they have the opportunity to "observe, learn, and comment in an iterative process of analysis and deliberation on policy alternatives."[40]

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, even though the impacts of HVHF well development may extend beyond the well site.

Chapter 2 examines options for improving how public values and concerns are incorporated into HVHF-related policy. The first section explores this question broadly by looking at how public values inform unconventional shale gas policies, in general, and by examining what opportunities exist for improvement. The remaining two sections explore how public interests are represented in state mineral rights leasing decisions and well permitting as these two activities both affect a question of primary importance to the public: where will HVHF occur.

Options for public involvement in HVHF-related policies

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 mineral rights leasing and well permitting practices, the state could consider implementing a number of other options to address the needs and concerns of residents. These include:

- Revising the content and usability of the DEQ website
- Requiring risk communication training for DEQ and DNR staff
- Participating in 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.
- Increasing stakeholder representation on the Oil and Gas Advisory Committee
- Appointing a multi-stakeholder advisory commission to further study the potential impacts of HVHF in Michigan
- Imposing a moratorium or ban on HVHF permitting

Options for public involvement in state mineral rights leasing

Michigan's existing policy of requiring public notice and comment before auctioning state mineral rights has been reasonably responsive to public concerns. Additional options for public involvement include:

- 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
- Requiring public notice and comment when well operators request modifications of existing state mineral rights leases
- Requiring responsiveness summaries of public input received

Options for public involvement in well permitting

Michigan's existing policy for involving the public in well permitting decisions is more inclusive than 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. Options that can help address these concerns include:

- Increasing public notice
- Requiring a public comment period
- Explicitly allowing adversely affected parties to petition for a public hearing

Water Resources

HVHF as commonly practiced requires water as a primary component in its operation. This crucial need for large volumes of water makes the regulation of water withdrawal and wastewater disposal strong tools for regulating HVHF activities themselves. The State of Michigan has a well-developed system for the management of water withdrawals, the Water Withdrawal Assessment Program (WWAP), which was developed as part of the Great Lakes Compact and instituted in 2009.[41] By managing water resources of the state, the WWAP offers a mechanism for managing HVHF operations. Currently, the state regulates HVHF water withdrawals along a parallel regulatory pathway. While HVHF water withdrawals are not governed by the WWAP, such water withdrawals are required to be assessed using the same online assessment tool—Water Withdrawal Assessment Tool (WWAT)—used for the WWAP. In addition to the required use of the WWAT, HVHF water withdrawals must identify existing nearby water withdrawal wells, install their own groundwater monitoring wells, and report all water withdrawal activities to the Supervisor of Wells.

If concerns over water withdrawal are held at the start of the HVHF process, at the other end of the process are concerns over the wastewater accumulated during the HVHF process. Indeed, concerns over impacts to water quality have also arisen in the popular media, scientific literature, and governmental reports. HVHF utilizes a suite of chemicals, which effectively contaminates the water used in the HVHF process, some of which returns back to the surface.

Chapter 3 is organized into two major sections. The first explores various methods in which improvements to the Supervisor of Wells regulations and 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 state-appointed Water Use Advisory Council.[42] The second section explores regulatory rules changes concerning management of wastewater from HVHF operations. Both sections use regulatory examples from other Great Lakes states, the Susquehanna River Basin Commission (SRBC), and the Delaware River Basin Commission (DRBC). All of these regions share a basis of water law (i.e., regulated riparianism[43]), which places them in a similar framework regarding their approach to governing water withdrawals.

Options for HVHF water withdrawal regulation

The parallel structure of governing water withdrawals in Michigan (through the Supervisor of Wells in the case of HVHF water withdrawals and through the WWAP for almost all other large scale water withdrawals) rests upon the common use of the WWAT for initial assessment of the withdrawal. However, since the water itself doesn't recognize regulatory boundaries, it is necessary to assess different aspects of water withdrawals in response to the additional physical and public perception challenges that HVHF brings to the table.

One of the major policy options presented in Chapter 3 is to update the WWAT. Updates to the WWAT would allow for greater precision and accuracy in assessing the impacts of large-volume water withdrawals from HVHF as well as other large water withdrawals across the state. Options include:

- Updating the scientific components of WWAT
- Implementing a mechanism for updating the models underlying WWAT

Other HVHF water withdrawal regulation options include altering the thresholds for enacting regulation. Enacting parallel measures within the WWAP and the Supervisor of Wells regulations could likely have negative consequences on certain types of water users but would also increase the strength and quality of water conservation throughout the state. Options include:

- Lowering water withdrawal thresholds for regulation
- Metering HVHF water withdrawal wells
- Setting total volumetric water withdrawal limits for certain types of withdrawals

Another major policy option revolves around water withdrawal permitting, the fees for such permitting, and the question of whether such permits might be transferrable. This last change could provide local water users greater ability to make their own decisions about water use. However, such changes would significantly alter the fundamental basis of water governance in the state, moving it more deeply into a regulated riparian system. Options such as fee schedules, like those used by the SRBC and DRBC, could be implemented to fund and improve water governance mechanisms and structures within the state. Water withdrawal permitting options include:

- Including HVHF water withdrawals within the current fee schedule
- Modifying water withdrawal fee schedules
- Prohibiting HVHF operations from obtaining a water withdrawal permit
- Providing a mechanism to transfer, sell, lease registered/permitted water withdrawals

In much of the area of the state where HVHF will take place, public concern over potential impacts stems from concern that watersheds may be over-allocated due to errors in the predictions of water available made by WWAT. At present Michigan has the site-specific review (SSR) mechanism to deal with potential overallocation of, and related impacts to, water resources. Additional monitoring and public engagement options include:

- Requiring SSRs for all HVHF water withdrawal proposals
- Providing a mechanism to use private monitoring
- Including HVHF operators in water users committees
- Incentivizing the organization of water resources assessment and education committees

Options for wastewater management and water quality

Presently, the wastewater management and water quality policies of the State of Michigan have been 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 HVHF, 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 being created by a single hydraulic fracturing well, a future with HVHF will be one where each well potentially creates hundreds-of-thousands of gallons of wastewater—several hundred times more than a historic hydraulic fracturing 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 law, it requires the disposal of hydraulic fracturing fluids into Class II wells.[44] Although Class II disposal wells are designed to keep underground drinking water supplies safe from contamination, there have been well casing failures in production wells in other states due to high pressure that have caused groundwater contamination. In addition, the public often perceives groundwater resources as vulnerable to hydraulic fracturing operations in general. Given these concerns, additional options for managing and monitoring wastewater disposals are presented. These include:

- Increasing monitoring and reporting requirements
- Obtaining primary authority over Class II well oversight by the state
- Requiring use of Class I hazardous industrial waste disposal 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 provides 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. Recycling wastewater and using alternative water resources both hold potential benefits of improved water quality through diminished demands for groundwater resources, even though both carry associated environmental risks. Additional options here include:

- Providing options for greater wastewater recycling
- Using 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 January 2011 and February 2013, the EPA identified approximately 700 different chemicals that were used in fracturing fluids.[45] The fracturing fluid for each well contained a median of 14 chemical additive ingredients, with a range of 4 to 28 ingredients.[1] 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,[46–49] as well as in other jurisdictions currently engaging in HVHF.[50,51] Nearly all chemical substances are characterized by one or more ecological and/or human health hazards (i.e., the potential to do harm). However, it is the conditions surrounding the presence of that chemical that determine the ecological and/or health risks (i.e., the probability of causing harm).

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.[52] In its strongest form, the precautionary approach would counsel banning an activity that could potentially result in severe harm.[53] The second is to adopt an adaptive approach. Policymakers may choose to take some regulatory action at the outset, then refine the policy as more information becomes available.[54] 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.[55]

Chapter 4 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 to reduce risk or set a performance standard; and response policies manage any contamination through emergency planning, cleanup, and liability requirements. The chapter focuses on the policies of eight states: Arkansas, Colorado, Illinois, New York, North Dakota, Ohio, Pennsylvania, and Texas. The states were chosen to reflect a range in the characteristics of production, demography, and policy.[56] For each type of policy tool, and building on the approaches to uncertainty, the chapter presents the range of state policies and describes Michigan's current policies. The chapter then offers three combinations of policy options the state could adopt, including returning to its previous policies.

Options for information policy

U.S. states have focused much of their policy attention on gathering information about chemical use in hydraulic fracturing through reporting and monitoring requirements. These policies build on existing laws that require well operators to submit reports on the methods used for completing a well. Mechanisms for regulating the provision of information by HVHF operators vary. Moreover, such mechanisms may or may not be specific to HVHF activities, but rather capture HVHF activities by their scope. Variation is evident in terms of their objective/s, obligations, penalties, and audience. Yet despite the differences in design, the overarching goal of such mechanisms is to increase transparency of otherwise private information. While the focus may be on increasing transparency between the operator and the state, 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. As this section illustrates, the mechanisms and/or tools adopted by the state will therefore depend on their overall policy objective around access to, use of, and availability of information.

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.

Michigan's existing information policies primarily adopt a remedial approach to uncertainty, the most common approach of the other states surveyed. Michigan gathers information about well integrity through pressure monitoring during HVHF and information about water quality through a baseline test; both are remedial policies that use the information to address contamination and liability. The exception is the state's chemical disclosure policy, which takes a precautionary approach. By requiring operators to provide information on chemical constituents prior to HVHF, the state can take preventative actions in permitting. These actions are limited, however, by the incomplete nature of the chemical information: operators may withhold the identities of chemical constituents considered to be a trade secret, and may use other chemicals in HVHF that are not disclosed in the permit application.

Options presented for information policy include:

- Chemical Use: Plain-language description of all chemicals; careful scrutiny of trade secret claims; full disclosure to the state of all constituents prior to HVHF activity
- Well Integrity: Monitoring during HVHF activity with problems reported immediately to state and nearby landowners; periodic tests through life of operating well not just when a problem is indicated
- Water Quality: Long-term monitoring, including baseline tests, of water resources including surface water based on characteristics of the aquifer/watershed; reporting results within 10 days to the state, owner, and public

Options for prescriptive policy

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 specified 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 initial 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.

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.

As in the majority of states surveyed, Michigan has adopted a combination of approaches. Michigan takes a precautionary approach to well siting through setback requirements, though the policy is limited to groundwater drinking sources. The state's policies controlling groundwater risks are primarily adaptive: well construction requirements are made flexible by the discretion given to permitting staff to set conditions. Yet the state also employs a precautionary approach by requiring operators to address potential conduits. Lastly, Michigan's policies controlling surface risks are both precautionary (requiring flowback to be stored in tanks) and remedial (mandating secondary containment measures for storage tank areas, though not for chemical staging areas).

Options presented for prescriptive policy include:

- Chemical Use: Developing a list of prohibited chemicals which could be amended over time; approving chemicals only if applicant demonstrates low toxicity
- Limitations on Siting: Modifying siting distances for wells and surface facilities over time based on new findings; no siting in protected areas
- Controls on Groundwater Risks: Modifying construction requirements over time based on groundwater monitoring data/best practices; relocation of well unless no risk from conduits
- Controls on Surface Risks: Storing flowback in pits or tanks, and modifying practices over time based on leakage data/best practices; requiring closed loop systems for chemical additives and flowback; imposing restrictions on additive handling

Options for response policy

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 can happen and seek to minimize harm and hold actors responsible.

State spill response policies primarily focus on four areas:

1. planning for emergencies;
2. reporting and cleanup;
3. financial responsibility; and
4. liability to private parties.

As in the majority of the states examined, Michigan's approach is remedial. In the event of a spill, the state requires quick reporting and cleanup. The state's financial responsibility policies encourage operators to take responsibility for a spill and remediate the site, but the state could do more to encourage prevention by also requiring liability insurance.

Options presented for response policy include:

- Emergency Planning: Requiring emergency response plans for HVHF wells in sensitive

areas and modifying the policy over time based on data; requiring emergency response plans for all HVHF wells
- Reporting and Cleanup: Cleanup criteria modified over time based on long-term monitoring data; immediate reporting of all spills to state, surface owners, and public
- Financial Responsibility: No blanket bonds; modifying individual bond amount over time based on restoration costs, requiring individual well bonds of $250,000 and liability insurance
- Liability to Private Parties: Liability if no environmental monitoring around well; strict liability unless operator can demonstrate caused by other sources; requiring the restoration of environment for all spills

OTHER MATERIAL

Broader Context

In response to public comments received during the IA process and broader context topics identified in the technical reports, Appendix B provides an overview of the literature on several key issues related to expanded shale gas production, including: 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 economic impacts should the U.S. expand natural gas exports, and methodological approaches to understanding and managing human health risks. While not exhaustive, these issues are central to the national debate and discourse regarding the challenges and opportunities of expanded shale gas production. For many of the topics, the results presented in the literature are mixed or uncertain due to the application of different methodological approaches, datasets, scenario assumptions, and other factors. In other areas, there are clearer indications of outcomes such as existing opportunities to reduce GHG emissions through existing technology and best practices, the influence of federal renewable mandates for transitioning to low- or zero-carbon technologies, economic benefits for gas-intensive industries from lower gas prices, and the price effects of expanding natural gas exports.

These discussions should not be read as definitive conclusions but a snapshot of current understandings of these topics. The body of peer-reviewed literature on the impacts of shale gas development is relatively new; one comprehensive review of the available scientific peer-reviewed literature estimated that 73% of the literature has been published since January 1, 2013.[57] As has been noted above, much still needs to be examined regarding expanded shale gas development, and there is significant work currently taking place that hopefully will better inform decision making moving forward.

Additional Issues

Drawing again from the range of public comments received during this project, as well as the IA technical reports, media releases, and scientific literature, Appendix C provides a scan of topics relevant to natural gas development in Michigan but not necessarily specific to HVHF. These include a range of potential environmental impacts, air quality concerns, landowner and local community impacts, as well as agency capacity and financing issues. For each of these issues, an overview of the potential impacts and concerns is provided along with a brief description of regulations or practices in Michigan related to the topic and a list of different approaches intended to address aspects of these concerns or examples from other states.

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List of Policy Options

CHAPTER 2: POLICY OPTIONS FOR PUBLIC ARTICIPATION	
2.2 INCORPORATING PUBLIC VALUES IN HVHF-RELATED POLICIES AND DECISION MAKING	
2.2.3.1	Keep existing Michigan policy • 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 state and local-level 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

2.3 PUBLIC INPUT IN STATE MINERAL RIGHTS LEASING	
2.3.3.1	Keep Michigan's existing state mineral rights leasing policy • NRC and DNR manage state-owned lands and mineral resources; DNR runs leasing program for state-owned mineral rights and is responsible for collection royalties from production; 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 parcel; notification at parcel itself if it is used as a public recreational area
2.3.3.3	Require DNR to prepare a responsiveness summary
2.3.3.4	Require public workshops prior to state mineral rights auctions
2.3.3.5	Increase public notice and comment when lessees submit an application to revise or reclassify a lease
2.4 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	Explicitly allow adversely affected parties to request a public hearing before a HVHF well permit is approved

3.2 REGULATING HVHF THROUGH WATER WITHDRAWAL REGULATION

3.2.1 REQUIREMENTS FOR WATER WITHDRAWAL APPROVAL

3.2.1.2.1	Keep existing Michigan policy for water withdrawal approval • No cumulative water withdrawals in subwatershed units may cause an adverse resource impact (ARI). HVHF water withdrawals must be submitted to Supervisor of Wells and run through WWAT; may not create Zone C (Zone B in a cold-transitional systems); and require identification of all nearby groundwater wells and installation of groundwater monitoring wells.
3.2.1.2.2	Revert to previous Michigan policy • Supervisor of Wells Instruction 1-2011 required of use of WWAT for HVHF and stated withdrawals causing an ARI would not be allowed.
3.2.1.2.3	Disallow any HVHF operation within a cold-transitional system
3.2.1.2.4	Make conservative estimates of HVHF water withdrawals

3.2.2 WATER WITHDRAWAL REGULATION THRESHOLDS

3.2.2.2.1	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)
3.2.2.2.2	Lower thresholds for regulation
3.2.2.2.3	Meter HVHF withdrawal wells
3.2.2.2.4	Set total volumetric water withdrawal limits

3.2.3 IMPROVEMENTS TO THE WWAT

3.2.3.1	Keep existing Michigan WWAT • The current WWAT reflects water quantity measures, regulatory subwatersheds, and Policy Zone determinations from 2008.
3.2.3.2	Update the scientific components of WWAT • Update scientific dataset; use numerical models; include lakes and wetlands
3.2.3.3	Implement a mechanism for updating the models underlying WWAT

3.2.4 WATER WITHDRAWAL FEE SCHEDULES

3.2.4.2.1	Keep existing Michigan water withdrawal fees • HVHF operators are exempt from the WWAP and pay no water withdrawal fees for registration.
3.2.4.2.2	Include HVHF water withdrawals within the current fee schedule
3.2.4.2.3	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

3.2.5 MODIFY WATER WITHDRAWAL PERMITTING

3.2.5.2.1	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)
3.2.5.2.2	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 Supervisor of Wells

3.2.6 TRANSFER/SALE/LEASE OF WATER WITHDRAWALS

3.2.6.2.1	Keep existing Michigan policy for transfer/sale/lease of water withdrawals • Responsibilities and liabilities associated with water withdrawals devolve to the property owner under statutes associated with WWAP; Supervisor of Wells HVHF regulations imply permittees much register or obtain permits for withdrawals
3.2.6.2.2	Provide a mechanism to transfer, sell, lease registered/permitted water withdrawals
3.2.6.2.3	Prohibit transfer or use of registered water withdrawals to HVHF operations

3.2.7 ADDITIONAL MONITORING

3.2.7.1.1	Keep existing Michigan policy for monitoring • Site-specific review may be conducted when ARI is suspected in a Policy Zone C subwatershed unit or when a proposed withdrawal would cause a Policy Zone C or D
3.2.7.1.2	Require site-specific reviews for all HVHF water withdrawal proposals
3.2.7.1.3	Provide a mechanism to use private monitoring

3.2.8 PUBLIC ENGAGEMENT ON NEW WATER WITHDRAWALS	
3.2.8.2.1	Keep existing Michigan policy for public engagement on new water withdrawals • Notification for withdrawal permits but not registrations
3.2.8.2.2	Include HVHF operators in water users committees
3.2.8.2.3	Incentivize the organization of water resources assessment and education committees
3.2.8.2.4	Require notifying the public about new high-capacity wells
3.3 WASTEWATER MANAGEMENT AND WATER QUALITY	
3.3.5 DEEP WELL INJECTION	
3.3.5.2.1	Keep existing Michigan policy for deep well injection • DEQ and USEPA manage 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	Obtain primary authority over Class II well oversight by the state
3.3.5.2.4	Require use of Class I hazardous industrial waste disposal wells
3.3.6 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

CHAPTER 4: POLICY OPTIONS FOR CHEMICAL USE	
4.2 INFORMATION POLICY	
4.2.2 CURRENT INFORMATION POLICY	
CHEMICAL USE	**Subject of disclosure:** hazardous constituents
	Means of disclosure: permit application; information posted on FracFocus
	Timing of disclosure: before HVHF and within 30 days of well completion
	Trade secret claim review: statement of claim; must use family name or other description
WELL INTEGRITY	**Pressure monitoring:** monitored during HVHF and reported immediately to state if problem; HVHF ceases until plan of action implemented; report all data within 60 days of completing operations
	Mechanical integrity test: when monitoring during HVHF 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: baseline test, >7 days but <6 months prior to drilling of new well or HVHF of existing well
	Test results: within 45 days to state and owner; immediate report of BTEX to state
4.2.4.1 OPTION A: INFORMATION POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH	
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 INTEGRITY	**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 INFORMATION POLICY *continued*

4.2.4.2 OPTION B: INFORMATION POLICY EMPLOYING AN ADAPTIVE APPROACH

CHEMICAL USE	**Subject of disclosure:** all constituents; plain-language description
	Means of disclosure: master list; state website; FracFocus
	Timing of disclosure: no change
	Trade secret claim review: careful scrutiny of claims
WELL INTEGRITY	**Pressure monitoring:** monitored during HVHF and reported immediately to state and nearby landowners if problem; status placed on website; HVHF ceases until plan of action implemented
	Mechanical integrity test: periodic tests through life of operating well
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
	Frequency of testing: baseline test; long-term regular monitoring
	Test results: within 10 days to state, owner and public; immediate report of contaminants of concern

4.2.4.3 OPTION C: INFORMATION POLICY EMPLOYING A 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 INTEGRITY	**Pressure monitoring:** monitored during HVHF and reported immediately to state and nearby landowners if problem; status placed on website; operator must demonstrate integrity before continuing
	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: based on importance of sources to be protected
	Frequency of testing: baseline test; long-term continuous monitoring of critical sources
	Test results: prior to approval of well and within 10 days to state, owner, and public; immediate report of all contaminants

4.3 PRESCRIPTIVE POLICY

4.3.2 CURRENT PRESCRIPTIVE POLICY

RESTRICTIONS ON CHEMICAL USE	**Restrictions:** none
LIMITATIONS ON SITING	**Object of siting:** oil or gas well; surface facility
	Distance: 300 feet; 800-2,000 feet
	Resource protected: freshwater wells; public water supply wells
CONTROLS ON GROUNDWATER RISK	**Well construction requirements:** casing and cementing requirements
	Area of review analysis: within 1,320 feet; relocation, demonstration of no movement, or other preventative actions
CONTROLS ON SURFACE RISK	**Handling of flowback and chemical additives:** flowback stored in tanks or approved containers; secondary containment for production wellheads and surface facilities, including flowback storage tanks; tanks monitored for leaks

4.3.4.1 OPTION A: PRESCRIPTIVE POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH

RESTRICTIONS ON CHEMICAL USE	**Restrictions:** none
LIMITATIONS ON SITING	**Object of siting:** no change
	Resource protected: no change
	Distance: no change
CONTROLS ON GROUNDWATER RISK	**Well construction requirements:** no change
	Area of review analysis: no change
CONTROLS ON SURFACE RISK	**Handling of flowback and chemical additives:** no substantive change

4.3.4.2 OPTION B: PRESCRIPTIVE POLICY EMPLOYING AN ADAPTIVE APPROACH

RESTRICTIONS ON CHEMICAL USE	**Restrictions:** list of prohibited chemicals, amended over time
LIMITATIONS ON SITING	**Object of siting:** oil or gas well site and storage areas, modified over time based on risks of activity
	Resource protected: particularly sensitive features, modified over time based on new findings/best practices
	Distance: change over time based on new findings/best practices
CONTROLS ON GROUNDWATER RISK	**Well construction requirements:** current requirements, modified over time based on groundwater monitoring data/best practices
	Area of review analysis: within area affected by HVHF; corrective action modified over time based on groundwater monitoring data/best practices
CONTROLS ON SURFACE RISK	**Handling of flowback and chemical additives:** flowback stored in pits or tanks; modified over time based on leakage data/ best practices

4.3.4.3 OPTION C: PRESCRIPTIVE POLICY EMPLOYING A PRECAUTIONARY APPROACH	
RESTRICTIONS ON CHEMICAL USE	**Restrictions:** approval of chemicals only if applicants demonstrate low toxicity
LIMITATIONS ON SITING	**Object of siting:** oil or gas well; storage and handling areas
	Resource protected: all potentially affected natural resources
	Distance: varies by feature with additional cushion; no siting in protected areas
CONTROLS ON GROUNDWATER RISK	**Well construction requirements:** additional requirements that create as many layers of safety as feasible
	Area of review analysis: within drilling unit or larger area; relocation of well unless no risk from conduits
CONTROLS ON SURFACE RISK	**Handling of flowback and chemical additives:** closed loop system for chemical additives, flowback; additive handling restrictions

4.4 RESPONSE POLICY

4.4.2 CURRENT RESPONSE POLICY	
EMERGENCY PLANNING	**Emergency response plan:** hydrogen sulfide wells; to state
REPORTING AND CLEANUP	**Notification:** all spills of chemical additives and fracturing fluid; larger spills of flowback reported within 8 hours; exception for small spills of flowback that can be quickly contained; to state and surface owners
	Remediation standard: general cleanup criteria
FINANCIAL RESPONSIBILITY	**Bonds and insurance:** $30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance
LIABILITY TO PRIVATE PARTIES	**Type of contamination:** State common law
	Presumption: none
	Remedy: State common law

4.4.4.1 OPTION A: RESPONSE POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH	
EMERGENCY PLANNING	**Emergency response plan:** no change
REPORTING AND CLEANUP	**Notification:** no change
	Remediation standard: no change
FINANCIAL RESPONSIBILITY	**Bonds and insurance:** no change
LIABILITY TO PRIVATE PARTIES	**Type of contamination:** no change
	Presumption: no change
	Remedy: no change

4.4.4.2 OPTION B: RESPONSE POLICY EMPLOYING AN ADAPTIVE APPROACH	
EMERGENCY PLANNING	**Emergency response plan:** HVHF wells in sensitive areas; policy modified over time based on spill data; to state, surface owners, nearby residents
REPORTING AND CLEANUP	**Notification:** all spills; larger spills reported immediately; threshold modified over time based on spill data; to state, surface owners, nearby residents
	Remediation standard: general cleanup criteria; criteria modified over time based on long-term monitoring data
FINANCIAL RESPONSIBILITY	**Bonds and insurance:** no blanket bonds; modify individual bond amount over time based on restoration costs
LIABILITY TO PRIVATE PARTIES	**Type of contamination:** all spills into groundwater
	Presumption: for liability if do not monitor environment around well
	Remedy: remediation; modified over time based on long-term monitoring

4.4.4.3 OPTION C: RESPONSE POLICY EMPLOYING A PRECAUTIONARY APPROACH	
EMERGENCY PLANNING	**Emergency response plan:** all HVHF wells; includes preventative considerations; to state, surface owners, and public
REPORTING AND CLEANUP	**Notification:** immediate reporting of all spills; to state, surface owners, and public
	Remediation standard: restoration of environment
FINANCIAL RESPONSIBILITY	**Bonds and insurance:** individual well bond to $250,000; liability insurance
LIABILITY TO PRIVATE PARTIES	**Type of contamination:** all spills
	Presumption: strict liability unless operator can demonstrate caused by other sources
	Remedy: restoration of environment

INTRODUCTION

Chapter 1

1.1 PURPOSE AND SCOPE

There is significant momentum behind natural gas extraction efforts in the United States, with many states viewing it as an opportunity to create jobs and foster economic growth. Natural gas extraction has also been championed as a way to move toward domestic energy security 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 the past 10 years, however, the hydraulic fracturing process and associated shale gas development activities have come under increased public scrutiny particularly with respect to high volume hydraulic fracturing (HVHF). Key concerns include, for example, a perceived lack of information transparency, potential chemical contamination from fracturing fluids, water use, wastewater disposal, and possible 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 Graham Sustainability Institute over a one year time frame (June 2011-June 2012) and involved conversations with several other University of Michigan (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 help inform decision makers. For more about the IA research framework, please visit: http://graham.umich.edu/knowledge/ia.

The assessment does not seek to predict a specific future for HVHF activity in Michigan. Rather, 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. Given that HVHF intersects many issues that are important to Michigan residents—drinking water, air quality, water supply, land use, energy security, economic growth, tourism, and natural resource protection—the assessment asks: ***What are the best environmental, economic, social, and technological approaches for managing hydraulic fracturing in the State of Michigan?***

This guiding question bounds the scope of the IA. The assessment focuses on Michigan, but it also incorporates the experience of other locations that are relevant to Michigan's geology,

Box 1: Key Terms

Terminology is important to any discussion of 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.

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.[4] 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.[5]

Shale Gas: Natural gas produced from low permeability shale formations[6]

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: HVHF well completion is defined by State of Michigan regulations as a "well completion operation that is intended to use a total volume of more than 100,000 gallons of primary carrier fluid."[7,8]

Experts and the public often use terminology differently, and often interchangeably. In some instances, for example, the public tends to view hydraulic fracturing—including lower and high volume completions—as the entirety of the natural gas development process from leasing and permitting, to drilling and well completion, to transporting and storing wastewater and chemicals. Industry and regulatory agencies hold a much narrower definition that is limited to the process of injecting hydraulic fracturing fluids into a well.[9]

regulations, and practices. Additionally, the IA primarily concentrates on HVHF (defined by State of Michigan regulations as well completion operations that intend to use a total volume of more than 100,000 gallons of primary carrier fluid),[2,3] but the analysis of options also considers implications for other practices and includes options for different subsets of wells.

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 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.

1.2 OVERVIEW OF ACTIVITY IN MICHIGAN

While recent interest from energy developers, lease sales, and permitting activities suggest increasing activity around HVHF in Michigan, consistently low gas prices for the past two years[10] has been identified as a key contributor to limited HVHF activity in Michigan at present.[11] Below are some key points regarding hydraulic fracturing in Michigan.

- According to the Michigan Department of Environmental Quality (DEQ), since 1952 more than 12,000 oil and gas wells have been fractured in the state, and regulators report no instances of adverse environmental impacts.[12] The distribution of wells throughout Michigan's Lower Peninsula is illustrated by Figure 1. Most of these are relatively shallow (1,000 to 2,000 feet deep) Antrim Shale[13] vertical wells drilled and completed in the late 1980s and early 1990s in the northern part of Michigan's Lower Peninsula. Some new activity will continue to take place in the Antrim in the short term, and a very small number of the old wells may be hydraulically fractured in the future. This appears, however, to be a "mature" play and is unlikely to be repeated and not subject to HVHF.
- The hydrocarbon resources in the Utica and Collingwood Shales in Michigan (4,000 to 10,000 feet below ground) will likely require HVHF and below-surface 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 [generally] horizontally through the target formation) up to two miles.[14]
- 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.[15,16] However, there has been limited production activity thus far under these leases.
- As of May 28, 2015, there were 14 producing HVHF-completed oil and gas wells in Michigan, 2 active applications, 16 active permit holders, 6 locations with completed plugging, and 13 locations with completed drilling.[17] Figure 1 provides a map of these locations.
- 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 1.2).
- Given the limited activity to date is it very difficult to predict the scale of future HVHF activity in Michigan but there is agreement that further development of the Utica and Collingwood Shales is likely years away given that current low gas prices make development less feasible economically.[18]
- Over the past few years, several bills have been proposed in Michigan to further regulate or study hydraulic fracturing,[19] state officials implemented new rules for HVHF in March 2015,[20] and a ballot question committee has been working to prohibit the use of horizontal hydraulic fracturing in the state.[21]

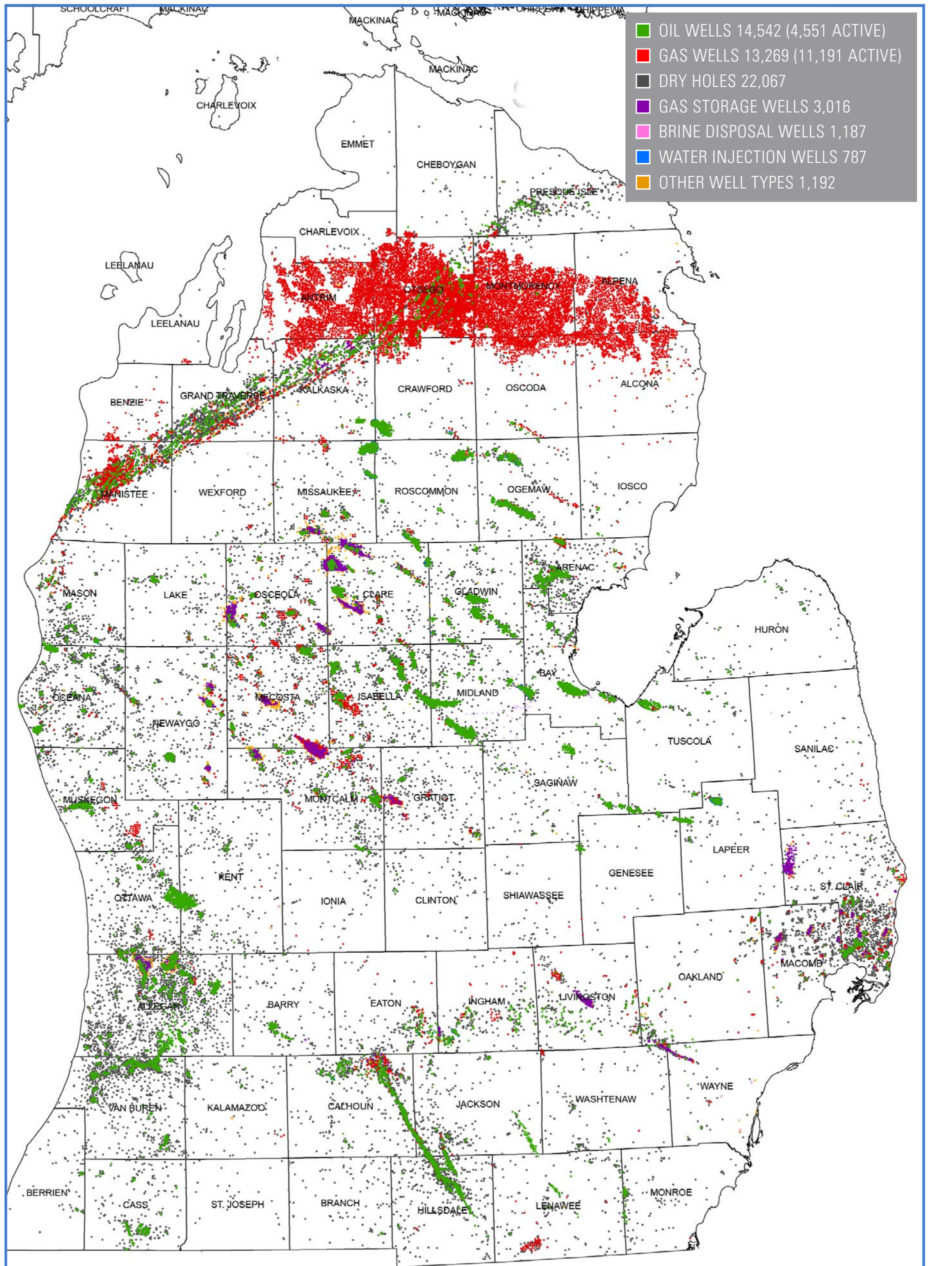

FIGURE 1.1a[i]: Activity in Michigan: oil and gas wells in 2005[22]

[i] Full size, zoomable map available at: http://www.michigan.gov/documents/deq/MICHIGAN_OIL_GAS_MAP_LP_411599_7.pdf

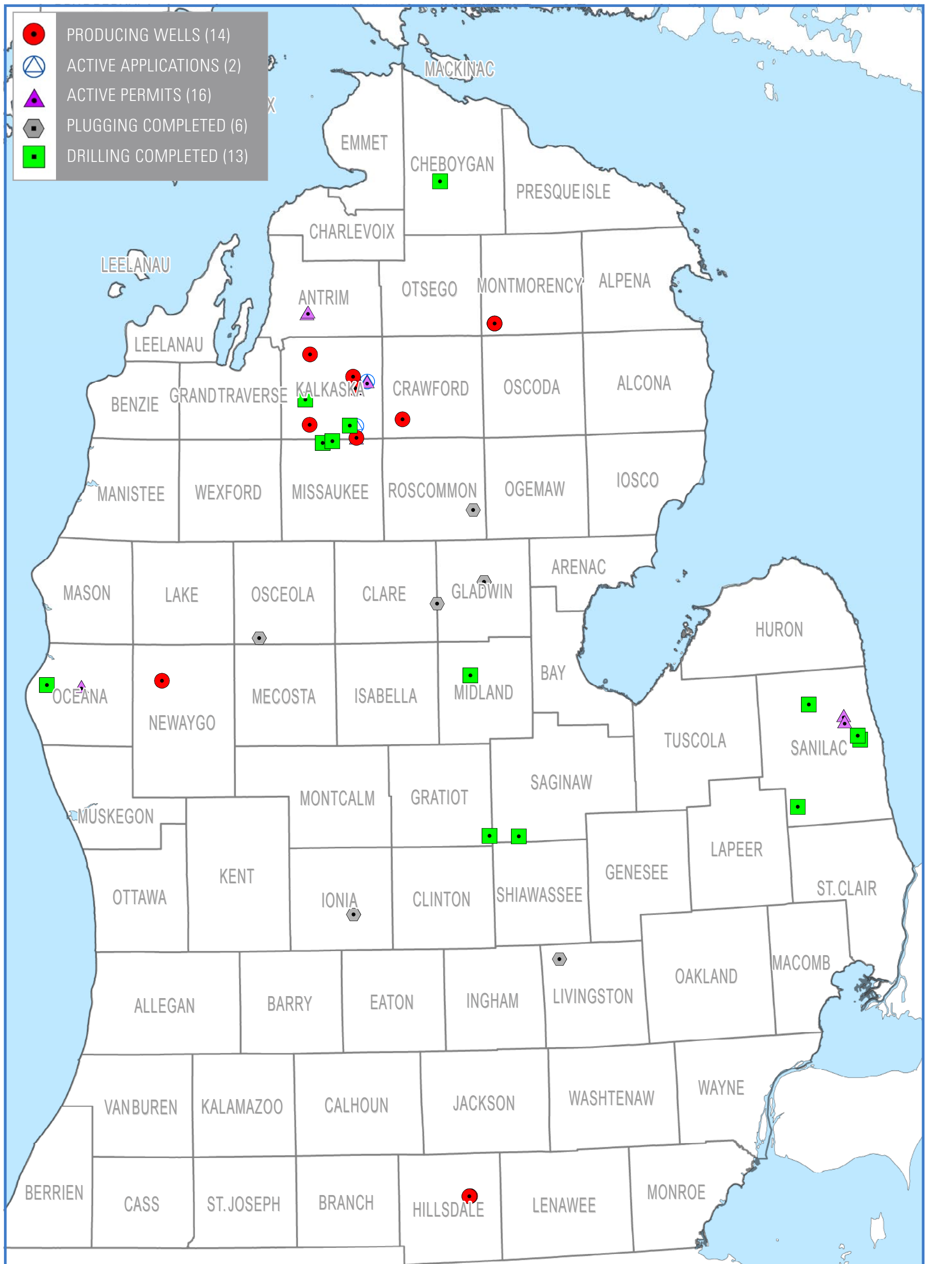

FIGURE 1.1b[i, ii]: Activity in Michigan: HVHF wells as of May 28, 2015.[23]

[i] Full size zoomable map available at: http://michigan.gov/documents/deq/hvhfwc_activity_map_new_symbols-jjv_483124_7.pdf

[ii] The source map contains the following disclaimer: "High volume hydraulically fractured well completions are defined in Supervisor of Well Instruction 1-2011 as a 'well completion operation that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid.' We made all efforts to trace back the well completion records thru 2008 to compile [sic] this map and list. This information provided here in is accurate to the best of our knowledge and is subject to change on a regular basis, without notice. While the Department of Environmental Quality - Office of Oil, Gas, And Minerals (DEQ-OOGM) makes every effort to provide useful and accurate information, we do not warrant the information to be authoritative, complete, factual, or timely. It is suggested that this information be combined with secondary sources as a means of verification. Information is provided 'as is' and an 'as available' basis. The State of Michigan disclaims any liability, loss, injury, or damage incurred as a consequence, directly or indirectly, resulting from the use, interpretation, and application of any of this information."

1.3 STRUCTURE OF THE REPORT

The remainder of Chapter 1 includes a summary of the previously released technical reports that provide the background to this report and an overview of the process used for this assessment including contributors, participants, 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 policy options presented in Chapter 2 (public participation), Chapter 3 (water resources) and Chapter 4 (chemical use) using adaptive and precautionary policy categories. Chapter 6 identifies the limits of this report and knowledge gaps. Several appendices are also included. Appendix A is a glossary of terminology used throughout the report and HVHF discussions. Appendix B provides an overview of key points of discussion within the broader context of expanded shale gas development that are not specific to Michigan. Appendix C 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. Each chapter provides an overview of the topic, a description of current policy in Michigan (including new HVHF rules implemented by the state in March 2015), and a range of approaches, including approaches from other states and novel approaches. Each of

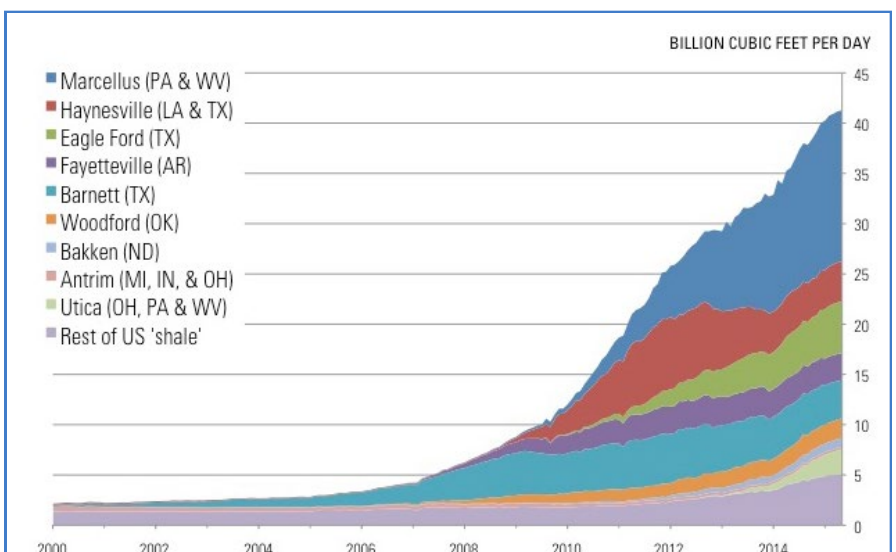

FIGURE 1.2: U.S. dry shale gas production[24]

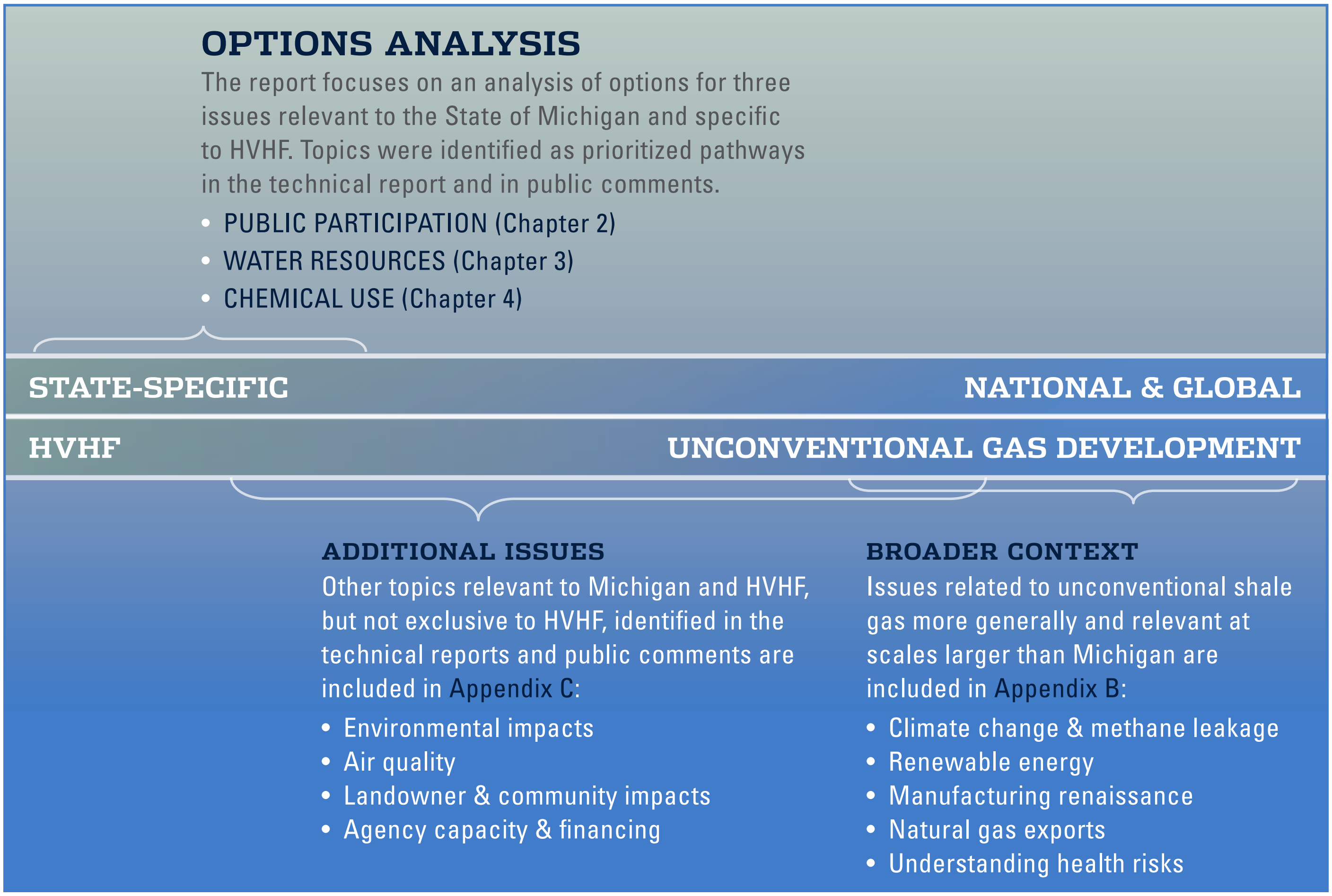

FIGURE 1.3: IA report organization

these chapters also provides an analysis of key strengths and weaknesses of the policy options. There is some variation in approach for each chapter given the range of policies and conditions which are addressed.

The technical reports and public comments also included other issues related, but not specific, to HVHF activity in Michigan. Although beyond the focus of this IA, these issues are important at geographic scales beyond Michigan and for unconventional shale gas development more generally. Appendix B addresses some of these issues at the national scale and in terms of general methodological approaches—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 economic impacts of expanding U.S. natural gas exports, and methodological approaches to understanding and managing human health risks. Appendix C presents topics directly relevant directly at the state and local levels including potential environmental impacts, air quality concerns, landowner and local community impacts, as well as agency capacity and financing issues. Despite not being exclusive to HVHF, these issues occur within the context of HVHF-drilled wells and are relevant to shale gas development more generally, and therefore are included in the appendix. Figure 1.3 illustrates the organization of the report around its focus on HVHF in Michigan.

1.4 TECHNICAL REPORTS SUMMARIES

The project's first phase (2012-2013) involved preparation of technical reports on key topics related to hydraulic fracturing in Michigan. These seven technical reports were peer-reviewed and made public in September 2013 (available at: http://graham.umich.edu/knowledge/ia/hydraulic-fracturing). Upon completion of the peer review process, final decisions regarding report content were made by the technical report authors in consultation with the Graham Institute. These reports provide decision makers and stakeholders with a solid foundation of information on the topic based primarily on analysis of existing data. The reports also identify additional information needed to fill knowledge gaps. The technical reports were informed by (but do not necessarily reflect the views of) an Advisory Committee, expert peer reviewers, and numerous public comments. The reports were downloaded more than 1,500 times in the year following their release. Below is a list of lead authors for the technical reports and summaries for each report. As it is not possible to include all of the information from the technical reports here, readers are encouraged to review the complete set of technical reports.

- **Technology:** John Wilson, Energy Institute; Johannes Schwank, Chemical Engineering
- **Geology/Hydrogeology:** Brian Ellis, Civil and Environmental Engineering
- **Environment/Ecology:** Allen Burton, School of Natural Resources & Environment; Knute Nadelhoffer, Department of Ecology and Evolutionary Biology
- **Public Health:** Nil Basu, School of Public Health (now at McGill University)
- **Policy/Law:** Sara Gosman, Law School (now at University of Arkansas)
- **Economics:** Roland Zullo, Institute for Research on Labor, Employment, & the Economy
- **Public Perceptions:** Kim Wolske and Andrew Hoffman, Erb Institute for Global Sustainable Enterprise

1.4.1 Technology

Hydraulic fracturing originated in 1947-1949, initially in Kansas, Oklahoma, and Texas as a means of stimulating production from uneconomic gas and (mostly) oil wells, and was quickly successful

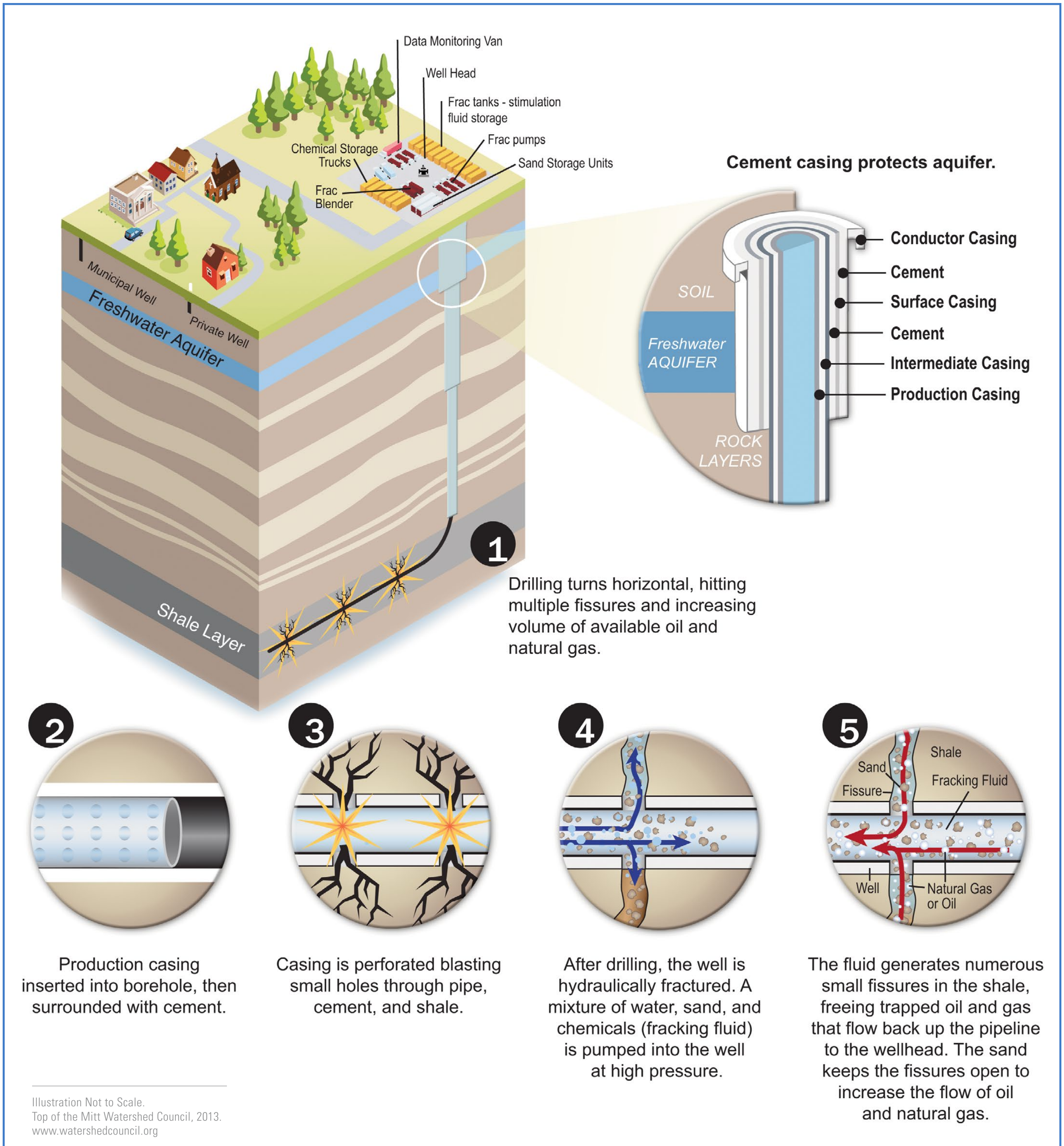

FIGURE 1.4: Hydraulic fracturing process[25]

at increasing production rates by 50% or more, typically using hydrocarbon fluids (not water) as the carrier. To date in the United States, an estimated more than 1.25 million vertical or directional oil/gas wells have been hydraulically fractured, with approximately 12,000 fractured wells located in Michigan.[25]

Most hydraulic fracturing begins with the construction of a drilling pad that may be 1–4 acres in area. The pad is now often covered with a thick polyethylene sheet and a thin layer of absorbent material (often just sand or soil) to minimize the impact of spills. The location of the pad site and the position of the drilling rig are primarily determined from a variety of information on the geological substructure and the estimated probability of striking oil and/or gas, but a wide range of environmental factors are also considered. A drilling rig is brought in and situated over the intended well site. Vertical drilling is then begun. In the case of formations like Michigan's Antrim shale, the hole is drilled down into the production zone, the rig is removed, and preparations are made to fracture the well. A drilling rig requires a lot of energy to turn the rotary drill bit and is usually powered by high-torque diesel-electric motors but, in response to environmental concerns, more rigs are using engines powered by compressed or even liquefied natural gas.

In some cases, lateral wells in shale may also be drilled using directional drilling. The lateral penetrates the hydrocarbon-bearing formation and provides more routes for product to enter the well. In the case of dry gas wells with no production of water or gas liquids, the lateral may be close to horizontal. In cases where liquid drainage must be managed or if the formation itself is not horizontal (common in basin structures), the lateral may be inclined to the horizontal. Laterals are typically 10,000-20,000 ft. in length, but a few have been as long as 40,000 ft. Once the well is drilled (or more usually concurrently with drilling), all of the well is cased throughout in one or more layers of high-strength steel tubing that are sealed to one another and to the well wall with cements developed for the purpose. This is especially true if the well passes through an aquifer, as most do, or through a part of the formation that may have low strength and therefore might collapse. All wells are cased through and below the fresh water zone with surface casing after the well has been drilled through the fresh water zone and before drilling can continue to deeper depths. All wells then have at least one deeper string of casing (and typically two or more) to or through the target zone. The purpose of the casing is to contain fluids within the appropriate zone and prevent uncontrolled flows into fresh water zones or other zones that must be protected.

Because the tubing must withstand fracturing pressures (especially the longitudinal stresses set up in the vertical bore), it is also normally constructed of high-strength steel, and joints between tubing segments are strengthened and may even be welded, although that is rare. Nevertheless, one of the most common reasons for well failures, usually during fracturing when the internal pressure is high, is tube joint failure or even tubing failure. In severe cases this can result in the ejection of a section of tubing from the well along with the "Christmas Tree", the complex arrangement of tubing at the top of the well that is designed to handle the produced gas or oil and that usually includes the blowout preventer(s). Very little fluid leaks under these circumstances because the fracturing pumps immediately detect the pressure drop and shut down.

Fracturing of deep and/or directional wells is most often done with several hundred thousand to several million gallons of high-pressure water that contains about 10-20% of sharp sand or an equivalent ceramic with controlled mesh size and about 0.5% of five to ten chemicals that are used to promote flow both into and subsequently out of the fractured formation. The list of chemicals includes hydrochloric acid to dissolve minerals and initiate cracks in the formation. Biocides such as glutaraldehyde or quaternary ammonium chloride may be added to eliminate bacteria that produce corrosive byproducts. Choline chloride, tetramethyl ammonium chloride, or sodium chloride may be added as clay stabilizers. Corrosion inhibitors such as isopropanol, methanol, formic acid, or acetaldehyde may be dissolved in the water, along with friction reducing compounds, like polyacrylamide. In some cases, scale inhibitors are mixed in, for example acrylamide/sodium acrylate copolymer, sodium polycarboxylate (commonly used in dishwasher detergents), or phosphoric acid salt. Surfactants such as lauryl sulfate are added to prevent emulsion formation, and in some cases, the surfactant is dispersed in a carrier fluid such as isopropyl alcohol. To adjust the pH, sodium or potassium hydroxide or carbonate is used. The sand or ceramic acts as a so-called "proppant" and helps to prop the cracks open. Sometimes, more complex proppants are used—rigid fibers, for example, or ceramic particles of controlled size and geometry. Calcined bauxite is common since it has very high crushing strength.

To facilitate fracturing, the steel casing that is inserted into the well is typically penetrated with pre-placed explosive charges. The fracturing mixture flows into the formation through the resulting holes, and these holes subsequently provide a route for product flow back into the production tubing. In deep wells with long laterals, the fracturing may be done in stages, beginning at the far end of the well bore, with the later stages separated by a temporary plug to isolate the section being fractured.

Once the well is fractured, the fracturing water that can be recovered (usually between 25 and 75% of the total used) is pumped out of the well or, if gas flows from the well under sufficient pressure, the water flows out of the well along with the produced gas. Wells in oil-bearing formations, especially those involving shale, are much more likely to require pumping. The 'lost water' disappears into areas around the fractured formation or enters deep saline aquifers in which it is diluted and eventually lost.[26] See Figure 1.4 for a simplified illustration of the hydraulic fracturing process.

Despite still producing significant levels of gas, yields from the main producing fields in the state—such as the Antrim shale and Utica Collingwood shale—have been in decline. For the Utica Collingwood shale however, this could be due to the greater depths of the shale gas, as well as the greater uncertainty surrounding quantities present. Natural gas production in Michigan peaked in 1997, at 280 billion cubic feet per year (bcf/y), and by 2010 had fallen to 141 bcf/y.[27]

1.4.2 Geology and Hydrogeology

One of the most widely cited issues regarding the environmental consequences of hydraulic fracturing operations is groundwater contamination, and water quality issues more broadly. One study, conducted by Osborn et al., concluded that water wells located near natural gas production sites in Pennsylvania had higher contribution of *thermogenic* methane than wells farther away from such operations, suggesting a possible (not definite) link between hydraulic fracturing and increased methane in drinking water.[29] Other studies, such as one by Molofsky et al., suggest that methane leakage occurs naturally, and may have more to do with land topography than hydraulic fracturing.[30]

One key concern surrounding the practice of hydraulic fracturing is that the induced fracture network will extend beyond the target formation. If this were to occur then flow pathways would exist between the target reservoir and overlying formations, possibly allowing for migration of fracturing fluids beyond the production reservoir. The topic of hydraulically-induced fractures has been studied extensively, as understanding how the fracture network develops is key to both evaluating the enhanced productivity of a well and ensuring the safety of overlying sources of potable water.[31,32] A study by Fisher and Warpinski looked at hydraulically fractured wells in states outside of Michigan over the course of nine years (ending in 2010), and found no evidence of induced fractures extending into overlying fresh water aquifers.[33] However, it is important to note that this study did not collect any data on how fractures propagate in formations in the Michigan Basin.

Another key concern about possible impacts from shale gas development includes the quantity of water used. Typically, HVHF will use over 100,000 gallons of fracturing fluid per well, the overwhelming majority of which is water, but some wells have used over 21 million gallons.[34] For perspective, an Olympic size swimming pool holds roughly 660,000 gallons of water. While many other industries and consumers of water may use more water, its use in shale gas development generally occurs over a very short timeframe, which could potentially lead to localized impacts for communities, industries, and ecosystems.

After injecting the fracturing fluid, fluid will return to the surface over the course of days or weeks. Depending on a variety of factors, this fluid may contain some or all of the original fracturing fluid (known now as *flowback water*), as well as minerals, water, or other compounds that were originally in the shale formation. In Michigan, the DEQ requires that all flowback and other produced fluids be contained in aboveground steel containers. This contaminated water is injected underground into special *Class II disposal wells*. One growing concern in states such as Oklahoma and Ohio is the risk of induced seismicity—where the injected wastewater could lubricate a nearby fault and cause an earthquake. In Michigan, however, the Basin has been tectonically stable since the Jurassic Period, and there have been no reports of induced seismicity in the state, despite many years of ongoing underground injection for a variety of waste fluids.

Finally, likely the greatest risk to water quality comes from surface contamination. One analysis

Box 1.2: Hydraulic Fracturing and High Volume Hydraulic Fracturing

A vertical well that is hydraulically fractured in Michigan may 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.

While HVHF completions use significantly more water per completion than shallower, vertical completions, there is discussion regarding the two completion techniques' relative overall use of water and efficiency of water use (the amount of water used standardized by the size of the reserves or amount of gas produced). Some argue that fewer large wells could produce more gas per volume of water used or size of production unit. Similar arguments are made regarding surface impact: that the development of multiple HVHF wells per site, rather than many individual wells and well pads, reduces the area of land disturbed.

However, HVHF activity is currently too limited in Michigan to draw any conclusions regarding these types of comparisons due to uncertainties such as, but not limited to, average production rates, decline curves, productive lifetimes, the extent of future development, and water use in the Utica and Collingwood. Additionally, some contend that comparisons between different shale resources are inherently problematic because different completion techniques and economic considerations are involved. Depending on the metric and assumptions used in these comparisons, one may reach different conclusions about the relative impacts.

in particular, by Rozell and Reaven, identified the risk of drinking water contamination from wastewater disposal, specifically around the Marcellus Shale region, to be several orders of magnitude higher than contamination from other sources, such as contaminant migration through underground fracture networks.[35] The handling of waste and production fluids from hydraulically fractured wells in Pennsylvania has been a continuing challenge, since there are only five disposal wells in the state, three of which are privately owned and operated. However, since all produced water is disposed of via deep-well injection in Michigan, and may not sit in open pits, as sometime occurs in Pennsylvania, the risk of this type of contamination will be lower than some other states.

1.4.3 Environment and Ecology

There are numerous potential ecological consequences of all shale gas development. First, operators may construct access roads in order to transport equipment and materials to and from sites. These roads are frequently unpaved, and without sufficient erosion controls, sediment and harmful pollutants could erode and be carried into nearby rivers, lakes, and streams. These sediments can decrease photosynthetic activity, destroy organisms and their habitats, and contaminate water and plant or animal life. Further, the truck traffic from these and other connected access roads can be substantial. This increased level of traffic can lead to air quality risks from engine exhaust.

More generally, wildlife and their habitats could also be affected, though the specific impacts may vary among different types and species. Exposure to light and noise is a concern, as they can cause localized disturbances, disrupting feeding, breeding, and rest patterns in animals and plants of all sizes. Depending on their magnitude and scope, these impacts could become more systemic in nature, potentially impacting entire ecosystems.

1.4.4 Public Health

As with many of the areas that shale gas development could impact, possible impacts on public health have yet to undergo a rigorous assessment, owing primarily to substantial gaps in data availability, both in Michigan and beyond. It is important that public policy and regulations around shale gas development be grounded in strong, objective peer-reviewed science (as opposed to anecdotes). Nonetheless, the health related concerns expressed by community members, especially those that are scientifically plausible or those that are recurring, need to be seriously evaluated.

Focusing on three main contexts—the workplace, the surrounding environment, and the nearby community—enables a detailed description of the public health risks and benefits to be created. In the workplace, possible hazards include accidents and injuries, exposure to silica and industrial chemicals, and shift or night work. In the surrounding environment, possible hazards include impaired local/regional air quality, water pollution, and the degradation of ecosystem services. In nearby communities, hazards include increased traffic and motor vehicle accidents, increased stress levels, and effects associated with boomtowns, such as strained healthcare systems and road degradation.

While not all of these potential hazards have evidence to support their presence in or relevance for Michigan, certain ones, such as noise and odor, were identified as such. Noise pollution has been associated with negative health outcomes such as annoyance, stress, irritation, unease, fatigue, headaches, and adverse visual effects. Since some hydraulic fracturing operations occur around-the-clock, the noise generated could also potentially interfere with the sleep quality of area residents.

Silica exposure is another potential hazard identified, primarily impacting workers, who may be exposed to respirable crystalline silica. Silica sand is often used as a ***proppant*** during operations. Proppants are pumped deep underground, where they are responsible for keeping fractures open and allowing natural gas to flow out of the well. Inhalation of silica can lead to the lung disease ***silicosis***, which can include symptoms ranging from reduced lung function, shortness of breath, massive fibrosis, and respiratory failure.

Exposure to chemicals used intentionally, as well as those generated as by-products represent additional risks with relevance to Michigan, where workers may be exposed to a wide variety of such chemicals. Two recent studies, one conducted by Colborn et al., and the other prepared for U.S. Representative Henry Waxman, found a total of 632 chemicals in 944 products.[36,37] Of these, only around half (56%, or 353 chemicals) could be connected with a Chemical Abstacts Service (CAS) number (needed to assure the correct identification of a specific chemical). Analysis of these 353 chemicals revealed that approximately 75% of them could adversely impact human health in ways ranging from respiratory to neurological to cardiovascular impacts, with 25% identified as known, probable, or possible carcinogens.

1.4.5 Policy and Law

There are a wide variety of laws and regulations on every level from federal to state to local that govern shale gas development and its associated activities. Traditionally in Michigan, a landowner (either a private or public entity) owns ***both*** the 'surface' of the land as well as the 'mineral interest' in the oil/gas beneath it. However, it is also possible for the mineral rights to be separated (severed) from the surface, resulting in what is known as a ***split estate***. When the rights are separated like this, with two different owners, the owner of the mineral interest is considered the dominant interest, and has the right to reasonably use the surface to extract the gas underneath. It is noteworthy that while the mineral interest owner has a reasonable opportunity to extract the gas, they do not actually have a right to the specific gas underneath that property.

In general, the owner of gas rights will lease those rights to an exploration and production company that has the expertise and capability to drill wells and manage production. Michigan's Department of Natural Resources (DNR), which is the largest owner of mineral interests in the state, has its own program for leasing state owned mineral interests. They face a balancing act, wherein they try to maximize revenue and ensure that the oil and gas is not being drained by wells on adjacent properties, while at the same time protecting the environmental, archaeological, and historical features on the surface.

Another state agency, the DEQ, is responsible for governing gas exploration, development, and production waste. With this authority, the DEQ issues specific rules and guidance, setting permitting conditions and enforcing requirements on the location, construction, completion, operation, plugging, and abandonment of wells. After obtaining rights from the mineral interest owners, gas companies must obtain a DEQ permit before drilling any wells. This permitting process includes a number of different components, including fees, bonds, reports, a public comment period, information regarding the technical details of the proposed well, and factors related to whether the applicant's plan would be in compliance with standard environmental conservation measures.

Traditionally, federal and state environmental agencies (such as the DEQ in Michigan) regulate the impacts of an activity on natural resources, while local governments regulate the location of land uses through zoning and planning. With regards to gas wells, the state regulates both the well location ***and*** the impacts of well sites, constraining the authority of localities. Michigan's DEQ has numerous requirements for well location, including a 300 foot setback from freshwater wells used for human consumption, and a 2,000 foot setback from larger public water supply wells. Furthermore, in the application process for a DEQ permit, the applicant must submit an environmental impact assessment identifying nearby natural resources and describing impacts of access roads, the well site, surface facilities, and flow lines.

With regard to the regulation of chemicals used in hydraulic fracturing operations in Michigan, this responsibility falls primarily on the DEQ. Once chemicals are on-site, there are no federal or state restrictions on which substances may be used in fracturing fluid. Currently, the operator must provide the DEQ with copies of Material Safety Data Sheets (MSDSs) for each additive within 60 days of well completion, along with the volume of each additive used.

1.4.6 Economics

In Michigan, the shale gas industry generates employment income for the state, but the employment effects are modest when compared with other industries, and are not large enough to 'make or break' the state's economy.

With regard to employment, there are two broad types of jobs to be found in the natural gas extraction industry: jobs directly involved in production and jobs that provide services to producers. While there tend to be fewer production jobs, they generally pay higher salaries and are less sensitive to well development than servicing jobs. It has been estimated that the number of production jobs in Michigan has ranged from 394 (in 2002) to 474 (in 2010), and the number of service industry jobs has ranged from 1,191 (in 2002) to 1,566 (in 2008).[38]

The State of Michigan receives taxes from revenue earned by private landowners ($32.6 million in 2010), as well as revenue from gas extracted from state property. Although low in comparison to previous periods in the past decade, in 2012, the Department of Natural Resources received $18.4 million in royalties, $7.7 million in bonuses and rent, and $0.1 million in storage fees. Revenue received from private taxes goes to the state's general fund, and almost all the revenue received from gas extraction on state property goes to improving state land and game areas.

1.4.7 Public Perceptions

Among the general public, roughly 50-60% of Americans are at least somewhat aware of hydraulic fracturing, and awareness seems to be on the rise. In Michigan, where HVHF is still in a relatively early stage of development, the issue is still relevant to residents, with 40% reporting they have heard "a lot" about hydraulic fracturing, and 48% saying they follow the issue "somewhat" to "very closely."

When asked to weigh the benefits of hydraulic fracturing against its risks, people tend to view it positively, with one survey with multiple samples finding that 53-62% of people believe that its benefits "somewhat" to "far" outweigh its risks. In Michigan specifically, a poll found that 52% of people believe that "drilling for natural gas" in the state had resulted in more benefits so far, 24% who thought it had led to more problems, and 8% who thought the benefits and problems were about equal.

In Michigan, residents identified economic benefits, energy independence, reduced carbon emissions, and reduced energy costs as some of the greatest possible benefits. Conversely, residents identified water contamination, health issues, pollution, and general environmental damage as the greatest possible risks from hydraulic fracturing.

Several surveys have found a fairly evenly divided nation on the issue of whether citizens favor or oppose "fracking." Based on results from a 2012 phone survey in Michigan, a majority of respondents (54%) either "somewhat supports" or "strongly supports" the extraction of natural gas from shale deposits in the state, while 35% somewhat to strongly oppose it.[39] In Pennsylvania, where there is extensive hydraulic fracturing activity, support for shale gas development is weaker: 49% somewhat or strongly support shale gas extraction, while 40% somewhat to strongly oppose it. A majority of respondents in both Michigan and Pennsylvania agree that their states should impose a moratorium on hydraulic fracturing until more is known about its potential risks.[40]

Different stakeholders in Michigan have different perspectives on shale gas development. Industry organizations emphasize the potential economic benefits of deep shale extraction and address potential risks by highlighting the strength of state regulations and otherwise, the negligibility of risks. Nonprofit and grassroots organizations can be divided into two broad categories—those that seek greater regulation of hydraulic fracturing, and those seeking a permanent ban on it. Regardless of their desired outcomes, these organizations tend to emphasize risks and uncertainties rather than potential benefits in their communications, framing high volume hydraulic fracturing as a new and unprecedented process. Finally, state agencies such as the DNR and DEQ are visible on the issue, as a result of their mandates and regulatory authority.

Ultimately, these differences highlight a few key points. The first is that different stakeholders define key terminology differently. The lack of a common language can sometimes lead to miscommunications and increased mistrust. Different conceptions of risk by different stakeholder groups (for instance, whether or not 'risk' includes psychological or social considerations) also can lead to miscommunications and to government or industry assuming that the public simply needs more technical information, when in actuality, greater involvement in collaborative decision-making processes might be a more effective solution.

1.5 INTEGRATED ASSESSMENT PROCESS

1.5.1 Contributors and participants

The preparation of the final IA, or second phase, has involved an iterative process among various groups and individuals as framed in Figure 1.5.

1.5.1.1 Integration Team

The Integration Team has been led by the U-M's Graham Institute and includes the U-M's Energy Institute, Risk Science Center, and Erb Institute. This team was charged with:

- Identifying U-M researchers to serve on the Report Team,
- Identifying experts to serve as peer review panelists,
- Coordinating Advisory Committee input and broader stakeholder engagement,
- Working with the Report Team to ensure the final IA products meet established guidelines and address significant comments received from the review panel, and
- Making final editorial decisions regarding IA content.

The Integration Team members are:

- Maggie Allan, Integrated Assessment Program Specialist, U-M Graham Sustainability Institute;
- Mark Barteau, Director, U-M Energy Institute;

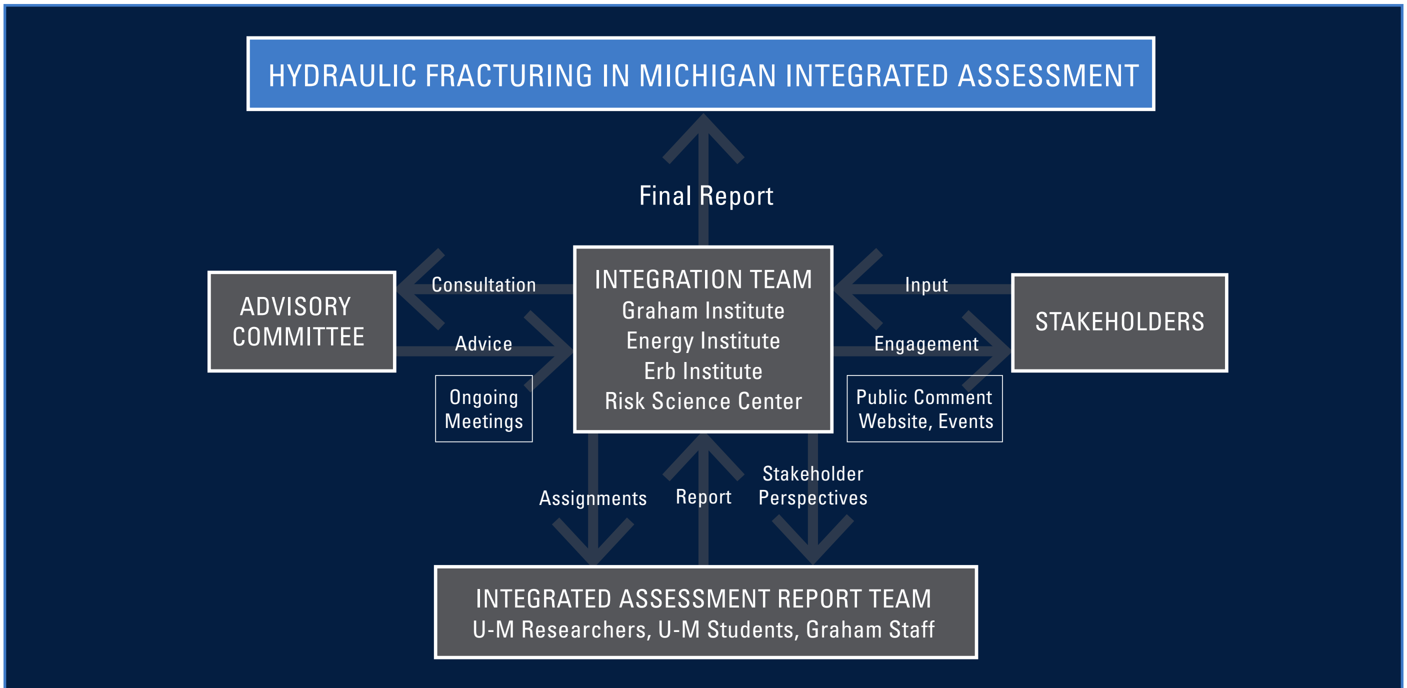

FIGURE 1.5: IA process

- John Callewaert, Integrated Assessment Center Director, U-M Graham Sustainability Institute;
- Andy Hoffman, Director, U-M Erb Institute for Global Sustainable Enterprise;
- Drew Horning, Deputy Director, U-M Graham Sustainability Institute;
- Andrew Maynard, Director, U-M Risk Science Center;
- Don Scavia, Director, U-M Graham Sustainability Institute; and
- Tracy Swinburn, Managing Director, U-M Risk Science Center.

1.5.1.2 Report Team

The Report Team consists of the following U-M researchers, listed below with their U-M unit affiliation and area of expertise.

Fully Engaged Members

- Diana Bowman, School of Public Health; Risk Science Center and Department of Health Management and Policy, *Risk science & health policy*
- Sara Gosman, Law School (now at the University of Arkansas), *Law*
- Shaw Lacy, Graham Sustainability Institute (now at the Pontificia Universidad Católica de Chile), *Environment/water*
- Ryan Lewis, School of Public Health; Department of Environmental Health Sciences (now in private consulting), *Environmental health*
- Kim Wolske, School of Natural Resources and Environment and the Ross School of Business; Erb Institute, *Risk communication & engagement*

Consulting Members

- Brian Ellis, College of Engineering; Department of Civil and Environmental Engineering, *Geology*
- Ryan Kellogg, College of Literature, Science, and the Arts; Department of Economics, *Economics*
- Eric Kort, College of Engineering; Department of Atmospheric, Oceanic and Space Sciences, *Atmospheric science*
- John Meeker, School of Public Health; Department of Environmental Health Sciences, *Environmental health*
- Johannes Schwank, College of Engineering; Department of Chemical Engineering, *Chemical engineering*

Fully engaged members are responsible for preparing major sections of the IA report and consulting members have contributed by reviewing and providing comments on report materials.

This team has:
- Received funding from the Graham Institute commensurate with their level of engagement to carry out the analysis;
- Collaborated with other Report Team members to identify common themes, strategies, and policies; and
- Sought consensus on the report and followed a process whereby if consensus cannot be reached on any issue, it will be brought to the Integration Team who may seek additional outside expertise. If the Integration Team could not reach consensus, then the Graham Institute made final editorial decisions.

The Report Team has been supported by numerous students and Graham Institute staff members throughout the entire process. Below is a list of students and staff who contributed to the project:

Mark Bradley	Marie Perkins
Kevin Chung	Kathleen Presley
Meredith Cote	Scott Robinson
Michelle Getchell	Susie Shutts
Mary Hirt	Joshua Sims
Manja Holland	Lukas Strickland
Boyu Jang	Alison Toivola
Drake Johnson	Sarah Wightman
Casey McFeely	Tianshu Zhang
Daniel Mitler	William Zhang

1.5.1.3 Advisory Committee

The following committee was assembled to advise project efforts:

- Valerie Brader, Senior Policy Advisor, Governor's Office of Strategic Policy, State of Michigan;
- James Clift, Policy Director, Michigan Environmental Council;
- John DeVries, Attorney, Mika Meyers Beckett & Jones; Michigan Oil and Gas Association;
- Hal Fitch, Director of Oil, Gas, and Minerals, Michigan Department of Environmental Quality;
- Gregory Fogle, Owner, Old Mission Energy; Michigan Oil and Gas Association;
- James Goodheart, Senior Policy Advisor, Michigan Department of Environmental Quality;
- Tammy Newcomb, Senior Water Policy Advisor, Michigan Department of Natural Resources;
- Grenetta Thomassey, Program Director, Tip of the Mitt Watershed Council; and
- John Wilson, President, TMGEnergy, LLC.

The Advisory Committee's role has been to provide advice reflecting the views of key stakeholder groups and input on the relevance of the IA scope for decision makers. Committee members have also provided data and input to the Report and Integration Teams throughout the process, including feedback on the policy topics, analytical approach, and format of the IA report. Over the course of the project the Advisory Committee met roughly twice per year with the Report and Integration teams. In addition, the committee received copies of the IA report and members were invited to provide input at three separate stages—prior to public release of the draft, during the public release of the draft, and prior to the preparation of the final version of the report. Key points of exchange during this process included the accurate description of current regulatory efforts, the appropriate tone and language for the report given a wide audience, the range of policy options, methods used to evaluate the strengths and weaknesses of proposed policy options in light of knowledge gaps regarding the risks or relative risks of the many aspects of the HF process, and the characterization of activity as relevant to all oil and gas development, hydraulic fracturing or high volume hydraulic fracturing. While the input from the Advisory Committee has been critically important to the development of the IA report, it is important to note that the report does not necessarily reflect the views of the Advisory Committee and there may be significant disagreement on particular sections of the report. As with preparation of the technical reports, all decisions regarding content of final IA report were determined by the IA Report and Integration Teams.

1.5.1.4 Stakeholders

Stakeholder input is an important part of any IA and has been a key component of this assessment. Key points of stakeholder engagement have included the following:

- An online comments/ideas submission webpage (http://graham.umich.edu/knowledge/ia/hydraulic-fracturing/comment) was established in the fall of 2012 at the start of the project to direct public input to the teams working on the IA, and it will remain open until the IA concludes in the fall of 2015. At this time, a contacts database for the project includes more than 1,000 individuals from primarily Michigan, but also other states and Canada, and from a variety of sectors: state government, nonprofit organizations, business associations and industry, federal agencies, academia, consulting firms, and the general public.
- During the preparation of the technical reports, the Graham Institute convened a meeting in Lansing, Michigan on March 5, 2013, to present research plans to nearly 100 decision makers and stakeholders.
- A public webinar was held on September 6, 2013 following the release of the technical reports.
- More than 200 comments were received following the release of the technical reports. They were carefully reviewed, organized, and shared with the technical report authors, Integration Team, Report Team, and Advisory Committee to aid in developing the IA plan.
- A public webinar was held on February 26, 2015 following the release of the draft IA report.
- Public comments on the draft IA report were collected through a publicly available web-based form and through direct solicitation of experts who represent a balanced mix of sectors with significant expertise and interest on the topic (e.g., industry affiliates, environmental organizations, academics, policymakers). As with the technical reports, these comments were carefully reviewed, organized, and shared with the technical report authors, Integration Team, Report Team, and Advisory Committee to aid in finalizing the IA report. A summary of these comments is included as an appendix to this report.
- Summaries and recordings of public events can be found at: http://graham.umich.edu/knowledge/ia/hydraulic-fracturing.

1.5.1.5 Review Panel

To ensure a rigorous, scientific analysis of the topic, the Integration Team identified subject area experts representing multiple disciplines to serve on a peer review panel. A preliminary list of potential participants was shared with the Advisory Committee for input. The Integration Team then extended invitations to participants and identified six individuals to serve on the review panel. As technical experts on the subject, reviewers evaluated the scientific credibility, rigor, and integrity of the assessment. Panelists received the draft IA report and a summary of the public and directly-solicited comments. After preparing individual reviews, panelists met in person to discuss their reviews and the draft IA report. The panel then prov`ided a single, final written review of the draft IA. Reviewers were reimbursed for travel expenses by the Graham Institute and received a modest honorarium for their time. As with input from the Advisory Committee and public comments, the Report Team worked with input provided by the review panel to prepare the final IA report. The review panel summary and responses from the Report Team can be found in an appendix to this report.

1.5.2 Funding

The project was entirely funded by the University of Michigan. The project cost approximately $600,000 with support coming from U-M's Graham Institute, Energy Institute and Risk Science Center. Funding sources were limited to the U-M General Fund and gift funds, all of which are governed solely by the University of Michigan

1.5.3 Ensuring a rigorous, scientific analysis

It was imperative that no aspect of the Integrated Assessment process be compromised by real or apparent conflicts of interest. For this initiative, the term "conflict of interest" means any financial or other interest that conflicts with the service of the individual because it (1) could significantly impair the individual's objectivity or (2) could create an unfair competitive advantage for any person or organization. Therefore, all Technical Report authors, IA Report and Integration Team members, and peer reviewers completed conflict of interest forms (adapted from National Academy of Sciences materials) indicating they have no conflicts (financial or otherwise) related to their contributions to this initiative. Advisory Committee members were not asked to complete conflict of interest forms as they served in an advisory capacity and did not receive compensation for their contributions.

ENDNOTES

1 Ground Water Protection Council (Oklahoma City, OK); ALL Consulting (Tulsa, OK).Modern Shale Gas Development in the United States: A Primer. [place unknown]: U.S. Department of Energy Office of Fossil Energy and National Energy Technology Laboratory; 2009 [accessed 2014 Sep 30]. Contract No.: DE-FG26-04NT15455. http://www.eogresources.com/responsibility/doeModernShaleGasDevelopment.pdf.

2 Michigan Department of Environmental Quality, Supervisor of Wells Instruction 1-2011 (2011), *available at* http://www.michigan.gov/documents/deq/SI_1-2011_353936_7.pdf (effective June 22, 2011). Michigan.

3 The new rules provide the following definition of high volume hydraulic fracturing: "High volume hydraulic fracturing" means a hydraulic fracturing well completion operation that is intended to use a total volume of more than 100,000 gallons of primary carrier fluid. If the primary carrier fluid consists of a base fluid with 2 or more components, the volume shall be calculated by adding the volumes of the components. If 1 or more of the components is a gas at prevailing temperatures and pressures, the volume of that component or components shall be calculated in the liquid phase. Mich. Admin. Code r.324.1402.

4 Canadian Association of Petroleum Producers. Conventional & Unconventional. [place unknown]: Canadian Association of Petroleum Producers; c2015 [accessed 2015 Feb 10]. http://www.capp.ca/CANADAINDUSTRY/NATURALGAS/CONVENTIONAL-UNCONVENTIONAL/Pages/default.aspx.

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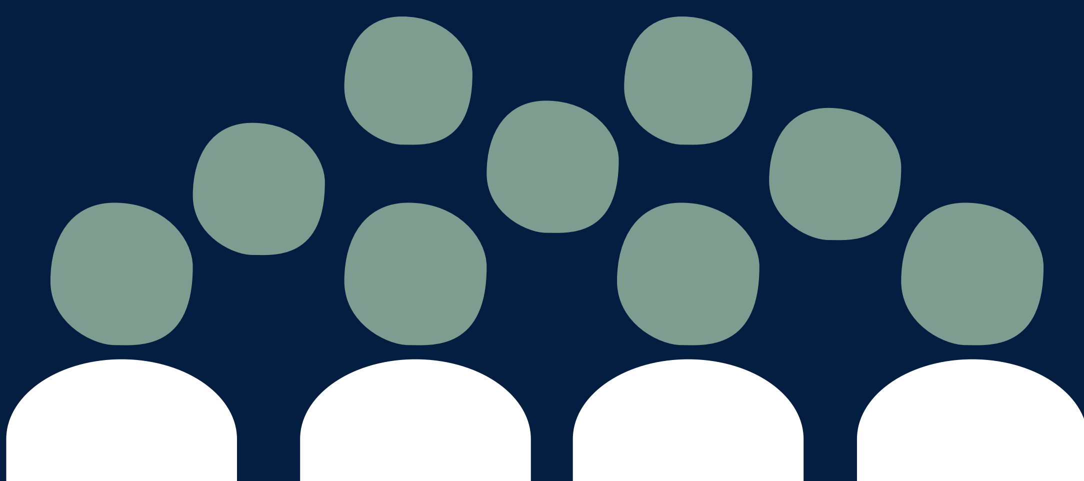

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Chapter 2

2.1 INTRODUCTION

Unconventional shale gas development through high volume hydraulic fracturing (HVHF) has garnered considerable controversy in much of the United States. While some praise HVHF for enabling development of previously inaccessible resources and bringing economic benefits, others decry it for its potential to negatively impact local communities. Common concerns include that the chemicals used in HVHF pose unacceptable risks to human health and the environment. Many also worry about potential impacts on quality of life, including road damage from truck traffic, increased noise pollution, and changes to the aesthetic character of affected communities. In addition to these concerns, deep shale gas development raises questions about the trajectory of future energy development and its implications for climate change. Some see shale gas as an important "bridge fuel" that will decrease reliance on more carbon-intensive coal; others argue that increased investment in shale gas extraction will shift focus away from cleaner sources of energy such as solar or wind.

These tensions about the costs and benefits of deep shale gas are echoed in Michigan. A 2012 public opinion poll found, for example, that while a slight majority (52%) of respondents believes the benefits of "fracking" will outweigh its risks, significant concerns remain about its potential impacts on water quality and human health.[1] Furthermore, thirty-six percent (36%) of respondents strongly agreed and sixteen percent (16%) somewhat agreed that Michigan should impose a moratorium on "fracking" until its potential risks are better known. Various nonprofit and grassroots organizations throughout the state have expressed similar concerns about the uncertainties of HVHF. Meanwhile, state agencies and industry groups contend that HVHF is safe.[2]

Given these different and often conflicting viewpoints, regulating HVHF and related activities in a manner that is socially acceptable can be challenging. Similar dilemmas have been provoked by technologies such as nuclear power plants and hazardous waste facilities. In these settings, a large body of research has argued that to arrive at sound public policies that reflect democratic decision making and address stakeholder concerns, the public must have a significant participatory role.[3–7]

There are numerous ways in which the public could inform deep shale gas development. These might include sharing knowledge about local conditions, identifying key concerns and risks, and helping decision makers prioritize needed regulations. How the public weighs in on these issues can take many forms. In the context of public policy, public participation is often construed as public comment periods and hearings, where the public might be described as having a consultative role.[8,9] 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,[10–12]
2. Be legitimate and perceived as fair,[13,14]
3. Reduce conflict and build trust in institutions,[15]
4. Lead to a shared understanding of the issues,[16] and
5. Improve the capacity of all parties to engage in policy-making.[17–20]

The extent to which these goals are achieved depends on a number of factors including the nature of the issue, the participatory processes used, and the group dynamics of involved stakeholders.[21,22] For issues where stakeholders are in agreement about what should be done, it may be sufficient to keep the public informed through educational websites and press releases.[23] But for controversial issues, such as HVHF, where stakeholders disagree about the issue or misunderstand each other's perspective, more interactive forms of public participation are generally needed.[24] In these contexts, research has shown that participation is more likely to lead to desirable outcomes when people are invited to the decision making process early and often, when the goals and expectations of a participation process are made clear upfront, and when the viewpoints of participants are considered in the final decision.[25] Public participation tends to be less successful when stakeholders are invited to the table late in the process, when the mechanisms for inviting public input are insufficient, or when people are put in a position of having to react to a near-final plan.

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. For example, the National Research Council, which serves as the working arm of the National Academy of Sciences, hosted two workshops in 2013 to examine risk management and governance issues in shale gas development.[26] One of the papers to emerge from this workshop argues that public participation efforts must go beyond simply informing the public about HVHF or allowing them to submit comments on proposed activities; instead, stakeholders should be engaged in analytic-deliberative processes where they have the opportunity to "observe, learn, and comment in an iterative process of analysis and deliberation on policy alternatives."[27] As the authors note, however, the existing policy process in the U.S. makes implementing this recommendation challenging.

The oil and gas industry is also paying more attention to the role of public engagement in its operations. The American Petroleum Institute (API), for example, recently released community engagement guidelines that outline how operators can "responsibly develop" oil and gas resources while considering community concerns.[28] These guidelines describe principles for how well operators should interact with a community as well as a recommended process for engaging stakeholders through each phase of an oil and gas project. Notably, one of the key principles for operating responsibly is to communicate effectively through a "two-way process of giving and receiving information."[29] The API Community Engagement Guidelines (page 2) suggest that effective communication may involve practices such as:

- "Promot[ing] education, awareness and learning" during each phase of an oil and gas project;
- "Provid[ing] clear information to all stakeholders… in addressing challenges and issues that can impact them;"
- "Provid[ing] structured forums for dialogue, planning, and implementation of projects and programs affecting the greater regional area;"
- "Establish[ing] a process to collect, assess, and manage issues of concerned stakeholders;" and
- "Design[ing] and carry[ing] out a communication strategy that addresses the community, cultural, economic, and environmental context where a project occurs, and that considers the norms, values, and beliefs of local stakeholders, and the way in which they live and interact with each other."[30]

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, even though the impacts of HVHF well development may extend beyond the well site. As discussed in the Public Perceptions Technical Report, relying on these one-way forms of communication where the public is, at best, consulted but unable to engage in genuine discussions about HVHF can contribute to feelings that the public's voice does not matter or that HVHF is being involuntarily imposed. These feelings may, in turn, further perpetuate controversy surrounding HVHF and hinder efforts to arrive at publicly-acceptable policies.

The remainder of this chapter examines options for improving how public values and concerns are incorporated into HVHF-related policy. The first section explores this question broadly by looking at how public values inform unconventional shale gas policies, in general, and by examining what opportunities exist for improvement. The remaining two sections explore how public interests are represented in state mineral rights leasing decisions and well permitting. We have focused on these two activities as both affect a question of primary importance to the public: where will HVHF occur.

For each of the above topics (i.e., HVHF policy in general, state mineral rights leasing, and well-permitting), we begin by providing a high-level summary of how various states have approached public engagement in the issue. We then describe and analyze a set of policy options that the State of Michigan might consider to incorporate public values into HVHF policy—including the option to keep Michigan's existing policy. For each option, we briefly describe the proposed policy and then examine its strengths and weaknesses in terms of potential environmental, economic, health, community, and governance impacts.

How the public is involved in other, more specific aspects of an HVHF operation, such as water and chemical use, are examined in-depth in other chapters of the report.

2.2 INCORPORATING PUBLIC VALUES IN HVHF-RELATED POLICIES AND DECISION MAKING

2.2.1 Introduction

Historically, the public has had few opportunities to significantly influence oil and gas policy in the U.S. Given the potential risks associated with HVHF well development to human health and the environment, many have questioned not only whether existing regulations are adequate, but also whether the public has been sufficiently involved in deciding the future of this practice.[31,32] As the following sections illustrate, the degree to which the public is able to influence HVHF-related policies varies widely across the U.S.: some states offer few to no opportunities for public input while others make a concerted effort to give the public a voice in setting future deep shale gas policy.

2.2.2 Range of approaches

2.2.2.1 Treat HVHF as a variant of other oil and gas activities

Most states, including Michigan, have dealt with HVHF by treating it as a variant of other oil and gas activities. Under these circumstances, rules or instructions may be issued regarding chemical disclosure and the physical aspects of HVHF (e.g., well spacing and setbacks) but the public is typically not afforded a meaningful opportunity to weigh in on whether or how unconventional deep shale gas development should occur. In such cases, the public's ability to influence HVHF well development is limited to whatever public participation mechanisms are built into the state's existing oil and gas regulations. In the majority of states, this means the public has limited opportunity to learn of proposed HVHF wells or to voice concerns about their development. Notice of well permit applications is typically limited to surface owners of the well site (e.g., Arkansas,[33] Oklahoma,[34] and Texas[35]) and in some states, owners of nearby property (e.g., Illinois,[36] New Mexico,[37] North Dakota,[38] Ohio,[39] and proposed in Alaska[40]). Only a few states mandate that the public be allowed to comment on permit applications (e.g., Colorado,[41] Illinois[42], proposed in Maryland[43]). In Michigan, the Department of Environmental Quality (DEQ) informally accepts comments on permit applications through its website, but there is no formal public notice of this opportunity. Some states allow adversely affected parties to contest approved permits (e.g., North Dakota[44]) or to request a public hearing before permits are approved (e.g., Illinois,[45] and proposed in Maryland[46]). In Michigan, interested parties who allege that "waste is taking place or is reasonably imminent" can petition for a hearing.[47] The DEQ interprets this to mean that interested parties can petition for a hearing at any time during the permit application process. Finally, if new HVHF-specific rules are promulgated, most states allow the public to submit comments on the rules or to testify in public hearings.

2.2.2.2 Public information

In states where HVHF is treated as an extension of other oil and gas practices, efforts to "engage" the public often focus on educating and informing the public about HVHF. Evidence of this can be seen in many of the reviews conducted on state oil and gas programs (e.g., Arkansas[48] and Oklahoma[49]) conducted by the State Review of Oil & Natural Gas Environmental Regulations (STRONGER). These public outreach efforts might include posting notice of proposed state mineral auctions and well permit applications on agency websites or presenting educational information about HVHF online and at informal public meetings. While providing this type of information is important for creating transparency about HVHF-related activities, this strategy, by itself, has been criticized for promoting an expert-knows-best model of decision making that ignores democratic ideals. Research has shown that for controversial issues such as HVHF, attempts to assuage public concerns through education and information alone can backfire and lead to further polarization of the issue (for more discussion on this topic, please see section 3.3 of the Public Perceptions Technical Report[50]).

2.2.2.3 Development moratoria and state-wide studies of HVHF

In response to public concerns, bills have been introduced in several states (including Michigan, North Carolina, New Jersey, New York, Ohio, and Pennsylvania), to impose a moratorium on HVHF.[51–54] Typically, the intention of the moratorium is to allow a development "time out" so that the state can gather more information about potential environmental, health, and economic impacts; devise HVHF-specific regulations; or generally postpone HVHF until its risks and long-term impacts are better known. North Carolina passed such a bill in 2012. The Clean Energy and Economic Security Act placed a moratorium on hydraulic fracturing (HF) permits until appropriate HF-specific regulations were in place.[55] This moratorium was lifted in June 2014.

In New York, a de facto moratorium on HVHF permitting has been in place since 2008, when

Governor David Paterson ordered the Department of Environmental Conservation to revise the 1992 Generic Environmental Impact Statement (GEIS) to account for HVHF impacts.[56,57] As part of this revision, the New York State Department of Health (DOH) was asked to review the potential health impacts of HVHF. The DOH's report, released in December 2014, recommended that HVHF should not proceed in New York until there is sufficient scientific information to determine the level of risk that HVHF poses to public health.[58] Governor Andrew Cuomo's administration subsequently announced a ban on HF, and the Department of Environmental Conservation issued a legally binding statement to prohibit HVHF in June 2015.[59]

2.2.2.4 Multi-stakeholder advisory boards and regulatory bodies

Given the possibility that HVHF might have far reaching impacts on human health, the environment, and the local economy, a few states have created multi-stakeholder advisory groups to review oil and gas policy and to determine whether changes are needed to prevent and/or manage potential impacts. For example, in Maryland, a special Advisory Commission was created as part of the Marcellus Shale Safe Drilling Initiative.[60] This initiative charged the Department of the Environment and the Department of Natural Resources, in consultation with the Advisory Commission, to conduct a study on "the short-term, long-term, and cumulative effects of natural gas exploration and production in the Marcellus shale," and to identify best practices to mitigate those risks. By executive order, the Advisory Commission included an expert on geology or natural gas production from a college or university, one representative from an oil and gas company, one from an environmental organization, and four representatives from communities in the Marcellus shale region, including a private citizen, a representative from the business community, and two representatives from local governments.

In Colorado, the composition of the Colorado Oil and Gas Conservation Commission (COGCC), the body that regulates oil and gas drilling and production, was reconfigured to better represent public interests in the state.[61] Formerly composed of seven members, the COGCC was expanded to nine, with two additional seats given to the directors of the Department of Natural Resources and the Department of Public Health and Environment. In addition, the composition of the remaining seven seats was altered, such that the number of seats for oil and gas industry representatives was reduced from five to three. By mandate, COGCC must also include a local government official, a member with expertise in environmental or wildlife protections, a member with expertise in soil conservation or reclamation, and a member actively engaged in agricultural production who is also a royalty owner. Furthermore, the bill stipulates that excluding the directors of the Department of Natural Resources and the Department of Public Health and Environment, the remaining seven members shall be appointed by the governor and no more than four members can be from the same political party.

2.2.2.5 State-wide studies of HVHF impacts and best management practices

As previously mentioned, a few states such as New York and Maryland have conducted studies to better understand the impacts of HVHF. In Maryland, the Marcellus Shale Safe Drilling Initiative also identified best management practices to minimize impacts and to establish standards of liability. In both states, the public was invited to review and comment on the study's findings. New York also held public hearings during the comment period,[62] and both states prepared "responsiveness summaries," which provided the public a written summary of significant comments received along with the agency's response to each issue.[63,64]

2.2.2.6 Town halls and public workshops to solicit public input

Some states and local municipalities have engaged the public in more deliberative discussions about HVHF. For example, after its reconfiguration, the COGCC traveled the state for nine months to conduct public meetings and facilitate stakeholder work groups in communities with large oil and gas plays.[65,66] Information gathered from these public forums was used to inform COGCC's draft rules for HVHF. Similarly in California, the Division of Oil, Gas, and Geothermal Resources (DOGGR) conducted multiple stakeholder workshops to discuss "pre-draft" versions of proposed regulations, before the formal rulemaking process was initiated. These full-day, moderated meetings involved very brief presentations about HVHF regulatory issues, with the majority of time dedicated to public questions, suggestions and discussion.[67–69]

2.2.3 Analysis of policy options

The following subsections examine policy options for incorporating public values and concerns into HVHF-related policies. These include:

- 2.2.3.1 Keep existing Michigan policy for public engagement
- 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 state and local-level 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

These policy options can be used individually or in combination. Policies that address public concerns about water resources and chemical use in HVHF are discussed in Chapter 3 and 4 respectively.

2.2.3.1 Keep existing Michigan policy

In Michigan, there are few mechanisms for incorporating public values into HVHF-related policies or for addressing their questions and concerns. The rules governing public participation around HVHF well development are the same as for other types of oil and gas activities. As will be discussed in later sections of this chapter, the public can submit comments on state mineral rights auctions, but opportunities to influence well permitting decisions are few. The public's greatest opportunity to influence HVHF-related activities is during rule promulgation. Under the Michigan Administrative Procedures Act, the public can submit comments on proposed rules and provide testimony at public hearings.[70] This process recently occurred in response to proposed rules concerning HVHF permitting.

Other efforts to engage the public are focused on informing or educating residents about HVHF. This occurs primarily through the DEQ website as well as presentations at public meetings and outreach events. In 2013 the DEQ held three public meetings on HF. DEQ staff have also participated on over 200 public engagement events on HF (H. Fitch, DEQ, personal communication, January 30, 2015).

The DEQ website provides users very basic information about HVHF, including notice of permit applications, a map of HVHF wells, information about the regulations that govern it, and a broad overview of how HVHF compares to other oil and gas activities. As discussed in the Public Perceptions Technical Report, the site is neither intuitive to navigate nor particularly responsive to public concerns. In both online materials and public forums, the DEQ appears to focus on persuading the public that "fracking" is safe. A commonly cited statistic, for example, is that Michigan has successfully regulated "fracking" for over 60 years and that over 12,000 wells have been safely fracked; there is no acknowledgement that that safety record is predominantly about conventional low-volume HF. Other materials similarly blur the distinctions between HVHF and low-volume HF. See sections 2.3.3 and 3.1 of the Public Perceptions Technical Report for a more detailed discussion of DEQ communications.[71]

Finally, public interests are also represented, to a limited extent, on Michigan's Oil and Gas Advisory Committee. This committee, which meets four times a year, advises the DEQ on matters related to oil and gas policy and procedures. Appointed by the Director of the DEQ, the committee is comprised of eight members, only two of which represent the public sector. The remaining six are from the oil and gas industry.[72]

2.2.3.1: KEEP EXISTING MICHIGAN POLICY FOR PUBLIC ENGAGEMENT		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Policy may be more protective of state lands than in other states (e.g., CO, NM, and TX), where the public cannot comment on proposed state mineral leases.	May lead to poorer environmental outcomes: • Important environmental considerations may be overlooked as current policy offers few opportunities to solicit local knowledge or expert opinions • Development may occur in piecemeal fashion without consideration of how HVHF is affecting larger landscape
ECONOMIC	Mineral rights owners, oil and gas companies, and the state may benefit from faster development of resource.	May negatively impact other industries (e.g., agriculture, tourism) if development occurs rapidly without much public deliberation
HEALTH		May lead to poorer health outcomes • Important health considerations may be overlooked as there are few opportunities to solicit local knowledge or expert opinions. • No public health experts sit on the Oil and Gas Advisory Committee. May contribute to stress and anxiety in impacted communities • When excluded from decision making, the public may feel HVHF has been involuntarily imposed. This may contribute to psychological distress for individuals in affected areas as well as create more anger and concern about HVHF. (See Public Perceptions Technical Report[73])
COMMUNITY		May lead to worse outcomes for impacted communities • May result in undesirable impacts that could have been lessened or avoided if the public had been involved (e.g., in the siting of well pads, the routing of truck traffic, etc.)
GOVERNANCE	May be easier to implement and have lower administrative costs than alternatives	May not address potential inequities in resource development • Neighboring landowners and community members may bear the risks and potential impacts of HVHF without any of the benefits. • Public may feel DNR and DEQ are not as transparent as they could be. • Limited public notice and reliance on one-way forms of communication may create the perception that information about HVHF-related activities is being withheld. May make it difficult for MI residents to become adequately informed about HVHF-related issues May increase distrust of DEQ • DEQ statements that fail to differentiate HVHF from HF may decrease trust in DEQ (e.g., statements that Michigan has safely "fracked" for over 60 years, when HVHF is relatively new). • DEQ and members of the public use the term "fracking" differently. This discrepancy can result in materials (such as the FAQ sheet online) that fail to fully acknowledge the public's concerns about deep shale gas development. Claims, for example, that "fracking" has not led to any environmental damage can seem misleading when the public can observe obvious physical changes to the landscape as a result of natural gas development through HVHF. Limited opportunities for participation may contribute to feelings that HVHF is involuntarily imposed. • Current processes may reduce legitimacy of decision making. • There are no formal provisions to guarantee that public input and values are considered in decision making.

2.2.3.2: REVISE THE DEQ WEBSITE TO IMPROVE TRANSPARENCY AND USABILITY		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL		Does not provide an opportunity for the public to inform decision making about potential environmental impacts
ECONOMIC		State may incur costs to revise site and have it reviewed.
HEALTH		Does not provide an opportunity for the public to inform decision making about potential health impacts
COMMUNITY	Public may be better informed to make decisions about leasing their own land.	Does not provide an opportunity for the public to inform decision making about potential community impacts
GOVERNANCE	May increase perceived transparency of DEQ if information is easier to access and addresses public's questions May increase trust in DEQ, especially if site is reviewed by a neutral third-party and/or if the public is invited to provide feedback on the site's content and design Public may be better informed when given other opportunities to weigh in on shale gas policy.	This option, by itself, is unlikely to fully address public concerns as it does not provide a meaningful way for the public to weigh in on HVHF-related activities.

In summary, Michigan, like many other states, primarily engages the public on HVHF by providing information on state agency websites and through public presentations. Opportunities for the public to influence HVHF-related decision making or policy are somewhat limited. Current regulations allow residents to submit comments on proposed state mineral rights leases and if new oil and gas rules are being promulgated. Comments are also informally invited on well permit applications, but there is no formal public notice of this opportunity. Given the controversial nature of HVHF and the uncertainty of its long-term impacts, this approach to public participation may have unintended negative consequences. In the short term, limiting the public's involvement in HVHF-related decision making may contribute to feelings that unconventional deep shale gas development is being involuntarily imposed and, thus, lead to greater distrust of state agencies. In the long term, leaving the public out of HVHF-related decision making may result in decisions that inadequately account for local conditions and cultural values.

2.2.3.2 Revise the DEQ website to improve transparency and usability

Currently, the DEQ website does not offer Michigan residents a user-friendly way to find answers to questions they may have about HVHF-related activities in the state. As a consequence, people may perceive that the DEQ is not being transparent about HVHF-related practices in the state. The current website may also lead residents to turn to other unofficial sources of information, some of which may be inaccurate for Michigan. A first step toward improving transparency about HVHF would be to restructure the DEQ website to improve navigability. For example, the website for Ohio's Division of Oil and Gas Resources,[74] organizes information based on the type of user (e.g., industry, citizens, and local governments). The Ohio site also explains oil and gas regulations using lay language in an easy to follow FAQ format.[75]

Besides improving navigation, informational content on the DEQ site could be revised to better address concerns raised by different stakeholder groups and to more clearly differentiate HVHF from low-volume HF. Revised content might include more detailed information about the potential impacts of activities related to HVHF on human health, water supplies, and the environment. The information could also more thoroughly explain why some perceived risks are unlikely and provide links to reputable references and resources where individuals can learn more. The "Visitor FAQS" page of Exploreshale.org, a public service site created by Penn State Public Broadcasting, provides an example of how common questions could be better addressed. The DEQ website could expand upon this approach by also providing an online forum where visitors can submit comments and questions about HVHF.

Finally, this policy option could require that the website undergo user testing and review by a neutral third party to ensure that it remains unbiased in its content and meets the public's needs.

If perceived to be user-friendly and credible, a revised website may help improve transparency about HVHF-related activities as well as potentially increase the public's trust in the DEQ. However, as a website remains a one-way form of communication, this policy—if implemented alone, without other, more participatory forums—is unlikely to fully address stakeholder concerns. To be more effective, this option could be combined with other mechanisms that enable stakeholders to provide direct input on HVHF policies (see e.g., Option 2.2.3.4).

2.2.3.3 Require risk communication training for DEQ and DNR employees

This policy option would require risk communication training for DEQ employees in the Office of Oil, Gas, and Minerals, as well as DNR employees who manage state mineral rights leasing programs. The National Research Council defines risk communication as an interactive process that facilitates the:

"exchange of information and opinion among individuals, groups, and institutions… [R]isk communication is successful only to the extent that it raises the level of understanding of relevant issues or actions and satisfies those involved that they are adequately informed within the limits of available knowledge."[76]

The intent of this policy option would be to improve agency communication and listening skills in order to increase transparency about HVHF and better respond to stakeholder concerns about HVHF-related activities. The U.S. Environmental Protection Agency (EPA) defines seven cardinal rules of risk communication:[77]

1. Accept and involve the public as a legitimate partner.
2. Plan carefully and evaluate your efforts.
3. Listen to the public's specific concern.
4. Be honest, frank, and open.
5. Coordinate and collaborate with other credible sources.
6. Meet the needs of the media.
7. Speak clearly and with compassion.

An underlying theme of these rules is that the public's concerns and perceptions of risk are important and should not be dismissed—even if they conflict with technical assessments of risk.

If staff members approach risk communication with an earnest desire to understand stakeholder values and perspectives, this option has the

2.2.3.3: REQUIRE RISK COMMUNICATION TRAINING FOR DEQ AND DNR EMPLOYEES		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May lead to better environmental outcomes • Agency staff may be more responsive to the public's concerns about particular ecological impacts.	
ECONOMIC		DEQ and DNR may incur costs to implement this option.
HEALTH	May reduce stress among certain groups • When individuals feel they can trust agency staff and that their concerns have been acknowledged, they may experience less anxiety about HVHF. • Agency staff may be more responsive to the public's concerns about potential health impacts.	
COMMUNITY	May reduce community impacts • Agency staff may be more responsive to the public's concerns about particular localized impacts.	
GOVERNANCE	May increase trust in DEQ and DNR • When members of the public feel they have been listened to and treated fairly, they are more likely trust the institutions involved.[78] May increase legitimacy of decisions by helping DEQ and DNR better incorporate public input into their decision making Public may be better informed to weigh in on HVHF-related policies.	Success of this option will vary with the quality of the training. Even with high quality training, effective risk communication may remain challenging given the multitude of stakeholder groups, each with different priorities and values.

potential to have far reaching effects. By learning how to better acknowledge and address public concerns, agency staff may be better equipped to engage the public in productive conversations about HVHF. This may be beneficial, for example, when DEQ and DNR staff participate in public meetings, give public presentations, or write content for agency websites.

2.2.3.4 Conduct public workshops to engage Michigan residents in state and local-level HVHF decision making

Under this option, the state could conduct a series of interactive workshops with the public. Beyond answering questions about HVHF, the purpose of these workshops would be to involve the public in defining the key risks of concern with HVHF as well as policy options that could be used to mitigate them. For these workshops to be successful, it is important that they be led by skilled facilitators trained in risk communication and public participation techniques.[79,80]

As described in the Public Perceptions Technical Report,[83] state and industry technical risk assessments are unlikely to account for all of the risks that the public associates with HVHF and unconventional shale gas development. Moderated workshops would offer a means for the public to ask questions, raise concerns, and engage in two-way discussions with state agency representatives. These interactive discussions may help stakeholders move past disagreements about, for example, the safety of HVHF, toward identifying priority issues that HVHF-related policies should address. The success of these workshops may depend on the skill of the facilitator(s) and the degree to which agency staff treat the public's concerns as important and legitimate (see Option 2.2.3.3).

2.2.3.5 Impose a state-wide moratorium on HVHF

To address public concerns about HVHF, the state could impose a moratorium on HVHF permitting. During the moratorium, the state could do one or more of the following:

1. Conduct studies on Michigan-specific HVHF impacts (see Option 2.2.3.7);
2. Identify best practices for mitigating HVHF impacts and devise additional HVHF-specific regulations to mitigate them (see Option 2.2.3.7); or
3. Engage Michigan residents in an analytical-deliberative process, so that public values may be more accurately accounted for in HVHF policy (see Option 2.2.3.4).

A statewide moratorium is supported by several municipalities[i] in the state[84] as well as nonprofit organizations such as Clean Water Action and the West Michigan Environmental Action Council.[85–87]

A moratorium, by itself, does not ensure that public values will be incorporated into HVHF-related policies, but this "time-out" from development would provide an opportunity to do so. Imposing a moratorium may also send a signal to the public that the state is taking their concerns seriously. While pausing development has the potential to ease tensions, it could also have the opposite effect and lead to further polarization of the issue.

2.2.3.6 Ban HVHF

To address public concerns about HVHF, Michigan could impose a ban on HVHF permitting. As with a moratorium, further study of HVHF's impacts could be conducted, and a ban could be reversed if science indicated minimum negative impacts and/or if public opinion shifted significantly in favor of HVHF. A statewide ban is supported by at least ten communities throughout the state, including Cross Village Township, Dearborn Heights,[90] Detroit,[91] Ferndale,[92] Heath Township, Ingham County,[93] Orangeville Township,[94] Thornapple Township,[95]Wayne County,[96] and Ypsilanti.[97] Several grassroots and nonprofit groups also support a HVHF ban (and HF in general), including Don't Frack Michigan,[98] Ban Michigan Fracking,[99] Committee to Ban Fracking in Michigan,[100] Friends of the Jordan River Watershed,[101] Friends of the Boyne River,[102] Michigan Citizens for Water Conservation,[103] Northern Michigan Environmental Action Council (NMEAC),[104] Food and Water Watch,[105] and the

[i] Ann Arbor, Atlas Township, Burleigh Township, Cannon Township, Courtland Township, Reno Township, Scio Township, and West Bloomfield Township. Another 11 communities have passed ordinances in support of a statewide ban.

2.2.3.4: CONDUCT PUBLIC WORKSHOPS TO ENGAGE MICHIGAN RESIDENTS IN STATE AND LOCAL-LEVEL HVHF DECISION MAKING		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Environmental impacts may be better accounted for in HVHF-related policies.	Some environmental concerns may not be adequately represented depending on who attends the meetings.
ECONOMIC		Economic cost to state to hold workshops and hire third-party moderators/facilitators
HEALTH	Health impacts may be better accounted for in HVHF-related policies.	Some health concerns may not be adequately represented depending on who attends the meetings.
COMMUNITY	Community impacts may be better accounted for in HVHF-related policies. May decrease stress and anxiety about HVHF for some stakeholders if workshops focus on issues of key concern to public.	Some community concerns may not be adequately represented depending on who attends the meetings.
GOVERNANCE	May increase trust in DEQ • When stakeholders feel they have been listened to and treated fairly, they are more likely trust the institutions involved[81,82] May increase perceived transparency of DEQ May increase perceived legitimacy of decisions May lead to higher-quality decisions and policies if public input is incorporated Public may be better informed to weigh in on future shale gas policies.	Organizing workshops and integrating learnings into DEQ policies will likely increase administrative burden. Hiring skilled facilitators will likely increase administrative costs. Workshops may not achieve intended outcomes depending on the group dynamics of attending participants.

Sierra Club Michigan Chapter.[106] A ban is opposed by the Michigan Chamber of Commerce[107] and oil and gas industry groups.

Banning HVHF provides a blanket solution for addressing concerns about the potential risks of unconventional shale gas development through HVHF. However, this option comes at the cost of reducing income to the mineral rights owners, industry, and the state by preventing development of the resource. A ban may also lead to other conflicts if mineral rights owners feel they are unfairly forced to give up potential income from their vested property rights.

2.2.3.7 Appoint a multi-stakeholder advisory commission to study HVHF impacts and identify best practices for mitigating them

Some of the public's concerns about HVHF-related activities arise from the uncertainty of their impacts. Following Maryland's lead, Michigan could undertake a multi-part study to further investigate the environmental, economic, and health risks of HVHF specific to Michigan.[110] This study could build off of the University of Michigan Integrated Assessment by doing a scientific risk assessment of HVHF and related well development activities, collecting data in regions likely to be impacted by HVHF, and making specific recommendations to address issues of greatest concern to Michigan. To balance stakeholder interests, the study could be led by an advisory commission comprised of experts in public health, ecology, economics, hydrogeology, and oil and gas production. House Bill 4901, sponsored by Representative Marcia Hovey-Wright in 2013 proposed a similar policy.[111] This process could be augmented by holding a series of public hearings to invite public comments on draft findings.

Encouraging further study of potential HVHF impacts in Michigan could help ensure that HVHF-related policies are adequately protective. At the same time, implementing this option may help demonstrate that the public's concerns have been heard. To promote greater involvement of the public, this option could be combined with Option 2.2.3.4 so that public workshops inform the advisory commission's recommendations. A similar process was used in 2013 when Governor Rick Snyder called for a one-year study of Michigan's energy future. A workgroup co-chaired by leaders of the Michigan Public Service Commission and the Michigan Energy Office conducted seven public forums to gather public input from around the state.

2.2.3.8 Increase stakeholder representation on Oil and Gas Advisory Committee

To help ensure that stakeholder interests are represented in oil and gas policy on an ongoing basis, the composition of Michigan's Oil and Gas Advisory Committee could be revised. Following the leads of other states, this could involve adding two seats to the eight-person committee as well as creating greater balance among stakeholder interests. For example, the number of seats held by the oil and gas industry could be reduced from six to three. The remaining seven seats could be allocated to a geology or oil and gas expert from a college or university, two representatives of different environmental organizations, a member with expertise in environmental or wildlife protection, a representative from the state's Department of Community Health (DCH), a public health expert from a college or university, and a representative from a local government in an area where HVHF is likely to occur. In addition, the responsibility for appointing committee members could be split among the directors of the DEQ, DNR, and DCH.

Overall, the strength of this option is that it increases the likelihood that a broad range of potential impacts—many of which are of concern to the public—will be considered on an on-going basis in HVHF-related policies. However, this option, alone, does not provide a mechanism for the public to directly influence decision making.

2.2.4 Summary of options for improving public involvement in HVHF-related policies

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 mineral rights 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 policies concerning unconventional shale gas development through HVHF. As a first step toward building the public's trust and signaling that public

2.2.3.5: IMPOSE A STATE-WIDE MORATORIUM ON HVHF		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Delays all known and unknown environmental impacts May provide time for protective policies to be put in place	May reduce the state's ability to acquire, develop, and maintain public recreational lands[88,89] (through loss of income to the Michigan Natural Resources Trust Fund and the Michigan State Parks Endowment Fund[ii])
ECONOMIC	Would avoid costs that may be incurred (e.g., from accidents, unknown health impacts, etc.) if deep shale gas development proceeds before its risks are fully known or adequate regulations are in place.	Will delay economic gains to state, industry, and mineral rights owners Industry may leave Michigan State may be subject to legal action as a result of taking property
HEALTH	Delays most known and unknown health impacts May provide time for protective policies to be put in place	May cause distress to mineral rights owners who anticipated income from mineral rights leases
COMMUNITY	Delays all known and unknown community impacts May provide time for protective policies to be put in place	Mineral rights owners may feel they are unfairly forced to sacrifice potential royalties May further polarize the issue as different stakeholder groups lobby either to continue or lift the moratorium
GOVERNANCE	May provide an opportunity for the public to influence unconventional shale gas policy before additional policy decisions are made or additional wells are fracked May lead to higher quality decisions if the moratorium is used to gather more information	May lead to pushback or lawsuits from industry and mineral rights owners If short and long-term impacts of HVHF are found to be minimal, reversing moratorium may require political momentum.

2.2.3.6: BAN HVHF		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Prevents all known and unknown environmental impacts of HVHF May encourage development of renewable energy industries	May reduce the state's ability to acquire, develop, and maintain public recreational lands[108,109] (through loss of income to the Michigan Natural Resources Trust Fund and the Michigan State Parks Endowment Fund)
ECONOMIC	Enables DNR and DEQ to dedicate limited staff resources to other activities under their jurisdictions	Prevents all economic gains from HVHF to State, industry and mineral rights owners Industry may leave Michigan. State may be subject to legal action as a result of taking property.
HEALTH	Prevents most known and unknown health impacts, including stress associated with HVHF operations that occur nearby	May cause distress to mineral rights owners who anticipated income from mineral rights leases
COMMUNITY	Prevents all known and unknown local impacts (e.g., changed landscapes, road damage, noise, odors, surface spills, etc.)	Mineral rights owners may feel they are unfairly forced to sacrifice potential royalties. May further polarize the issue as different stakeholder groups lobby to lift the ban
GOVERNANCE	May provide adequate time for study and analysis of HVHF's potential impacts Some segments of the public may feel that their concerns have been recognized	If short and long-term impacts of HVHF are found to be minimal, reversing ban may require political momentum. May lead to lawsuits from industry and mineral rights owners Does not directly involve the public in the decision making process, unless a ban is proposed through a legislative ballot initiative

[ii] MNRTF is funded through royalties from the sale and lease of State-owned mineral rights

2.2.3.7: APPOINT A MULTI-STAKEHOLDER ADVISORY COMMISSION TO STUDY HVHF IMPACTS AND IDENTIFY BEST PRACTICES FOR MITIGATING THEM		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Environmental impacts may be better accounted for in HVHF-related policies.	
ECONOMIC	Development of the resource continues while further study occurs, resulting in economic benefit to State, well operators and mineral rights owners.	State may incur cost to appoint commission.
HEALTH	Health impacts may be better accounted for in HVHF-related policies.	
COMMUNITY	Community impacts may be better accounted for in HVHF-related policies.	
GOVERNANCE	May better represent public interests and values in HVHF policy May increase public trust in state May increase perceived legitimacy of HVHF policies	Organizing the commission may increase administrative burden to state.

2.2.3.8: INCREASE STAKEHOLDER REPRESENTATION ON OIL AND GAS ADVISORY COMMITTEE		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Environmental impacts may be better accounted for in HVHF-specific and other oil and gas policy.	Does not provide an opportunity for the public to inform decision making about potential environmental impacts
HEALTH	Health impacts may be better accounted for in HVHF-specific and other oil and gas policy.	Does not provide an opportunity for the public to inform decision making about potential health impacts
COMMUNITY	Community impacts may be better accounted for in HVHF-specific and other oil and gas policy.	Does not provide an opportunity for the public to inform decision making about potential community impacts
GOVERNANCE	May help ensure that public interests and values are considered in HVHF-related policy on an on-going basis	Does not directly involve the public in decision making Reducing the number of seats for oil and gas industry representatives may diminish the ability of the OGAC to advise on technical matters.

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 participating in 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.

2.3 PUBLIC INPUT IN STATE MINERAL RIGHTS LEASING

2.3.1 Introduction

The state is the largest owner of mineral interests in Michigan with over 3.8 million acres of combined surface and mineral rights, 2.1 million acres of mineral rights (without surface rights), and 25 million acres of Great Lakes bottomlands.[112] Under current policy, the DNR is responsible for running the state's oil and gas mineral rights lease auctions and determining the extent to which state-owned land can be developed for oil and gas activity.

As many state lands include areas of scenic, ecological, or recreational value, the leasing of oil and gas rights for possible oil and gas development can create significant concerns among the public. While a lease by itself does not guarantee that oil or gas development will occur, the public may nonetheless worry that approving state-owned mineral rights for development moves those parcels of land one step closer to being drilled. Such concerns have been raised in public comments and lawsuits related to several recent leases in Michigan. For example, in a lawsuit challenging planned leases in Allegan State Game Area, Barry State Game Reserve, and Yankee Springs Parks and Recreation Area, nearby property owners questioned the impact of oil and gas leasing on ecologically-valuable land, citing the possibility of groundwater contamination and the destruction of unique wildlife habitat if drilling were to occur.[113] Similarly, in the case of the approved lease of the Holy Waters of the Au Sable River, a coalition of 17 nonprofits, businesses, and local municipalities wrote a letter to the director of the DNR voicing concerns that oil and gas activities would ruin the area's essential aesthetic and recreational character as well as threaten the endangered Kirtland Warbler.[114] The group also expressed a desire for greater public involvement in state mineral rights lease decisions: "[I]n the future, let's have a process where we can say there are some areas in the state's ownership that aren't appropriate for oil and gas development because there are competing and incompatible uses."[115]

2.3.2 Range of approaches

Mechanisms for involving the public in state leasing decisions vary by state, ranging from no mechanism for public input to more complex policies that ensure public input is widely solicited and reviewed.[iii] In most states, public input on state oil and gas leases is solicited through a formal public comment period. Notice of this public comment period is usually posted in local newspapers and on agency websites, anywhere from one to 60 days before leases are awarded. Some states, such as Alaska, advertise more broadly by posting in public places (libraries, post-offices, etc.), sending paper mailings and emails to self-identified subscribers, and notifying parties known or likely to be affected.[116] A few states, including Alaska and New York, hold public hearings or workshops to directly solicit public comments.[117,118] Following the comment period, a decision is made whether to auction the land for leasing. In New York, a responsiveness summary of public comments received is also provided to any interested party.[119]

2.3.3 Analysis of policy options

This section considers five policy options for addressing public concerns about the leasing of state mineral rights:

- 2.3.3.1 Keep Michigan's existing state mineral rights leasing policy
- 2.3.3.2 Increase public notice about proposed state mineral rights leases
- 2.3.3.3 Require DNR to prepare a responsiveness summary
- 2.3.3.4 Require public workshops prior to state mineral rights auctions
- 2.3.3.5 Increase public notice and comment when lessees submit an application to revise or reclassify a lease

These options may be used independently or implemented together.

2.3.3.1 Keep Michigan's existing state mineral rights leasing policy

The Natural Resource Commission (NRC) and DNR are responsible for managing state-owned lands and mineral resources "to ensure protection and enhancement of the public trust."[120] As such, the DNR runs its own leasing program for state-owned mineral rights and is responsible for collecting royalties if production occurs. The majority of leases are made available through public auction twice per year, though in limited cases the DNR is authorized to enter into oil and gas leases directly. Michigan's constitution requires that the revenue generated from leasing state-owned oil and gas rights goes into the Michigan State Parks Endowment Fund and the Game and Fish Protection Trust Fund, which allows for improvements in parks and increased opportunities for recreation.[121]

DNR staff classifies Michigan's oil and gas rights into categories that determine whether the mineral rights can be leased as well as the extent to which development can occur on the surface.[122] These categories include:

- **Non-leasable:** Mineral rights cannot be leased and surface land is protected from development. However, this classification does not prevent possible drainage of minerals by others.
- **Non-development:** Mineral rights are leasable, but surface use is not allowed without separate written permissions. These leases prevent drainage by others, thereby preventing loss of state revenue. This classification applies to public parks and recreation areas, wetlands, dunes, and other areas that have cultural or ecological value, including the bottomlands of all inland lakes

2.3.3.1: KEEP MICHIGAN'S EXISTING STATE MINERAL RIGHTS LEASING POLICY		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May help protect environmentally valued land	Some environmental considerations may not be accounted for. • Limited distribution of public notice may prevent some stakeholders from voicing relevant concerns.
HEALTH		Some health considerations may not be accounted for. • Limited distribution of public notice may prevent some stakeholders from voicing relevant concerns.
COMMUNITY	May help protect culturally valued areas • Comment process allows public to identify valued areas that should be protected from oil and gas development activities.	Some community impacts may not be accounted for. • Limited distribution of public notice may prevent some stakeholders from voicing relevant concerns.
GOVERNANCE	May increase legitimacy of DNR decisions • Policy is more participatory than states that do not have any public notice or comment.	Transparency and legitimacy of decision making could be improved. • Posting public notice in newspapers and online may not reach all interested stakeholders. • It is unclear how public comments influence DNR decision. • Stakeholder groups have criticized Michigan's policy for allowing the DNR to administratively modify the terms of authorized leases without first seeking public input through a formal public comment period.[132,133] As a result of this process, parcels designated as non-development, which prohibits surface activities, may later have pipelines, roads, or other infrastructure built on the surface. • The procedure of automatically classifying nominated parcels in excess of 125,000 acres as Leasable Non-development may be perceived as a loophole.

[iii] States reviewed include Alaska, Arkansas, Colorado, Illinois, Louisiana, Maryland, Michigan, New Mexico, New York, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, and West Virginia.

and streams (excluding the Great Lakes).

- **Development:** Mineral rights are leasable and surface use may be allowed after written permission is obtained following review of development plans. Standard lease procedures apply to this classification.
- **Development with restriction:** Mineral rights are leasable and surface use may be allowed under specific conditions following review of submitted development plans. These leases may have restrictions based on natural features of the parcels and/or other current surface uses.

In Michigan, the process for auctioning oil and gas leases begins with advertisements to the oil and gas industry, which then nominates public oil and gas rights it wishes to lease.[123] The DNR then compiles an auction list based on leasable lands, mails out individual notifications to surface owners of publically owned mineral rights on the list, and publishes a notice of all auction list lands and their development classifications for public comment and review.[124] The notice is published in counties where the lands are located and in major regional newspapers at least 30 days in advance of the DNR Director's decision to hold the auction. In addition, the DNR sends information regarding proposed leases to the counties and townships where parcels are located. Information regarding the procedures and forms used to lease public lands in the State of Michigan as well as a list of lands that have been nominated for lease are also posted on the DNR website. Following public notice, the DNR then prepares a memo for the Director incorporating public comments.[125] Although there is no requirement for the state to formally respond to public input, the DNR, in practice, responds to every comment received (T. Newcomb, DNR, personal communication, January 30, 2015). Direct leases, which are only used in limited circumstances and make up a small percentage of total leases, go through the same public comment procedure 30 days before the Director's decision.[126] Auction results are made available online.[127] After a lease is awarded, the lessee may submit an application to the DNR to request a reclassification of the lease, variances from the lease terms, or a change in restrictions associated with the lease.[128–130] The DNR posts information about these activities on its online department calendar. When a lessee submits an application to reclassify a lease, the DNR requires the lessee to publish a public notice in local newspapers at least 30 days before the reclassification is approved.[131] At that time, the DNR also notifies self-subscribed members of its email list.

When an oil and gas company nominates over 125,000 acres of land at one time, the DNR reviews the first 125,000 acres and automatically classifies the rest as Leasable Non-development (T. Newcomb, DNR, personal communication, March 2015). To develop these additional acres,

2.3.3.2: INCREASE PUBLIC NOTICE ABOUT STATE MINERAL RIGHTS LEASING

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May improve environmental outcomes • Through increased notice, DNR may learn of additional environmental conditions that should be considered in its decision making.	
ECONOMIC		More expensive for DNR to execute
HEALTH	May improve health outcomes • Through increased notice, DNR may learn of additional conditions that should be considered in its decision making.	May cause stress for some local residents • Increasing public notice may distress some community members who would otherwise not have known about proposed leases.
COMMUNITY	May improve community outcomes • Through increased notice, DNR may learn of additional local conditions or culturally valued aspects of the land that should be considered in its decision making.	
GOVERNANCE	Easy to implement and enforce May increase perceived transparency of DNR decision making May increase legitimacy of DNR decision • Increases likelihood that potentially affected parties have an opportunity to comment on proposed leases	Increased administrative burden • DNR would have to identify and mail notices to nearby landowners.

2.3.3.3: REQUIRE DNR TO PREPARE A RESPONSIVENESS SUMMARY

	STRENGTHS	WEAKNESSES
GOVERNANCE	Easy to implement and enforce May lead to greater sense of accountability and transparency in DNR decision making May increase trust in DNR May increase perceived legitimacy of DNR decision • Requiring a responsiveness summary would demonstrate that public comments have been dutifully considered. • May increase public trust in process	May increase administrative burden • DNR would have to dedicate more resources to process public comments. • May delay timeline for holding auction May be viewed by some as creating red tape

the lessee must request reclassification through the process outlined above. Plans submitted by the lessee are reviewed by DNR staff, including wildlife, biology, and forestry specialists.

Michigan's policy is more participatory than other states that do not have a public comment period for state mineral rights leases. As evidenced by past proposed leases, the process for notifying the public and inviting comments can be effective. For example, in the case of the Au Sable River Holy Waters, an outpouring of negative public comments directed the agency to change the classification of nine proposed "restricted development" leases to "non-development."[134] Likewise, the classification for some proposed leases within Hartwick Pines State Park, the state's largest stand of old growth white pine in the Lower Peninsula, was changed from non-development to non-leasable after the public comment period.[135] While these examples illustrate that the DNR can be responsive to the public's input, concerns remain that the process is one-way and does not allow the public to engage in a dialogue with the state about where and whether HVHF should occur on public land. There are also concerns that the DNR may modify lease terms without a formal public comment period.[136,137]

2.3.3.2 Increase public notice

Under this option, Michigan's existing policy would be revised to expand the distribution of public notice. Currently, Michigan requires public notice in newspapers in the counties and regions where the lands nominated for leasing are located. Notice is also sent to the local DNR office, township supervisors, county commissioners, legislators, and surface owners. In addition, information is posted on the DNR website and sent to subscribers of the DNR's mailing list. To ensure that potentially affected parties are notified of the proposed leases, notification could be required to all landowners whose property lies adjacent to the nominated land. For land that is used by the public for recreational purposes, public notice could also be required at the parcel itself to ensure that users of the affected lands are notified.

Expanding public notice offers a relatively inexpensive way to increase transparency about potential state mineral rights leasing and ensure that affected parties have an opportunity to comment. This may, in turn, lead to more favorable impressions of how the DNR handles state mineral rights leasing—provided that the DNR is responsive to the public comments received.

2.3.3.3 Require DNR to prepare a responsiveness summary

Currently, the DNR is not required to respond in any way to public comments on state mineral rights leases. This policy option would require the DNR to prepare a responsiveness summary that includes a summary of the public's comments, suggestions, and criticisms as well as the DNR's responses to those comments. The responsiveness summary should also describe how public input influenced the DNR's final decision regarding the lease classification of each nominated parcel and, where applicable, an explanation of why specific suggestions made by the public were rejected. The responsiveness summary would be made publicly available through the DNR website and to any interested party who requests it. Other state programs such as Michigan's Air Pollution Control Program (under the DEQ) provide these types of responsiveness summaries.[138]

The strength of this option is that it could make the DNR more accountable to public comments. By directly answering the public's questions and addressing their concerns, responsiveness summaries help demonstrate that the public's opinions are valued. Implementing this option may, in turn, increase public trust in the DNR.

2.3.3.4 Require public workshops prior to state mineral rights auctions

Under this option, the DNR would be required to host public workshops before state mineral rights auctions so that the public has an opportunity to ask questions, provide input, and engage in conversations with DNR staff. Input received during these workshops would be factored into DNR's decision making along with other written comments received. DNR has successfully used a similar process to invite public input on state forest planning.[139]

This option could augment Michigan's existing policy by providing a mechanism for the public to engage in a two-way dialogue with the DNR about proposed state mineral rights leases.

2.3.3.4: REQUIRE PUBLIC WORKSHOPS PRIOR TO STATE MINERAL RIGHTS AUCTIONS

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May improve environmental outcomes • By allowing public comment, DNR may learn of important local conditions that should be considered in its decision making.	
ECONOMIC		Economic cost to state to hold workshops and hire third-party moderators/facilitators
HEALTH	May improve health outcomes • Allowing the public to engage in conversations with DNR staff about proposed leases may reduce the stress associated with the uncertainty of having HVHF operations nearby. • Public comments may bring to light public health considerations that will improve DNR's decision making.	
COMMUNITY	May improve community outcomes • Inviting public comments would allow affected parties to identify potential concerns before well construction, such that some impacts may be lessened or avoided.	May further polarize communities. May decrease DNR legitimacy if seen as a bureaucratic process rather than meaningful public engagement.
GOVERNANCE	May increase legitimacy of DNR's decision May increase public sense of procedural fairness May increase public trust in DNR	Increased administrative burden • DNR may have to dedicate more resources to host workshops and find appropriate facilitators. Workshops may not achieve intended outcomes depending on the group dynamics of attending participants.

2.3.3.5: INCREASE PUBLIC NOTICE AND COMMENT WHEN LESSEES SUBMIT AN APPLICATION TO REVISE OR RECLASSIFY A LEASE		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May improve environmental outcomes • By allowing public comment, DNR may learn of important environmental conditions that should be considered in its decision making.	
ECONOMIC		May delay well development Increased economic burden to DNR, particularly if nearby landowners are notified
HEALTH	May improve health outcomes • DNR may learn of potential community impacts or concerns that should be considered when evaluating variances from the lease's terms or restrictions. • Allowing public comment and improving transparency may reduce stress and anxiety for some nearby residents.	May cause stress for local residents • Increasing public notice may distress some community members who would otherwise not have known about planned changes to the lease.
COMMUNITY	May improve community outcomes • DNR may learn of potential community impacts or concerns that should be considered when evaluating variances from the terms of the lease or changes in restrictions.	
GOVERNANCE	Easy to implement and enforce May increase public's sense of procedural fairness May increase public trust in DNR May increase transparency about DNR decision making May increase legitimacy of DNR decision	Increased administrative burden • DNR would have to dedicate more resources to collect and process public comments.

Workshops may enable the public to ask questions of the DNR as well as contribute important local knowledge that may not be adequately captured in written comments. As a result, this option may help increase not only the transparency of DNR's decision making, but also its legitimacy.

2.3.3.5 Increase public notice and comment when lessees submit an application to revise or reclassify a lease

Currently, the DNR posts notice of applications to modify a lease on its website and to subscribers of its email list. It also requires the lessee to post notice in regional newspapers. This option would require the DNR to have a formal public notice and comment period with notice posted in regional newspapers and at the parcel where the lease is held. The public notice and comment period could follow the same procedure as used for lease auctions, with public notice made at least 30 days before a decision is made. Ideally, nearby landowners and users of the land would also be notified, in accordance with proposed Option 2.3.3.2.

This final option would address stakeholder concerns that state mineral rights leases may be modified without public input. Subjecting lease modifications to public notice and comment in regional newspapers could increase transparency about DNR's decision making as well as increase trust in the DNR. As a result of inviting broader public comment, the DNR may learn of important local considerations that should be factored into its review of the lease modification application.

2.3.4 Summary of options for improving public involvement in state mineral rights leasing

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 mineral rights leases. Each of these steps could enhance transparency about state mineral rights leasing as well as increase the likelihood that the DNR's decisions will be informed by relevant environmental, health, and community considerations. Requiring responsiveness summaries of public input received could further increase the perceived legitimacy and accountability of the state mineral rights leasing process. The absence of such accountability may lead to greater mistrust of the DNR.

2.4 PUBLIC PARTICIPATION AND WELL PERMITTING

2.4.1 Introduction

Once an oil and gas company obtains a lease for either privately or publicly-owned mineral rights, it must obtain a drilling permit from the Michigan DEQ. DEQ staff has a period of 50 days to review a permit application before issuing or denying the permit, or requesting further information from the applicant. While there is no formal public notice and comment period, the DEQ maintains a weekly list on its website of oil and gas well permits that have been applied for and issued. A hyperlinked e-mail address enables site visitors to submit comments about applications that are being considered.[140] The DEQ also regularly updates a map of HVHF activity in the state, including active applications. When reviewing a permit application, the DEQ considers whether the applicant will comply with conservation measures, the number of other wells in the area, and the well's proximity to natural and cultural resources (see the Policy and Law Technical Report[141] for a more detailed description of the permitting process and permit considerations).

Numerous stakeholder groups in Michigan have advocated for greater transparency about the location of wells to be completed with HVHF as well as greater opportunity for the public to participate in decisions about permits and drilling activities.[142–145] As nearby shale gas operations can have negative impacts on neighboring landowners and community members, many people feel they have, at minimum, a right to know where HVHF operations are planned, if not a say in whether HVHF should occur in certain locations. From the perspective of mineral rights owners, however, public involvement may be unwelcome as it may impede development of the resource.

The following discussion examines approaches and policy options for involving the public in HVHF well permitting decisions. Policies related to water use and chemical disclosure requirements for each well site are explored in Chapters 3 and 4, respectively.

2.4.2 Range of approaches

The extent to which the public can influence well permitting decisions varies from state to state. In several states, the public has limited opportunity to learn of permit applications as notice is only required to surface owners (e.g., Arkansas,[146] Michigan,[147] Oklahoma,[148] Pennsylvania,[149] Texas[150]) and/or to local units of government (e.g., Michigan,[151] New Mexico,[152] Pennsylvania,[153] proposed in New York before ban[154]). In other states, public notice is extended to property owners within a certain distance of the proposed well site (e.g., Louisiana,[155] North Dakota,[156] Ohio,[157] Pennsylvania[158]) and to newspapers in the county in which the proposed well site resides (e.g., Illinois[159] and Maryland[160]). In Michigan, members of the general public can only learn of well permit applications by submitting a written request to the state or by browsing the state's website. In Illinois, by contrast, public notice and comment periods are mandated as part of the permitting process.[161,162] Some states allow adversely affected parties to request a public hearing before permits are approved (e.g., Illinois[163] and proposed in Maryland[164]) or to contest approved permits (e.g., North Dakota[165]). In Michigan, interested parties who allege that "waste is taking place or is reasonably imminent" can petition for a hearing. [166] The DEQ interprets this to mean that interested parties can petition for a hearing at any time during the permit application process.

2.4.3 Analysis of policy options

This section considers four policy options for involving the public in HVHF permitting decisions:

- 2.4.3.1 Keep existing Michigan well permitting policy
- 2.4.3.2 Increase notification of permit applications
- 2.4.3.3 Require a public comment period with mandatory DEQ response
- 2.4.3.4 Explicitly allow adversely affected parties to request a public hearing before a HVHF well permit is approved

Policy options related to water and chemical use are discussed, respectively, in Chapter 3: Water Resources and Chapter 4: Chemical Use.

2.4.3.1: KEEP EXISTING MICHIGAN WELL PERMITTING POLICY

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL		Potentially worse environmental outcomes • By limiting public notice and comment, DEQ may not learn of important local environmental conditions that may be impacted by HVHF-related activities.
ECONOMIC	May benefit mineral rights owners, well operators, and the state through faster development of the resource	
HEALTH		May contribute to adverse health outcomes • Uncertainty about where HVHF activities are proposed may distress nearby community members who fear changes to their local landscape and/or possible health consequences.[172] • By limiting public notice and comment, DEQ may not learn of important public health considerations that may be impacted by HVHF-related activities.
COMMUNITY		May contribute to adverse community impacts • By limiting public notice and comment, DEQ may not learn of potential community impacts that could be lessened or avoided.
GOVERNANCE	Limited distribution of public notice may reduce administrative burden on DEQ.	Policy may be perceived as procedurally unfair and non-transparent. • Citizens—including those who may be directly affected by nearby shale gas development operations—are excluded from public notice and comment. • Residents seeking permit application information must look to the DEQ website, which is counterintuitive and difficult to navigate. • The process to petition for a hearing is not as clear as in other states such as Illinois.[173] May contribute to distrust of DEQ and public outrage about HVHF • Policy and lack of transparency may be perceived as procedurally unfair. Lack of public participation may heighten controversy around HVHF Unclear how comments received are incorporated into DEQ decision making • While DEQ is required to consider comments from local units of government, this requirement is broad and difficult to enforce. • The DEQ informally accepts public comments, but there is no assurance that these comments inform its decision.

2.4.3.1 Keep existing Michigan well permitting policy

The DEQ is required to give notice of permit applications to the surface owner, the county in which the well is proposed, and the city, village, or township in which the oil or gas well is proposed *if* that city, village, or township has a population of 70,000 or more.[167] As a matter of practice, the DEQ also provides notice to every city, village, or township, regardless of population size. A copy of the application is also mailed to the county clerk. The public notice contains the name and address of the applicant, the location of the proposed well, the well name and number, the proposed depth of the well, the proposed formation, the surface owner, and whether hydrogen sulfide gas is expected.[168] Any city, village, township, or county in which a well is proposed can provide written comments and recommendations on the permit application to the DEQ, which the DEQ is required by statute to consider. The DEQ is not required, however, to summarize or formally respond to input received.

Though not mandatory, the DEQ also posts notices of permit applications through its website and an email list of self-subscribed interested parties.[169] In addition, while there is no requirement to solicit public input on permit applications, the DEQ informally accepts any comments that are submitted.[170]

There is no explicit procedure for allowing parties who may be adversely affected by HVHF to contest well permits. However, "interested persons" who allege that "waste is taking place or is reasonably imminent" can petition for an administrative hearing. Waste includes, among other things, unnecessary damage to or destruction of the environment and unnecessary endangerment of public health. If waste is found to be occurring or reasonably imminent, the "Supervisor of Wells" (the director of the DEQ) must determine what action should be taken to prevent waste. Although the DEQ interprets this statute to mean that parties can contest well permits, in practice, "interested person" has been interpreted quite narrowly and may not apply to individuals merely because they own adjoining or nearby property.[171]

When it comes to notifying the public of well permitting applications and inviting public comment, Michigan's current practices are more inclusive than some states and less inclusive than others. DEQ's practices of posting information about oil and gas applications on its website and allowing members of the public to submit comments are a positive step toward incorporating public values in its decision making. However, in the absence of a formal public notice and comment period, affected communities may feel that HVHF is being involuntarily imposed. Finally, while the current procedures may facilitate expedient processing of permit applications, they may also overlook important environmental, health, and community considerations.

2.4.3.2: INCREASE NOTIFICATION OF PERMIT APPLICATIONS

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May improve environmental outcomes • By increasing notice to other local units of government, DEQ may learn of important local conditions that should be considered in its decision making.	
ECONOMIC		May delay well development
HEALTH	May decrease stress for some • Increased transparency about where HVHF is planned may decrease stress for some community members by reducing uncertainty.	May increase stress for others • Increasing public notice may distress some community members who would otherwise not have known about potential nearby HVHF-related activities.
COMMUNITY	May improve community outcomes • Increased public notice may ensure that local units of government have ample opportunity to consider and comment on potential adverse impacts (e.g., noise, light, smells, road wear, etc.).	
GOVERNANCE	Easy to implement and enforce May increase perceived transparency • Ensures all units of government are notified of potential wells • Ensures nearby landowners are aware of planned HF operations nearby May increase public trust in DEQ	Would likely increase administrative burden This option, if used alone, does not promote public participation.

2.4.3.2 Increase notification of permit applications

Under this option, existing Michigan policy would be revised to increase public notice of permit applications. This would include removing the population threshold from the current statute, such that all cities, villages, and townships are notified of permit applications for wells to be constructed within their boundaries, regardless of the area's population size. Michigan legislators introduced a similar bill in 2013.[174] In addition, this policy option could require public notice in local newspapers as well as to landowners whose property lies in close proximity to the land where the proposed well will be drilled. To reduce burden on DEQ, this requirement could be fulfilled by the permit applicant. Illinois, for example, requires HVHF permit applicants to post notice in county newspapers and to mail notices to all landowners within 1500 feet of the proposed well.[175]

Increasing public notice of well permit applications would increase transparency about where HVHF operations may occur. In addition, by notifying all local units of government where a well is proposed—regardless of population size—the DEQ may learn of other important environmental, health, and community factors that should be considered in its decision making. The benefits of this option would be magnified if it were combined with an option that formally allowed the public to comment on proposed well permits (see Option 2.4.3.3). To further enhance transparency, the DEQ could post the entire well permit application online.

2.4.3.3 Require a public comment period with mandatory DEQ response

While DEQ informally accepts comments from the public about proposed wells, there is no formal mechanism to ensure that Michigan residents have a say in whether HVHF occurs in their communities. This policy option would mandate a 30 day public comment period following public notice of a permit application. To demonstrate

2.4.3.3: REQUIRE A PUBLIC COMMENT PERIOD WITH MANDATORY DEQ RESPONSE		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May improve environmental outcomes • By allowing public comment, DEQ may learn of important local conditions that should be considered in its decision making.	
ECONOMIC		May delay well development Potential loss of revenue for mineral rights owners and lessees • Policy may result in fewer permits being approved. Mineral rights owners would lose out on royalties. Oil and gas companies would lose income from the untapped resource.
HEALTH	May improve health outcomes • Allowing the public to comment on well permit applications may reduce the stress associated with being involuntarily subjected to the risks of HVHF. • Public comments may bring to light public health considerations that will improve DEQ's decision making.	
COMMUNITY	May improve community outcomes • Inviting public comments would allow impacted communities to identify potential concerns before well construction, such that some impacts may be lessened or avoided.	
GOVERNANCE	Easy to enforce May increase legitimacy of DEQ's decision May increase public sense of procedural fairness May increase public trust in DEQ and well operator Compatible with industry guidelines • The API's community engagement guidelines advocate that well operators communicate effectively with local communities through a two-way process of giving and receiving information that respects local stakeholders' concerns.[178]	Increased administrative burden • DEQ may have to dedicate more resources to collect and process public comments.

that public comments have been heard and dutifully considered, this option could require the DEQ to prepare a responsiveness summary for all substantive comments received. DEQ prepares a similar "Response to Comment Document" as part of Michigan's Air Pollution Control Program.[176] Furthermore, the DEQ could require the well operator applying for the permit to address any substantive public comments received. Illinois included a similar provision in its Hydraulic Fracturing Regulatory Act.[177]

While this option may increase DEQ's administrative burden, it may have several positive benefits. By inviting the public to comment on permit applications, the DEQ may learn of important local considerations that should be factored into its decision making. At the same time, including the public in this decision making process may help relieve stress in affected communities as well as increase perceptions that DEQ is being transparent and treating the public fairly.

2.4.3.4 Explicitly allow adversely affected parties to request a public hearing before a HVHF well permit is approved

Another option to address public concerns about HVHF well permitting would be to explicitly allow local units of governments as well as parties who may be adversely affected to petition for a public hearing. Illinois recently enacted such a policy as part of its Hydraulic Fracturing Regulatory Act,[179] and legislators in the Michigan House proposed a similar policy in 2013.[180] Under this option, DEQ would be required, if requested, to hold a public hearing in the city, village, township, or county where the well is to be located prior to making a decision on the application. Similar to Illinois' policy, the DEQ could deny "frivolous" requests. During the hearing, interested parties could provide testimony or submit written comments to the DEQ, which the DEQ would be required to consider. The hearing could be followed by a 15-day public comment period, during which the public could respond to evidence and testimony provided at the hearing.[181] To demonstrate transparency in its decision making, the DEQ could provide a summary of the public hearing and an explanation of how testimony was considered. A variation of this option would be to also require participation of the permit applicant so that government officials and the public could directly ask questions of the well operator.

The strength of this option is that it gives a voice to parties who may be adversely affected by a proposed unconventional shale gas operation. This may help ensure that DEQ's decisions on permit applications account for impacts to nearby landowners.

2.4.4 Summary of options for improving public involvement in well permitting

Michigan's existing policy for involving the public in well permitting decisions is more inclusive than many states but less inclusive than others. By only notifying surface owners and local units of

2.4.3.4: EXPLICITLY ALLOW ADVERSELY AFFECTED PARTIES TO REQUEST A PUBLIC HEARING BEFORE A HVHF WELL PERMIT IS APPROVED	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May improve environmental outcomes • Public hearings may bring to light to environmental considerations that will improve DEQ's decision making,	
ECONOMIC		May delay well development Potential loss of revenue for mineral rights owners and lessees • Policy may result in fewer permits being approved. Mineral rights owners would lose out on royalties. Oil and gas companies would lose bonuses paid to mineral rights owners as well as income from the untapped resource.
HEALTH	May improve health outcomes • Allowing adversely affected parties to petition for a public hearing may reduce the stress associated with being involuntarily subjected to the risks of HVHF. • Public hearings may bring to light public health considerations that will improve DEQ's decision making.	
COMMUNITY	May improve community outcomes • A public hearing would allow parties directly affected by a proposed well to identify potential communication impacts that the well operator may be able to lessen or avoid.	
GOVERNANCE	May increase transparency • Compared to current policy, this option would clarify procedures for requesting a public hearing. • Requiring a responsiveness summary would increase transparency about DEQ's decision making. May increase legitimacy of DEQ's decision • If hearing participants feel that their concerns were genuinely heard and considered, the perceived legitimacy of DEQ's decision may increase. May increase public sense of procedural fairness and concerns about HVHF being involuntarily imposed Participation of the well operator would be compatible with industry guidelines. • The API's community engagement guidelines advocate that well operators communicate effectively with local communities through a two-way process of giving and receiving information that respects local stakeholders' concerns.[182]	Will likely increase administrative burden • DEQ would have to dedicate more resources to conduct and summarize public hearings. May not be sufficiently participatory to alleviate or address public concerns • Public hearings remain a weak form of participation as they do not encourage dialogue or discussion about the issues. If the public views public hearings as pro forma, they may not achieve their intended outcomes.

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 explicitly allowing adversely affected parties to petition for a public hearing are all options that can help address these concerns. To be most inclusive, these options should be implemented together.

2.5 SUMMARY OF OPTIONS FOR IMPROVING PUBLIC PARTICIPATION

Compared to other states, Michigan's policies regarding public participation in HVHF decision making are middle-of-the-road. The state primarily engages the public on HVHF through online informational materials and public presentations. Opportunities for the public to influence deep shale gas development are the same as for other types of oil and gas activities: the public can comment on proposed state mineral rights leases, participate in hearings when new rules are promulgated, and petition for hearings if, as an interested party, they can demonstrate that HVHF well development will result in "waste." The public can also informally comment on well permit applications, but this opportunity is not made known through formal public notice.

Past research on controversial technologies suggests there may be benefits to increasing transparency around HVHF and to providing more participatory mechanisms for the public to shape HVHF-related policies. This chapter has outlined numerous options that may help achieve these goals. Most are adaptive, "no regrets" policies that are likely to be beneficial no matter the level of HVHF activity in the state. These include several options to improve basic communications about HVHF such as increasing the user-friendliness of the DEQ website, requiring risk communication training for DEQ and DNR employees who work on oil and gas issues, and offering third-party moderated public workshops where stakeholders can interact and discuss HVHF-related activities.

Other options are designed to increase the likelihood that public values are accounted for in HVHF decision making. This includes, for example, revising the composition of the Oil and Gas Advisory Committee to better represent public health and environmental interests. The state could also consider appointing a multi-stakeholder advisory group to study HVHF-related impacts in Michigan and to identify best management practices for addressing them.

In the context of state mineral rights leasing, existing policy could be enhanced 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 preparing responsiveness summaries of input received. Each of these options might improve both the transparency of state mineral rights leasing as well as the perceived legitimacy of DNR decisions.

Several options aim to increase the transparency of the well permitting process and give the public a greater voice in well permitting decisions. These include requiring public notice and comment on HVHF permit applications, offering responsiveness summaries of public input received, and explicitly allowing adversely affected parties to petition for a public hearing. Finally, this chapter considered two precautionary policies: imposing a state-wide moratorium on HVHF and banning it outright.

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WATER RESOURCES

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Chapter 3

3.1 INTRODUCTION

The water wealth of Michigan is derived not only from the Great Lakes that give the state its moniker, but it also extends to the many inland lakes, rivers, and wetlands that bathe the landscape, providing habitat for many types of fish species, from largemouth bass in warmer waters to brook trout found in the cold waters of the state. While the presence of so many trout streams in the state represents significant cultural pride and identity for many Michiganders, their presence is due to the rich groundwater reserves that feed these streams that provide the state with a class of fish that is naturally found only in snow-and-glacier-fed mountain streams. It is this recognition and understanding that informs concerns regarding large-scale water withdrawals in Michigan. This intimate link between fish populations and groundwater formed a basis for the state's regulation of water withdrawals under the current Water Withdrawal Assessment Program (WWAP).[1]

Since 2009, Michigan has been managing almost all new large-volume water withdrawals within the state through the WWAP. Anyone wishing to make a large-volume water withdrawal must first determine whether their proposed water withdrawal would require registration or of a water withdrawal permit from the Michigan Department of Environmental Quality (DEQ) (Table 3.1). In addition, the proposed water withdrawal cannot cause an Adverse Resource Impact (ARI).

The WWAP accomplishes its regulatory function through a series of regulatory tools meant to provide greater information and a streamlined assessment process for a potential water user. The major piece within the WWAP is the Water Withdrawal Assessment Tool (WWAT), which is an automated online screening tool used to provide an initial assessment of whether a proposed water withdrawal from groundwater or stream is likely to cause an ARI. A proposed water withdrawal is input to the tool via the online interface.[2] Each query will immediately return a determination of allowance to withdraw the proposed volume of water. The determination can range from an automatic go-ahead to withdraw the water to the requirement of a site-specific review (SSR). As an increasing amount of water is withdrawn for use in a subwatershed, the designation changes toward increasing regulation until it reaches a determination of an ARI, after which no additional water may be withdrawn. For more information, see Box 3.1.

The WWAP is supposed to undergo regular assessments and adaptive updates. The models underlying the WWAT were developed based on data and scientific models available at the time of its development.[3] The regulatory framework of the WWAP was also developed based on untested assumptions of conservation based on specific thresholds for action. The entire process was originally meant to be adaptive and malleable, with periodic assessments to determine how to improve it for better water conservation goals.[4]

TABLE 3.1: DIFFERENT REQUIREMENTS FOR REGISTRATION AND PERMITTING OF LARGE-VOLUME WATER WITHDRAWALS IN MICHIGAN UNDER WWAP

	WITHDRAWAL RATE[i]	AVERAGE PUMPING DURATION	COST ($)
	Lower threshold	Lower threshold	
REGISTRATION	100,000 gpd (70 gpm)	30 days	$200.00[ii]
PERMIT[iii]	2,000,000 gpd (1,388 gpm)	N/A	$2,000.00
PERMIT[iv]	1,000,000 gpd (694 gpm)	N/A	$2,000.00
PERMIT[v]	100,000 gpd (70 gpm)	90 days	$2,000.00

[i] Water withdrawal rates are presented as both gallons per day (gpd) and gallons per minute (gpm). The legislation cites all water withdrawals as rates of gallons per day (gpd). However, this chapter of this report uses the far more common metric of gallons per minute (gpm).

[ii] Use of the Water Withdrawal Assessment Tool is free, requesting a site-specific reviewis free, and registration with the system is free. The $200 refers to the annual reporting fee, which all water withdrawals regulated by the WWAP must pay, except agricultural uses and withdrawals less than 1.5 million gallons per year.

[iii] For water withdrawal permits in Policy Zone A and B subwatersheds. Referred to as a "General water withdrawal permit" in the text.

[iv] For water withdrawal permits in Policy Zone C subwatersheds. Referred to as a "Zone C water withdrawal permit" in the text.

[v] For water withdrawal permits for intrabasin water withdrawals. Referred to as an "Intrabasin water withdrawal permit" in the text (See Box 3.1).

Box 3.1 The WWAT and SSR

A major part of the WWAP used by Michigan in governing the water conservation goals outlined by the Great Lakes-St. Lawrence River Basin Water Resources Compact (Great Lakes Compact) is the automated WWAT, whose primary public access portal is a free, web-based interface, accessed at www.deq.state.mi.us/wwat. The WWAT acts as an initial screening tool that is meant to "filter in" most of the proposed water withdrawals based on conservative estimates built into the automated decision-making process. The interface is built upon a set of science-based, spatially defined groundwater, surface water, and fish ecology models.[5] The WWAT defines the water temperature profile, upstream drainage area, and index flow of 5,356 subwatersheds units throughout the State. The watercourse flowing through each subwatershed unit is defined as one of 11 river types, based on each subwatershed unit's water temperature (cold, cold-transitional, cool, and warm) and upstream watershed area (streams, small-rivers, and large-rivers). Finally, a fish-response curve is associated with each river type, based on data-derived ecological relationships.

Using the modeled index flow value for each subwatershed, the WWAT determines the percent-withdrawal limits, based on the fish curve for the subwatershed. These percent-withdrawal limits delimit the boundaries of four statutorily defined Policy Zones (A, B, C, and D)[6] for each of the river types.

When a proposed water withdrawal is submitted to the WWAT, the proposed withdrawal capacity is added to the existing registered water withdrawals in that subwatershed. This total withdrawal value is compared against the percent withdrawal limits for the subwatershed, and a Policy Zone determination is made for the proposed withdrawal, based on the amount of calculated water available. If a water withdrawal is registered in the system, the amount of remaining water potentially available for withdrawal, as recorded in the "water accounting" module, is automatically updated to reflect the changes in the stream flow depletion.

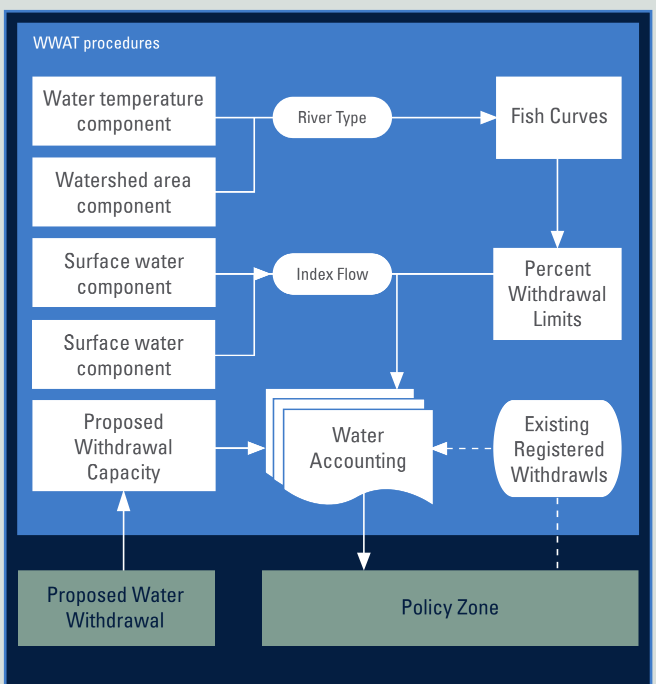

FIGURE 3.1. Simplified structure of the various components of the WWAT, indicating how a proposed water proposal generates a Policy Zone assessment.
Modified from Lacy, 2013.[7]

For each Policy Zone, there is an associated action that the DEQ will carry out, as follows:

Zone A: The proposed water withdrawal is accepted. The withdrawal is registered automatically with the DEQ. No further action taken.

Zone B: The proposed water withdrawal is accepted. In cold-transitional systems, large water withdrawal permit holders—such as utilities—are to be notified, and an SSR is required.

Zone C: The proposed water withdrawal is not accepted. SSR must be conducted. All water withdrawers are to be notified of a Zone C SSR. Water users committees may be formed.

Zone D: Adverse Resource Impact (ARI). The proposed water withdrawal is rejected. A SSR must be conducted if the proposed withdrawal is still desired.

If a proposed water withdrawal project has the potential to cause an ARI and interest in the proposed withdrawal remains, then as SSR must be completed (Figure 3.2). An SSR is also required for proposed withdrawals in Zone C or for proposed withdrawals in Zone B cold-transitional streams.[8] In an SSR, the DEQ examines the accuracy of the modeled data within WWAT at the location of the proposed water withdrawal project. The DEQ may conduct an investigation of local conditions or consult other studies about the site. The DEQ can utilize different groundwater flow models that may better assess the unique conditions of the subwatershed unit in question. (Note that an SSR is *not* the same as a physical, on-site visit and assessment of local conditions by the DEQ, but usually involves a review of all relevant data and modeling assumptions that the DEQ has that is specific to the site in question.) If, after their review, the DEQ determines that no ARI is likely to occur, then it registers the withdrawal and notifies the applicant. The DEQ must complete its SSR within 10 working days after the submittal of the SSR request.[9] If the potential for an ARI remains after the initial assessment, the DEQ contacts the applicant to discuss potential modifications to the water withdrawal plan. If the applicant agrees to modifications that avoid an ARI, then the DEQ registers the withdrawal. If the applicant does not agree to modifications that avoid an ARI, then the DEQ issues a Zone D determination, and the withdrawal may not go forward. When a withdrawal is registered in Zone C (or in Zone B for cold-transitional streams), the DEQ must inform all registered users, permit holders, and local government units.

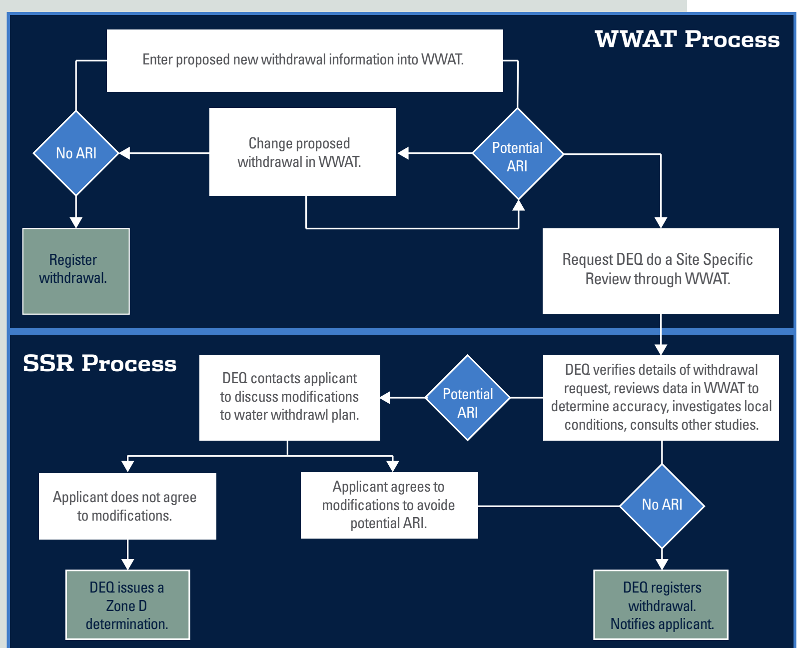

FIGURE 3.2: Flow diagram of the process of registering a water withdrawal through the WWAT and potential SSR process
Flow chart based on SWMWRC, 2014.[10]

TABLE 3.2: RELATIVE WATER USE RATES ASSOCIATED WITH DIFFERENT TYPES OF HYDRAULIC FRACTURING [12]

	Northern Antrim Shale	Minimum HVHF definition	Utica-Collingwood Shale
Natural gas depth	800–2,000 ft	Varies	9,000–10,000 ft
Total water volume[i]	~50,000 gal.	100,000 gal.	>10,000,000 gal.[13]
Water withdrawal rate[ii]	~1 gpm	~2 gpm	>230 gpm
	DOESN'T NEED TO RUN WWAT	MUST RUN WWAT	

[i] Water withdrawal volumes refer to orders of magnitude, and not absolute cut-off volumes for types of hydraulic fracturing.

[ii] Presumes the total water volume is withdrawn 24 hours a day for a 30-day period and is done solely for comparison purposes. Individual wells will differ depending on withdrawal rates.

3.1.1 Water use and high volume hydraulic fracturing

High volume hydraulic fracturing (HVHF) as commonly practiced requires water as a primary component in its operation. This crucial need for large volumes of water makes the regulation of water withdrawal and wastewater disposal strong tools for regulating HVHF activities themselves. Depending on the type of regulation enacted to address large-scale water withdrawals like those used for HVHF, operators may respond in a variety of ways, including transporting water from other jurisdictions or withdrawing smaller volumes from many more sources. Other Eastern states have recognized this association between hydraulic fracturing and water withdrawal and have used water withdrawal regulation as a mechanism for governing the scope and scale of HVHF activities for the protection of water-related resources.

Water withdrawal for use in hydraulic fracturing does have a history in Michigan (see Figure 3 from the Geology/Hydrogeology Technical Report[11]), but at far lower rates of water withdrawal than projected in future HVHF operations. For example, in the northern portion of the Lower Peninsula, the historic hydraulic fracturing operations in the northern Antrim Shale have, for many decades, been using withdrawn water for their operations at rates far below the current regulatory thresholds. Similarly, more recent high volume water withdrawals for hydraulic fracturing have occurred in various locations around the Lower Peninsula unassociated with any shale formation. In contrast to these types of water use, the expected rates of water withdrawal in the Utica-Collingwood Shale are expected to be an order of magnitude higher for fracturing operations (Table 3.2).

NOTE: Michigan defines HVHF as well completion operations that intend to use a total volume of more than 100,000 gallons of primary carrier fluid, which typically consists primarily of water. Although the fluid volume that defines an HVHF completion is 100,000 gallons, this chapter will focus on the order-of-magnitude-greater water withdrawals expected to occur with operations within the Utica-Collingwood Shale formation.

Therefore, for the purpose of this chapter, all further references to "high volume hydraulic fracturing" or "HVHF" in the context of Michigan will

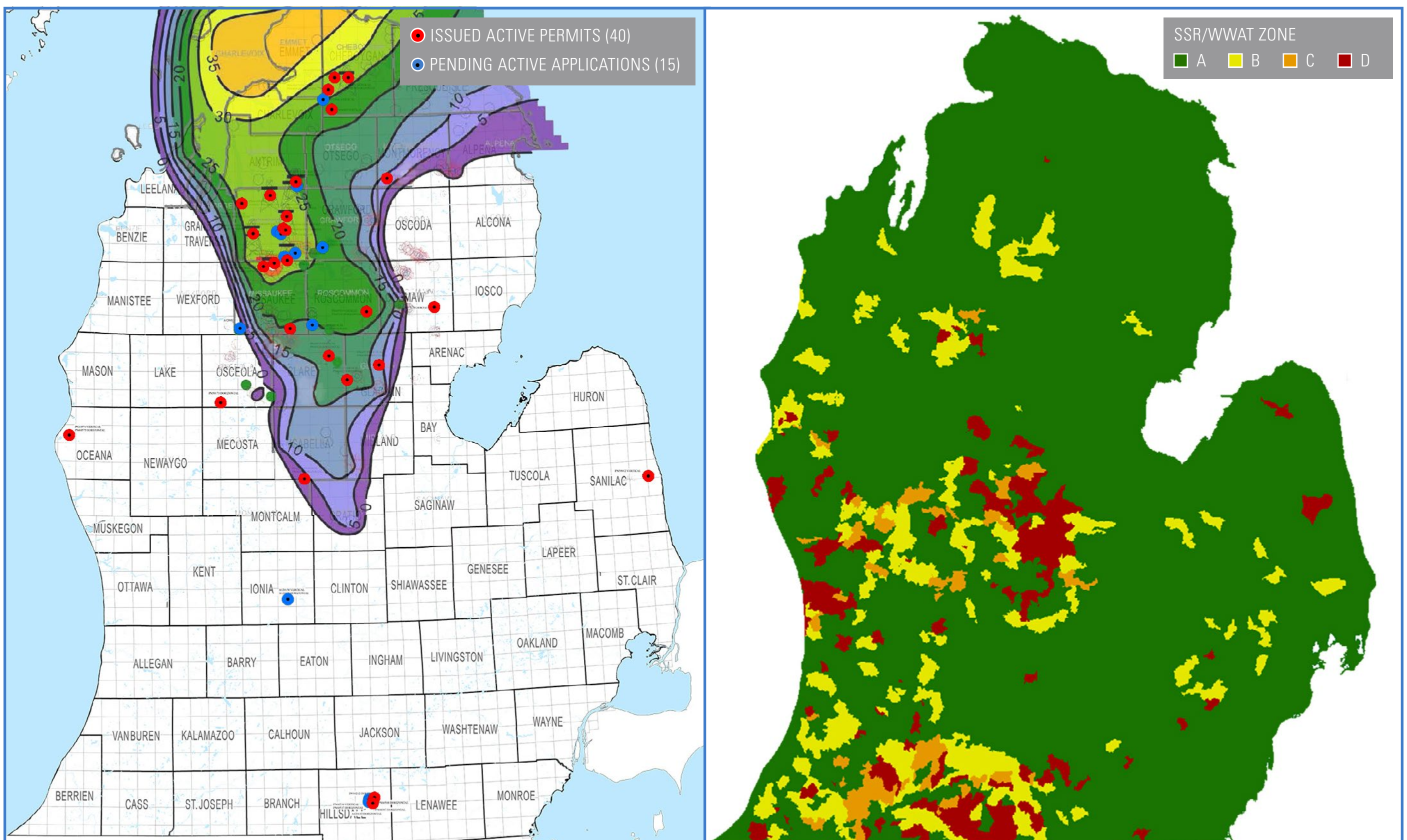

FIGURE 3.3: Location of Utica-Collingwood Shale and existing and pending large-scale water withdrawals associated with State-defined HVHF operations (left) and existing policy zone designations through January 2014[14] (right)
Left image taken from Ellis, B.[15]

refer (except where noted) to the type of operation that is expected to drill to 9,000 feet or more, and use 10,000,000 gallons or more of water, except where specifically noted otherwise.

The recent HVHF operations in the Utica-Collingwood Shale have been as a response to the economic feasibility to extract shale gas from deep geological formations under parts of the Lower Peninsula. It is important to recognize the strong geographic association between natural gas extraction through HVHF and the Utica-Collingwood Shale, much like the historic presence of shale gas associated with the Northern Antrim Shale.[16] Due to the geographic extent of the Utica-Collingwood Shale, and the high likelihood that HVHF operations—if approved—will be concentrated above this shale formation (see Figure 3.3[17]), it is primarily within this region that the large volumes of water associated with HVHF will be withdrawn.

HVHF water withdrawal activities are not governed by the WWAP. Regulation of HVHF water withdrawals are done through the Supervisor of Wells, but the regulation rests upon the use of and water accounting in the same WWAT,[18] since water withdrawn for HVHF does have an impact on local water availability (see Box 3.2). What's more, the regulations require that no HVHF water withdrawal cause an ARI and have associated requirements (see Section 3.2.1.2). This places HVHF water withdrawals within a parallel framework to that of the WWAP, alongside existing water withdrawal uses, even if the current regulations do not treat such withdrawals in exactly the same way as others.

Could HVHF operations shift a subwatershed unit to the edge of an ARI? It is important to recognize that non-HVHF activities have already pushed subwatershed units to their withdrawal maxima, with many nearby subwatersheds in Policy Zones C, and many entering into an ARI under additional proposed withdrawals (Figure 3.3). By examining five stream-sized subwatershed units whose water withdrawal registrations have placed them into subsequently increased Policy Zone status (Table 3.3),[19] it is possible to observe a few salient points. First, each subwatershed unit is unique in the registered withdrawal volumes necessary in shifting its Policy Zone determination. Next, all the cool- and warm-water streams were able to accommodate well over 1,000 gpm of pumping before the WWAT or a subsequent SSR returned a determination of an ARI for a proposed water withdrawal. Even the cold-water stream could accommodate the better part of 1,000 gpm. Finally, all of the water withdrawals for these six streams were registered as irrigation withdrawals—a traditional water use. From this perspective, HVHF withdrawals are not special in and of themselves, and one cannot simply make a blanket statement about how any large quantity water withdrawals will affect subwatersheds, since each is effectively unique in the amount of water available and the numbers of registered (and unregistered) users. In short, while HVHF water withdrawals are new, they are—in general—unlikely to become the sole cause of a potential ARI.

Based on the HVHF water withdrawals already associated with and submitted for the Utica-Collingwood (Figure 3.3), there will likely be impacts in some subwatershed units. Cold-transitional units will suffer the greatest impact, followed by cold-water units. In comparison, cool and warm-water units will see far fewer impacts. This is due primarily to the ways in which allowable limits for water withdrawal are determined for these types of rivers. See Hamilton & Seelbach[20] for more technical information beyond that presented in this report.

It is crucial to recognize that HVHF was not a consideration during the development of the WWAP (2006-2008). Specifically, the online WWAT (which is integral to the WWAP) might not be adequate to the task of accurately assessing the impacts of high volume, short-duration water extractions associated with HVHF, since it was designed to look at long-term, effectively continuous water withdrawals. Despite this potential weakness, the WWAP is the regulatory process through which large water withdrawals are governed in Michigan. It is necessary to recognize that any large-scale water withdrawal will have physical impacts, and governing water use and conservation within the framework of the WWAP is currently the best way to manage a shared resource (Box 3.2). If, however, the WWAP is to serve as the water governance mechanism for all water uses in the state—including HVHF—then it must be amended and/or updated in order to address the potentially different rates of water extraction that HVHF operations entail. To those ends, this chapter will present modifications to the WWAP as a means to govern HVHF activities within the state as well as a means of improving the WWAP itself.

At the time of writing this chapter, the U.S. Environmental Protection Agency (EPA) report on the impacts of hydraulic fracturing on drinking water sources was not yet released, but based on the available preliminary drafts, the findings of the EPA report appear to correspond well with the analogous points raised in this chapter. Comparisons between this chapter and the EPA report must recognize the different purposes and geographic scopes of the two documents before reaching conclusions that might not be applicable when transferred from one to the other.[21]

3.1.2 HVHF and water quality

If concerns over water withdrawal are held at the start of the HVHF process, at the other end of the process are concerns over the wastewater accumulated during the HVHF process. Indeed, concerns over impacts to water quality have also arisen, within the popular media, scientific literature, and governmental reports. The process of HVHF utilizes a suite of chemicals (see Chapter 4, Chemical Use), which effectively contaminates the water used in the HVHF process, some of which returns back to the surface. Contact with or

TABLE 3.3: COMPARISON OF REGISTERED WATER WITHDRAWAL CAPACITIES IN SIX STREAM-SIZED SUBWATERSHED UNITS IN MICHIGAN THAT HAVE NO MORE AVAILABLE WATER FOR WITHDRAWAL

SUBWATERSHED (MAJOR WATERSHED)	STREAM TYPE	AREA SQ MI	REGISTERED WITHDRAWALS* (GPM)				% WATER USE FOR IRRIGATION
			A**	B**	C**	D**	
N. Branch Chippewa River (Chippewa River)	Cold	2.9	347	–	764	1111	100%
Pony Creek (Chippewa River)	Cold-transitional	11.9	–	590	–	938	100%
Pigeon River (Macatawa Lake)	Cool	21.7	3167	3861	5528	5771	100%
Bear Creek (St. Joseph River)	Warm	20.2	903	1389	2326	2547	100%
Bass River (Grand River)	Warm	30	1840	4948	5885	6024	100%

* All values represent registered withdrawal capacity; all values represent intermittent withdrawals; most withdrawals during June, July, and August; values are through January 2014

** Original values reported in gpd; values converted to gpm to remain consistent with the chapter. Values for A, B, and C represent the net registered withdrawals registered within each policy zone. Values for D represent the net minimum reported capacity that would trigger an ARI. Note: all cases of Policy Zone D withdrawal applications were noted as being rejected.

Box 3.2 Why use the WWAT if it wasn't designed for HVHF?

While there have been calls for assessing the water extractions closely associated with HVHF activities through the WWAT, there have also been calls to not use the WWAT, due to the issues of modeling error that it may have in dealing with the intense, short-duration water withdrawals associated with HVHF, especially in headwater areas. The argument against using the WWAT is that it was never designed to address the intense, short-term water withdrawals associated with HVHF and thus it shouldn't be used. This argument, on the surface, seems to have merit. After all, if the WWAT was not designed to do address a task that it was not designed to do, it might be best to not use it at all.

Not using the WWAT can create a plethora of problems. Water withdrawn for HVHF operations is equally as consumed from its source aquifer as water withdrawn from that same aquifer for more conventional purposes, like irrigation, drinking water supply, or manufacturing. The DEQ has recognized this association and has been including reported HVHF water withdrawals even before the regulatory requirement was formalized in 2015. By *not* including HVHF water withdrawals within WWAP, cumulative impacts to water resources (which are required by the Great Lakes Compact to be monitored and governed) will not be monitored, since HVHF withdrawals will no longer be monitored alongside conventional withdrawals.

While the WWAT does not—at present—provide a perfect approach to governing water withdrawals associated with HVHF (which is why a major policy option considered in this chapter is the updating of the WWAT in Section 3.2.3), it is the central piece upon which both the WWAP and the Supervisor of Wells regulations rest. As such, it is the pre-existing means by which all significant water withdrawals are monitored and the potential impacts of new withdrawals are assessed. Requiring a separate system of water withdrawal governance would be treating water withdrawals from HVHF as different from more traditional water withdrawals already governed by WWAP, and would create a fundamentally different system of governing a resource that is shared across multiple uses, thus creating difficulties in governance and oversight.

spills of this water could pose risks to human and environmental health, and there should therefore be appropriate regulation and oversight of these pollutants' treatment and disposal.

However, just like concerns surrounding the use of chemicals during the active period of a well, so, too, are there concerns about the holding, treatment, and disposal of the wastewater from HVHF. Unlike the framework governing water withdrawals, issues of water quality are governed by both state and federal regulations. Furthermore, at the present time, Michigan law only prescribes wastewater disposal in deep-injection wells. However, recent technological advances in water treatment technology, as well as the (sometimes painful) lessons learned in neighboring states—which have a longer history of dealing with HVHF—can provide insight into different ways of addressing concerns over the handling, treatment, and disposal of hydraulic fracturing wastewater.

3.1.3 Chapter overview

This chapter is organized into two major sections. The first explores the various methods in which improvements to the Supervisor of Wells regulations and the WWAP may provide mechanisms to govern water withdrawals associated with HVHF. Many of these improvements have been raised in public comments in various fora relating to hydraulic fracturing and HVHF in Michigan, including comments for this IA, as well as in public meetings of the state-appointed Water Use Advisory Council.[22] The section is broken up into various major categories of water withdrawal regulation, such as lowered thresholds for regulation, fees for water use, etc. Following an introduction for each major category for regulation, regional comparisons are presented (where appropriate), followed by a brief description of the current condition in Michigan under the WWAP. Following this review, a number of policy options are presented that would improve or alter the WWAP or Supervisor of Wells regulations in order to implement the respective regulatory policy. Since some of these policy options are parallel alterations to the both the WWAP and the Supervisor of Wells regulations, additional information is provided to explain how such an alteration would provide benefits in governing HVHF in Michigan.

It is important to recognize that some changes to the WWAP are being considered outside of the process of HVHF regulation. Furthermore, it is important to understand that any parallel change to the WWAP and the Supervisor of Wells regulations will have impacts across several water-use sectors in the state. For example, if the threshold for registering a water withdrawal were reduced from 70 gpm, this could have significant impacts on users that have chosen to withdraw water up to the regulatory threshold but may have a lesser impact on other users that withdraw water at rates far above the 70 gpm threshold. Conversely, if water withdrawals were no longer averaged over 30 days, this would affect short-term users far more than continual users.

The second section explores regulatory changes concerning management of waste water used in HVHF. Since the WWAT does not consider questions of water quality, these proposed policy options are presented within a separate framework of policy options. Furthermore, since issues of water quality are governed through the federal Clean Water Act (CWA) in addition to the state's various water quality and wastewater discharge laws, it is necessary to first outline the various ways in which state and federal regulations govern HVHF wastewaters. Finally, since the policy options presented in this chapter are meant for decision makers in Michigan, policy options that would require federal legislation or federal regulations will not be proposed.

Both sections use regulatory examples from other Great Lakes states, the Susquehanna River Basin Commission (SRBC), and the Delaware River Basin Commission (DRBC). All of these regions share a basis of water law (i.e., regulated riparianism[23]), which places them in a similar framework regarding their approach to governing water withdrawals. While some lessons can be gleaned from Western states (which use a system of water law in which rights to volumes of water can be purchased, traded, and enforced) more direct lessons can be learned by examining the processes by which other regulated riparian states operate. Furthermore, both the SRBC and the DRBC provide examples of watershed-based regulation and planning within single regulatory frameworks and can be seen as analogues of Michigan.

Throughout the chapter, and in discussion of water and HVHF in general, there are often a lot of numbers that are brought up and compared. It is important to recognize that this report will be focused on specific water metrics of total water volume and water withdrawal rates for a single operation (See Box 3.3). Although the discussion of HVHF and water use may involve other types of water metrics, these two were chosen because they are the ones that are governed by current regulations. Other discussions may include discussions of efficiency or try to compare sector-wide water uses; note that these metrics are not discussed in this chapter because they are not used in the framework of water governance.

3.2 REGULATING HVHF THROUGH WATER WITHDRAWAL REGULATION

The WWAP was implemented in Michigan in 2009 in fulfillment of the Great Lakes Compact. As such, the goal of the WWAP is to conserve the waters and water-dependent natural resources of the state from diversions out of the Great Lakes Basin or from cumulative uses.[24] Michigan is unique among other Great Lakes states in that its process of managing water

Box 3.3 Water Metrics

Making a measurement requires a metric appropriate for the purpose of the measurement. Measuring or applying the wrong metric will provide irrelevant information and may cause confusion. Choosing the right metric for familiar tasks is simple, but water metrics are less familiar, creating the possibility for confusion. The metrics below are pertinent in the discussion of water resources and hydraulic fracturing, describing characteristics of volume, rate, and efficiency.

Total Volume. In Michigan, HVHF is defined in part as those operations using over ***100,000 total gallons*** of primary carrier fluid (mostly water), regardless of the intensity of water withdrawal. The average total volume of the Northern Antrim wells was roughly 50,000 total gallons of water, roughly half the legal definitional threshold. A number of wells scattered throughout the state and unassociated with any major shale formation have used more than 100,000 total gallons of water, and are classified HVHF. In contrast, the estimated total water volume necessary in Utica-Collingwood ranges from 10,000,000 total gallons and up. Although defined as HVHF, note that Utica-Collingwood volumes are 100 times more water than the definitional threshold of 100,000 total gallons, effectively placing Utica-Collingwood operations in a distinct group. For this reason, this chapter focuses primarily on this group.

Rates. Whereas HVHF is defined based on total volume, large-volume water withdrawals are defined in the WWAP based on water withdrawal rates. A large-volume water withdrawal is defined as a withdrawal averaging at least ***100,000 gallons per day*** over a 30-day period (Table 3.1). With this threshold, it is possible to determine whether a hydraulic fracturing water withdrawal could be high-volume water withdrawal. For example, at 100,000 gallons per day, it would take 12 hours to withdraw the total volume of a typical Northern Antrim well (50,000 total gallons), one day to withdraw the minimum total volume needed to qualify as HVHF (100,000 total gallons), and 100 days to withdraw the estimated total volume for Utica-Collingwood operations (10,000,000 total gallons). Such water withdrawal rates in the Utica-Collingwood operations would be classified as large-volume water withdrawals, and for this reason, this chapter focuses on this group. Note that increasing pumping rates shortens pumping periods, and such short-term, high-intensity water withdrawals, which are also characteristic of HVHF water withdrawals, can have a greater local impact to hydrology and ecology than long-term, lower-intensity water withdrawals. The potential for such local impacts also drives a number of policy options in this chapter.

Efficiency. Efficiency is often measured when comparing costs associated with an operation. Energy recovery rate is one crucial metric when determining the costs of a hydraulic fracturing well. The more units of gas that can be taken out of a shale deposit for every unit of water volume used, the lower the overall costs associated with the operation. Although water efficiency metrics can be useful in some discussions of water use and hydraulic fracturing, they do not fit into Michigan's regulatory framework, and thus will not discussed further in this chapter.

withdrawals is based in an online, automated screening tool, the WWAT, which provides water users with a determination of whether a proposed withdrawal will cause an ARI in their subwatershed unit. At the present time, however, HVHF water withdrawals are governed by parallel regulations under the Supervisor of Wells.[25]

Given the innate requirement of water in HVHF operations, one way in which many states and river commissions have regulated the practice is through regulations of water withdrawals and water use. An extreme case that demonstrates the potential power of such regulation is the DRBC, which in 2010 issued a moratorium on the issuance of all future water withdrawal permits for water withdrawals associated with all types of hydraulic fracturing until a set of rules for this use were passed.[26] While hydraulic fracturing operations could conceivably continue within the Delaware River Basin, all water would need to be transported from outside of the watershed, and all wastewater would need to be transported back out of the watershed, which would drastically increase the costs of operation. The neighboring SRBC instituted a special fee for all hydraulic fracturing water withdrawals, and regulates all such water withdrawals, down to "gallon one."[27] States neighboring Michigan also have general requirements in place for large-scale water withdrawal, including the requirement to obtain a permit (such as in Ohio and Indiana) or a threshold for regulation that is far lower than Michigan's (such as in Minnesota).

In Michigan, all of these types of regulatory control are presently handled in a framework that is parallel to the existing WWAP framework, but using many key components of the WWAP (such as the WWAT and the Policy Zone designations). Conversely, the institution of a completely separate system for managing water withdrawals associated with hydraulic fracturing would create an independent standard and method for water conservation (see Box 3.2) and is not pursued in this report. Recognizing that the WWAP was designed with adaptive management in mind, with periodic assessments of the overall water conservation program, the current iteration—"WWAP version 1.0"—was under review by Michigan's Water Use Advisory Council.[28] Given how the Supervisor of Wells regulations rest upon the same technical components as the WWAP, upgrades of these components will result in adaptive management processes in both the WWAP and the Supervisor of Wells regulations. While updates and modifications to various parts of WWAP may happen, not all of them relate directly to governance of HVHF activities. This section presents a number of major categories of water withdrawal management. Of course, in order for any of these modifications and alterations to the WWAP to be effective in governing HVHF activities, parallel changes to the WWAP would need to be effectuated in the Supervisor of Wells regulations.

3.2.1 Requirements for water withdrawal approval

Given strong sentiments about water conservation, especially with HVHF operations, one means of regulating such operations would be to have more stringent water withdrawal requirements associated with HVHF.

3.2.1.1 Current regional standards

Pennsylvania requires that any water withdrawal associated specifically with hydraulic fracturing must be approved in the form of a water management plan submitted to the Department of Environmental Protection, regardless of whether the withdrawal occurs on the same property where the gas well is located.[29] The plan must include the location, quantity, withdrawal rate, and timing of the water withdrawal.[30] Furthermore, the plan must show that the withdrawal will not adversely affect the quantity or quality of the water,[31] will protect and maintain existing water uses,[32] and will not cause an ARI to water quality throughout the watershed,[33] as well as include a reuse plan for the hydraulic fracturing fluids.[34] Within the Susquehanna River Basin, the Commission regulates all surface and groundwater withdrawals associated with hydraulic fracturing, beginning with "gallon one."[35]

At present, the DRBC has a moratorium on all water withdrawals associated with hydraulic fracturing that has been in place since 2010,[36] a more stringent water withdrawal requirement.

3.2.1.2 Michigan's current policy status

Within the context of Michigan's WWAP, the Policy Zone determination from the WWAT provides the policy action taken, including the determination of an ARI. All water withdrawals are treated equally in determining environmental impact, and all registered and permitted water withdrawals are treated equally under Zone B and Zone C conditions. Finally, there is the formalized—if presently untested—process of Water Users Committees (WUCs) that are in place to determine how water withdrawals ought to be managed under conditions of water scarcity with the possibility of the DEQ requiring water permit holders to diminish their withdrawals.

HVHF-related water withdrawals are technically exempt from regulation under the WWAP framework, but are governed by the Supervisor of Wells (Part 615), which requires all new HVHF water withdrawals be run through the WWAT and that no new withdrawals can create an ARI, as determined by an SSR. Furthermore, the current regulations require that no HVHF withdrawal can cause a Zone B in cold-transitional systems or a Zone C in other waterways, unless water conservation measures are implemented or unless the HVHF operator obtains a water withdrawal permit.[37] (Note that obtaining a water withdrawal permit would place such water withdrawals under the WWAP.)

The current regulations also require additional monitoring requirements for new HVHF water withdrawals. Specifically, the HVHF operator must identify the location of all "available well logs of all recorded fresh water wells and reasonably identifiable fresh water wells within 1,320 feet of water withdrawal location." Furthermore, the applicant must provide "a supplemental plat of the well site showing … the proposed location of water withdrawal wells, [l]ocation of all recorded fresh water wells and reasonably identifiable fresh water wells within 1,320 feet of water withdrawal location(s) or locations, [and p]roposed fresh water pit impoundment, containment, location, and dimensions."[38] Finally, the applicant must provide "a contingency plan, if deemed necessary, to prevent or mitigate potential loss of water availability in the fresh water wells identified…"[39] In addition, "If 1 or more fresh water wells are present within 1,320 feet of a proposed large volume water withdrawal, the [HVHF well permittee] shall install a monitor well between the water withdrawal well or wells and the nearest fresh water well before beginning the water withdrawal. … The [HVHF well permittee] shall measure and record the water level in the monitor well daily during water withdrawal and weekly thereafter until the water level stabilizes. The [HVHF well permittee] shall report all water level data weekly to the supervisor or authorized representative of the supervisor."[40] And finally, "[An HVHF well permittee] shall collect baseline samples from all available water sources, up to a maximum of 10, within a 1/4- mile radius of the well location."[41]

All water withdrawal activities must go through the Supervisor of Wells.

> "[An HVHF well permittee] shall not begin a large volume water withdrawal for a high volume hydraulic fracturing operation without approval of the supervisor or authorized representative of the supervisor. [An HVHF well permittee] shall make a written request for approval to conduct a large volume water withdrawal and shall file the request with the supervisor at least 30 days before the [HVHF well permittee] intends to begin the withdrawal. The [HVHF well permittee] may file the request with the application for a permit to drill and operate a well or may provide the request separately to the supervisor or authorized representative of the supervisor."

3.2.1.2.1: KEEP EXISTING MICHIGAN POLICY FOR WATER WITHDRAWAL APPROVAL

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	The WWAP provides a series of "Policy Zones" to ensure the conservation of water resources. The policy effectively allows only Zone A and Zone B impacts. This means an increased level of conservation in cold and cold-transitional rivers. Increased monitoring of groundwater resources Provides additional information about changes in local water conditions Provides an assessment of initial conditions, which is important for determining the scale of potential impacts	HVHF impacts—which may have a different sort of local impact to water quantities than traditional water withdrawals due to the potential difference in withdrawal rates—will be treated equally as all other withdrawals. Water withdrawals could theoretically be allowed to continue into Policy Zone D. The monitoring is only included in the presence of existing withdrawal wells.
ECONOMIC	Could provide cheap source of water for HVHF operators	
COMMUNITY	WUCs present a means for local governance of water withdrawals among registered users. Applicant must identify all existing water withdrawal wells within ¼ mile of their proposed wells. Greater information provides more capacity to make local water decisions.	No WUCs have been implemented to date. No evidence exists that a radius of ¼ mile is sufficient in protecting existing water withdrawals in the region.
GOVERNANCE	Pumping within Policy Zone C is not allowed, unless an applicant can successfully obtain a water withdrawal permit. Diminishes the number of SSRs (see Box 3.1). Greater information provides DEQ with more reliable information of local water resources, improves SSR process, and provides more time to make a notification of Zone C or ARI. Will require all HVHF large water withdrawals be filed with and approved by the Supervisor of Wells	Unclear if a rejection of an ARI-causing HVHF withdrawal could stand a legal challenge

3.2.1.2.1 Keep existing Michigan policy for water withdrawal approval

Although HVHF water withdrawals are technically not a part of the WWAP, existing Michigan policy requires all new HVHF water withdrawals be run through the WWAT, that no withdrawal create Zone C (Zone B in cold-transitional waterways), the identification of all nearby groundwater wells, installation of groundwater monitoring wells, and submittal all requests through the Supervisor of Wells.

3.2.1.2.2: REVERT TO PREVIOUS MICHIGAN POLICY FOR WATER WITHDRAWAL APPROVAL		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL		Would diminish the amount of groundwater monitoring Would allow cold-transitional waterways to reach Zone B and all other waterways to reach Zone C
ECONOMIC	Would diminish the costs of conforming to regulations	
COMMUNITY		Would not require the identification of existing groundwater wells near an HVHF operation
GOVERNANCE	Simplifies the requirements associated with HVHF water withdrawals	Is based on Supervisor of Wells instruction, and not a set of formalized regulations

3.2.1.2.3: DISALLOW ANY HVHF OPERATIONS WITHIN A COLD TRANSITIONAL SYSTEM		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Would provide additional protections for the most fragile river systems in the state	In regions with many cold-transitional systems, water for HVHF will likely be trucked in.
ECONOMIC		Could increase costs associated with water acquisition
COMMUNITY	Ensures water withdrawals are held for local community uses	Will increase trucking if HVHF operations are within a cold-transitional watershed
GOVERNANCE	Simplifies the registration process for HVHF operations by creating an absolute ban on an entire class of river systems	

3.2.1.2.4: MAKE CONSERVATIVE ESTIMATES OF HVHF WATER WITHDRAWALS		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Would provide increased level of water conservation protections	
ECONOMIC		HVHF operators might need to pay for baseline measurements to use in an SSR, if an SSR is required.
COMMUNITY	Assures a greater quantity of water uses for local communities	Could increase trucking if HVHF operations are within a cold-transitional watershed
GOVERNANCE	Would provide additional assurance against massive impacts to local systems, given the current WWAT	Could lead to more SSRs

3.2.1.2.2: Revert to previous Michigan policy for water withdrawal approval

The current Michigan regulations were only recently implemented, and it is useful to assess the previous HVHF water withdrawal regulatory structure. Previously, HVHF regulation in Michigan was based on the Supervisor of Wells Instruction 1-2011, which required that all new water withdrawals use the WWAT to assess the potential impacts of their water withdrawal. The Instruction also made the statement that the Supervisor of Wells would not allow any water withdrawal that would cause an ARI to go forward. However, the instruction was not a formalized regulation.

3.2.1.2.3 Disallow any HVHF operations within a cold-transitional system

Cold-transitional systems have the lowest allowable water withdrawals, require an SSR be conducted for any Zone B withdrawal, and lack any designation of Zone C. Due to public concern about the impacts of HVHF activities on water availability, and due to the inherently fragile nature and special conservation concern associated with cold-transitional systems, a complete ban on HVHF operation in cold-transitional streams could be implemented within the Supervisor of Wells regulations.

3.2.1.2.4 Make conservative estimates of HVHF water withdrawals

Since HVHF water withdrawals are considered by the public to be a special kind of water withdrawal that is wholly consumptive,[42] one way to be conservative when assessing their impacts is to overcompensate for their proposed withdrawal when running the WWAT. Multiplying the proposed withdrawal rate by a safety factor would provide an additional level of safety and assurance to the public when assessing the potential impacts from HVHF water withdrawals. Being conservative when assessing potential impacts to waterways could be a benefit for HVHF operators, since the go-ahead by the WWAT of any proposed HVHF water withdrawal would be even greater indication that no ARIs would result. Furthermore, if an SSR is required (see Box 3.1), then the DEQ would be able to assess any possible impacts due to local conditions and actual project numbers.

3.2.2 Water withdrawal regulation thresholds

The Great Lakes Compact, under which Michigan's WWAP operates, requires a threshold for regulation of 70 gpm for achieving water conservation. However, in a recent assessment of watershed-wide impacts of unregulated rates of sectoral water withdrawals just below the threshold,[43] the 70 gpm rate was shown to lead to significant rates of unregulated water consumption that would be banned, but for the minimum threshold rate.[44] Given that there is no significant physical difference between pumping rates of 69 gpm and 70 gpm and given that a minimum regulatory threshold provides a behavioral choice in maximizing returns by approaching the threshold but not crossing it, a widely adopted maximization of a relatively generous (physically speaking) water withdrawal rate of 70 gpm would create a system-wide condition of non-conservation, which goes against the goals of the Compact. Some regions have chosen lower regulatory thresholds, which could be adopted in Michigan.

3.2.2.1 Current regional standards

While all Great Lakes states comply with the common standard required by the Great Lakes Compact, some states have lower thresholds for registration, based on a shorter time-period, such as Ohio, which uses a one-day standard,[45] or a lower withdrawal rate, such as Minnesota, which uses a 7 gpm threshold,[46] with an additional threshold of no more than 1,000,000 gallons per year for a "low use permit"[47] (note that many residential wells operate at pumping rates between 10 and 20 gpm).

In addition, some Great Lakes states do not have an option for registration of high volume water withdrawals, requiring permits for all such withdrawals. In New York[48] and Wisconsin,[49] a permit is required if water withdrawal rates exceed an average of 70 gallons per day over a 30-day period for users within the Great Lakes Basin[50] and an average of 1,388 gpm over a 30-day period statewide.[51] In Pennsylvania and New York, river basins that are part of other regional water compacts (i.e., the Susquehanna and Delaware River Compacts) require the obtainment of water withdrawal permits based on those compacts' standards (14 gpm[52],[53] and 7 gpm,[54],[55] respectively).

3.2.2.2 Michigan's current policy status

Currently, the WWAP requires the registration of a large quantity withdrawal, specifically defined as "[one] or more cumulative total withdrawals of over [70 gallons of water per minute] average in any consecutive 30-day period that supply a common distribution system."[56] At the time of the creation of the WWAP, this limit was discussed in the public as a threshold that might be higher than could reasonably conserve water resources,[57] and a modeling assessment of the Muskegon River watershed, the 70 gpm threshold level was demonstrated to provide little regulatory oversight while being non-conservative when widely adopted.[58] In the same analysis, the lower threshold of 7 gpm—used in Minnesota[59]—was shown to provide a far greater level of regulatory oversight, despite also being mildly non-conservative.

In order to conserve all water resources of the state equivalently, any significant volumetric withdrawal of water, withdrawn for any length of time, ought to be understood to be equivalent to any other significant volumetric withdrawal, regardless of the purpose to which that withdrawal will be put. Indeed, the modeled impacts of water withdrawals at just below 70 gpm (as well as at just below 7 gpm) in the Muskegon River shows that ARI conditions could easily result at volumes just below the regulatory threshold.

The Supervisor of Wells regulations require that all HVHF water withdrawals use the WWAT and conform to specific actions based on the resulting Policy Zone assessment.

3.2.2.2.1: KEEP EXISTING MICHIGAN POLICY FOR WATER WITHDRAWAL REGULATION

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Requirement to run all water withdrawals through the WWAT No water withdrawal can cause an ARI or Zone C (Zone B in cold-transitional waters).	Cumulative maximized unregulated withdrawals can have significant physical impacts on rivers.
ECONOMIC	No additional costs	No additional revenue to address HVHF issues
GOVERNANCE	Continued inclusion of HVHF withdrawals in assessing water availability for other users within the WWAP	Potential major shortfalls in DEQ's capacity to manage significant water withdrawals

3.2.2.2.2: LOWER THRESHOLDS FOR REGULATION

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Greater oversight over the total numbers of water withdrawals can lead to better awareness of an impending ARI.	Possibility of overland transport means increased environmental impacts associated with trucking.
ECONOMIC	Greater funds to DEQ due to increased number of registrations	Increased costs associated with more people having to register more types of withdrawals
COMMUNITY	Increased information about local water resources	May lead to more overland transport of water to site
GOVERNANCE	Greater oversight over the total amount of water in each watershed	Some HVHF water withdrawals might not fall within reporting criteria. Greater oversight will require greater agency capacity commensurate with the increased number of withdrawal operations to be registered in the system.

3.2.2.2.1 Keep existing Michigan policy for water withdrawal regulation

The current Supervisor of Wells regulations require all HVHF water withdrawals be run through the WWAT to determine whether they will cause an ARI. Furthermore, no water withdrawal can be made if it is deemed to cause a Zone C flow (or a Zone B flow in cold-transitional rivers), unless the operator will engage in water conservation measures.

3.2.2.2.2 Lower thresholds for regulation

Any large-scale water withdrawal could be managed in such a way as to take maximum advantage of the regulatory thresholds by optimizing (1) the duration or (2) pumping rate of the water withdrawal. By diminishing the duration threshold or water withdrawal rate threshold, the WWAP would effectively increase the oversight on water conservation within the state by requiring more water uses to be registered. Other states and regions already have lowered regulatory thresholds for pumping duration (e.g. New York) and pumping rate (e.g. Minnesota). Any lowered threshold would lead to an increased number of registrants, which would require an increase in DEQ capacity commensurate with that increase in order for the agency to meet its statutory requirements under the WWAP.

HVHF APPLICABILITY: In order to maintain parallel regulations, the Supervisor of Wells regulations can be modified to match the WWAP

Box 3.4 Groundwater withdrawal, geographic scale, and the concept of consumptive use

The concept of consumptive use of water is generally defined as the withdrawal (and use) of water that does not return to the local or regional hydrologic system. The USGS defines consumptive use as, "water that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from an immediate water environment."[61] Within the Great Lakes Compact, consumptive use is never defined, but the Compact does require all states (including Michigan) to "develop and maintain a compatible base of Water use information … [of] any Person who Withdraws Water in an amount of [70 gpm] or greater average in any 30-day period (including Consumptive Uses)."[62] The Great Lakes Compact and the WWAP (and, by extension, the Supervisor of Wells regulations) are concerned with consumptive uses at larger spatial scales, and what might be considered non-consumptive at this large scale can change at spatially smaller (and temporally shorter) scales.

One of the major stated concerns voiced over water withdrawals associated with HVHF is that the water use is consumptive; all the water is to be deep well injected, and no water used in HVHF is supposed to return to the immediate hydrologic cycle of the Great Lakes. This meets the technical and legal definitions of consumptive use. However, at the local scale where most concern is stated, there may be little physical distinction between a withdrawal for drinking water (regionally non-consumptive, locally consumptive) and an equal-sized withdrawal for HVHF (regionally and locally consumptive). Both withdrawals would remove the same volume of water from a subwatershed and return none of that water back to that same subwatershed. Analogously, waters withdrawn for agricultural uses are partially consumed (being incorporated into the crops or evaporating away) and with a relatively small percentage returning to the local groundwater. While the comparable utility of water uses can be debated, from a volumetric standpoint, any large-scale water withdrawal (whether it is for drinking water, mine dewatering, agriculture, or HVHF operations) can create consumptive use effects ***at the local scale***.

From a physical perspective, the argument that HVHF water withdrawals will have a substantially different ***local*** consumptive-use impact to groundwater than any other water withdrawal ***of the same rate*** is not generally valid. A more generally valid argument about the effects of consumptive use could be made at ***larger scales***. With regard to consumptive uses and existing water governance, many consumptive water withdrawals are required to be registered (agriculture and industry are classic examples with significant consumptive use). What the WWAP and the Supervisor of Wells regulations do is allow for a certain level of withdrawal and utilization of waters in every subwatershed, with incrementally greater management and governance actions. Within their shared framework, all registered water withdrawals are treated as impacts based on their withdrawal rates and durations, not on the purpose of the withdrawal.

3.2.2.2.3: METER HVHF WATER WITHDRAWAL WELLS

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Increased oversight over the changes in available water resources	
COMMUNITY	Greater detail of information about water resource availability, leading to possibility for better planning	
GOVERNANCE	Increase the temporal resolution of monitoring water resources in the state	Increased data management costs Increased rates of data collection from regions of relatively constant water use may have lower utility.

3.2.2.2.4: SET TOTAL VOLUMETRIC WATER WITHDRAWAL LIMITS

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	May improve water conservation by placing an additional cap on water withdrawals	May create incentives to conduct a series of several unregulated withdrawals, which cumulatively could cause significant environmental impacts
ECONOMIC		Can increase costs for obtaining water for HVHF operations
COMMUNITY	Can limit the impacts from HVHF in any one subwatershed unit	Can increase trucking of water from other subwatershed units

limits. HVHF operators, like other large-scale water users, would have less ability to optimize their water withdrawals to fall below regulatory thresholds. More HVHF water uses will be registered, providing more public knowledge of water use and water availability.

3.2.2.2.3 Meter HVHF water withdrawal wells

Due to the shorter period of water withdrawals associated with HVHF, the Supervisor of Wells regulations could require HVHF water withdrawal wells be metered. In this way DEQ could be provided with real-time water withdrawal data that could directly be monitored against reported withdrawal rates, downstream river discharge measurements (both private[60] and public), and reports of potential ARIs.

3.2.2.2.4 Set total volumetric water withdrawal limits

Total volumetric water withdrawal limits could be imposed for HVHF operations. A maximum 30-day withdrawal volume could be set for withdrawal operations, which could mimic the threshold structure for obtaining a water withdrawal permit, save for shifting the withdrawal time period to 30 days from 90 days. In order to maintain parallel regulations, the Supervisor of Wells regulations can be modified to match the WWAP limits.

3.2.3 Improvements to the WWAT

The WWAT relies on a series of models, including a surface water hydrology model,[63] a groundwater hydrology model,[64] and a fish population model.[65] (see Figure 3.1). Although these models and the associations between them are robust, they are each only as good as the data that defined them and the assumptions used in making them. As the scientific understanding of Michigan's water resources improves, it would be useful for these improvements to be included in the management of the state's waters.[66] The WWAT was meant to provide a common technical platform for water governance within the state that is calibrated, validated, and peer-reviewed. Furthermore, it forms the central piece of the WWAP as well as the Supervisor of Wells regulations concerning HVHF water withdrawals.

The WWAT was developed in 2008 to serve as the first iteration of an assessment tool that would operate one part of the larger water withdrawal assessment process. The WWAT is based on a series of statistical models and relationships between groundwater, surface water, and fish ecology that have a strong scientific basis. However, it is important to recognize the limitations of what was meant to be the first version of an automated assessment tool, not the be-all-end-all.

As it currently stands, the WWAT is designed to assess the expected impacts of large-volume and persistent water withdrawals from groundwater, and is best able to predict the changes in characteristic fish populations of medium- and large-sized rivers. In contrast, smaller rivers and streams—especially headwater systems—often have the least amount of data, creating greater levels of uncertainty within the WWAT models.[67] This is purely a function of the type of data that was used to initially create the various models of the WWAT, which predict cumulative stream flow depletions after 5 years of pumping, with the assumption of the shallow aquifer being unconfined. Presently, updates to the model components of the WWAT are only legislated as corrective updates to the predictions via SSR[68] and as updates to the water accounting.[69] Although vague language in the law states there be regular updates, it does not specify the manner, degree, or regularity of these updates.

In its current iteration, the WWAT does not directly consider all impacts to ponds, lakes, and wetlands,[70] simply because the underlying models do not apply to water bodies that are not directly connected to streams and rivers, even though the Great Lakes Compact is also specifically meant to conserve these waters as well. An improvement to the WWAT so as to include these additional water bodies would improve the standard of the existing WWAT.

3.2.3.1: KEEP EXISTING MICHIGAN WWAT

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Water conservation of the entire state via a scientifically robust, online water withdrawal assessment tool	Potential for misallocation of available water resources due to assumptions in the models of WWAT
ECONOMIC	The impacts of a proposed high-volume water withdrawal are immediate and free-of-charge.	
COMMUNITY	Information about local water uses is available via the tool.	
GOVERNANCE	Clear mechanisms for policy action at different levels of cumulative water withdrawal	Current WWAT does not adequately address HVHF-type water withdrawals.

3.2.3.2: UPDATE THE SCIENTIFIC COMPONENTS OF WWAT

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Updated models will provide a mechanism to assess the impacts of a greater range of water withdrawal types, including high-volume, short-term water withdrawals characteristic of HVHF.	The time required for developing new scientific models will likely be longer than the timeline for initiating HVHF operations.
ECONOMIC	Improved models can provide better knowledge of available water resources in a subwatershed unit, improving operational efficiency and diminishing operating costs.	Will cost money to develop new scientific models
HEALTH	Linkages of water quantity models with water quality models could improve monitoring around the state.	Currently, water quality is managed outside the framework of the WWAP.
COMMUNITY	Improved scientific models could provide better knowledge of local water resources, thus improving the capabilities of WUCs.	
GOVERNANCE	Will improve WWAT to include impacts of high-volume, short-term withdrawals, removing the need for proxy metrics	May uncover problems with overallocation associated with the current version of WWAT Could redefine subwatershed units as more restrictive river types, creating immediate problems of overallocation

3.2.3.1 Keep existing Michigan WWAT

The current WWAT functions adequately to meet the needs it was developed to address in 2008. Not changing the WWAT means that the 2008 water quantity measures, the current regulatory subwatersheds, and the existing Policy Zone determinations thresholds are maintained. Retaining the current WWAT would thus minimize any disruptions to statewide water management that will inevitably occur once updates and improvements are initiated.

HVHF APPLICABILITY: The current WWAT may not adequately address the water withdrawal profiles associated with HVHF. The WWAT predicts cumulative impacts over 5 years of pumping from an aquifer assumed to be unconfined. This could mean that local impacts to water quantity may diverge from the predictions of the current WWAT, with some predictions being overestimates of stream flow impact.

3.2.3.2 Update the scientific components of WWAT

The predictions of the WWAT rely on existing hydrologic and fish data, but the richness of the ecological and hydrological implications of HVHF on Michigan waters are not yet accounted for. There are many ways of updating the scientific components of WWAT. These include requiring updates to the scientific dataset within the WWAT whenever an SSR is conducted, updating the underlying groundwater model to a numerical model that could better capture the local hydrogeological conditions, and building models to assess the impacts of water withdrawals to lakes and wetlands.

Updating the values for each relevant component whenever an SSR is conducted could act as a means of improving portions of the WWAT as different parts of the state undergo SSRs. Although such updates would be useful in slowly improving the characterization of individual watersheds, it does not change the underlying models.

A major option for improving the WWAT would be to upgrade the components that make up the tool. These options could include implementing assessments based on numerical models of groundwater flows. Numerical models would be able to assess the impacts of short-term, high-volume water withdrawals characteristic of HVHF, but they need further development. Furthermore, these could be created to be more representative of the hydrogeological conditions found within a system, instead of making conservative estimates that allow for assessments to be valid across the entire state. Test cases of different groundwater models are being piloted, especially in southwest Michigan, which may offer better assessments in that region in the future.

Finally, the expansion of the WWAT to include models of impacts to lakes and wetlands would meet the requirements of water conservation already mandated in the WWAP and provide a consistent assessment framework across all waters.

HVHF APPLICABILITY: The effects of water withdrawals from HVHF operations would be better modeled with mechanistic models that can account for short-term, high-volume water withdrawals, which are not adequately captured in the current models of the WWAT.

The geographic area associated with projected future HVHF activity (i.e., the northern Lower Peninsula) has many lakes and wetlands that are crucial for the tourism industry. An understanding of the impacts of high volume fracturing to the lakes and wetlands of these areas could provide a crucial planning tool for local residents and government units.

Finally, upgrades to the WWAT will directly affect HVHF water withdrawals, since the Supervisor of Wells regulations concerning such withdrawals requires the use of the WWAT. Any improvement of the WWAT to ensure water conservation will be beneficial for HVHF operators as well.

3.2.3.3: IMPLEMENT A MECHANISM FOR UPDATING THE MODELS UNDERLYING WWAT

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Providing mechanisms to update WWAT will provide for strategies to improve water conservation models that underlie the assessment tool.	If mechanisms for updating all significant functions of the WWAT are not enabled, future updates will have a limited impact on water conservation.
ECONOMIC	A standardized and defined mechanism for updating the state's water withdrawal regulatory mechanism creates a predictable timeline and process of updating and managing. Greater predictability provides better planning for businesses.	
COMMUNITY		Updates to water availability models may cause problems with existing registered withdrawals, especially if a subwatershed is redefined as a more conserved river type.
GOVERNANCE	Provides mechanisms to keep the WWAP adaptive Will provide a mechanism to deal with redefinitions of river type that could result in determinations of overallocation	Not a direct means of addressing HVHF water withdrawals

3.2.3.3 Implement a mechanism for updating the models underlying WWAT

At the present time, the only ways that the WWAT can be updated are through an SSR (which alters the determination of remaining water availability and/or the river type) and through the automated water accounting (which updates the remaining water availability and concomitant Policy Zone designation). If the models that underlie the WWAT—like any technology—are to undergo periodic updates to ensure high-quality decision making, legislation should be passed that explicitly provides a mechanism by which the DEQ can assess and implement new water governance models that incorporate the best scientific tools available.

HVHF APPLICABILITY: The type of water withdrawal associated with HVHF—short-term and high-volume consumptive withdrawals—were not envisioned during the development of the WWAT. Furthermore, no mechanism for incorporating modeling updates that could address such withdrawals was included in the WWAP. In order to address this new form of water withdrawal under a governance framework consistent with other large-scale water withdrawals, the WWAT would need to be updated, and to do so, a formal process of assessing model updates would need to be provided to DEQ, a task that could be undertaken by a future Water Use Advisory Council.

3.2.4 Water withdrawal fee schedules

One way in which those who stand to gain significantly from publicly held resources can be made to help defray the public's payment of their oversight of their acquisition and private profit of a public resource is through the imposition of a fee schedule. In the case of water quantity withdrawals, various types of fees have been used in other Great Lakes and Eastern states to defray the costs of government oversight, pay for research, and fund public projects to improve water security within the governed watersheds.

3.2.4.1 Current regional standards

Water withdrawal fee schedules are implemented for all water withdrawal projects above 14 gpm in the Susquehanna River basin and projects above 7 gpm in the Delaware River basin, based on the proposed water withdrawal rate and the type of project in addition to planning fees and annual water use fees. In addition Minnesota imposes fees based on a combination of total annual water withdrawals and the seasonality the water withdrawal.[71]

The SRBC has several project categories, including consumptive water uses from 14 gpm to over 3,400 gpm, surface water withdrawals from 70 gpm to over 6,900 gpm, groundwater withdrawals from 70 gpm to over 6,900 gpm, and diversions into and out of the basin, as well as a number of preparatory assessments. For illustrative purposes, a new groundwater withdrawal of 14 gpm (i.e., the minimum threshold for regulation) of private consumptive use, the SRBC would require an aquatic resource survey ($6,800), a pre-drill well site review ($2,250), an aquifer testing plan ($4,650), a groundwater withdrawal fee ($6,125), and a consumptive water use fee ($3,000), totaling $22,825.[72]

In contrast, the DRBC charges project review fees based on the cost of the project, and whether the project is private or public. Private projects costing between $250,001 and $10,000,000 are charged 0.4 percent of the project cost (i.e., between $1,000 and $40,000), with fees doubled for out-of-basin diversions.[73]

In comparison, Minnesota charges based on a combination of annual water withdrawal volume and the season of the water withdrawal. For example, total annual water withdrawals of less than 50,000,000 gallons have an associated fee of $140 (i.e., the lowest rate). If, however, the withdrawal occurs solely during the summer months, an additional $90 (i.e., $30 per million gallons withdrawn above the rate withdrawn in January) would be added to the fees. Minnesota does also include a fee for "one-through heating and cooling systems" which would amount to an additional $420 per million gallons of water, if an HVHF operation were to use water for that purpose.

3.2.4.2 Michigan's current policy status

Presently, Michigan requires an annual $200 water use reporting fee for all registered water withdrawals[74] (save for agricultural water users and water withdrawals of less than 1.5 million gallons per year) and a fee of $2,000 for obtaining a water withdrawal permit.[75] (See Table 3.1) Michigan imposes no additional water withdrawal fees apart from these two fees. Water withdrawals that are exempt from the WWAP—such as hydraulic fracturing—do not have to pay these fees.

3.2.4.2.1 Keep existing Michigan water withdrawal fees

The current fee requirements—$200/year for registration, $2,000 for a permit—are relatively low compared to river basin commissions that actively govern water use. Given the number of registrations—over 2,500 registrations since 2009—Michigan currently receives roughly $500,000/year by registrants (assuming water withdrawals are not discontinued) alone.

HVHF APPLICABILITY: HVHF operators do not have to pay water withdrawal-related fees for registration under the WWAP, since these activities are exempted from the WWAP. If an HVHF operator seeks to obtain a water withdrawal permit, they would have to pay the $2,000 fee associated with a permit.

3.2.4.2.1: KEEP EXISTING MICHIGAN WATER WITHDRAWAL FEES

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL		A lack of water withdrawal fees or schedules does not create incentives for considering water conservation mechanisms.
ECONOMIC	No water withdrawal fees for HVHF operators, unless operators obtain a water withdrawal permit	Fees will unlikely cover the additional costs of personnel and monitoring that will be required to ensure the quality of DEQ oversight.
GOVERNANCE		A glut of registrations into WWAT could require SSRs—which must be completed on a legally defined schedule (see Box 3.1).

3.2.4.2.2: INCLUDE HVHF WATER WITHDRAWALS WITHIN THE CURRENT FEE SCHEDULE

	STRENGTHS	WEAKNESSES
ECONOMIC		Additional cost of $200/year
GOVERNANCE	HVHF water withdrawals will bring additional fees.	

3.2.4.2.3: MODIFY WATER WITHDRAWAL FEE SCHEDULES

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Increased costs associated with conducting large-scale water withdrawals will encourage water efficiency.	
ECONOMIC	Increased revenues for DEQ that can be used to manage and improve WWAP	Increased costs associated with water withdrawals
GOVERNANCE	Projects that are classified as higher risk or higher impact will have greater fees that can be used to offset potential rehabilitation costs. Additional funds can result in the hiring of additional personnel in the Water Resources Division.	Can create greater incentives to under-report or to not report water use

3.2.4.2.2 Include HVHF water withdrawals within the current fee schedule

Include HVHF water withdrawals within the current fee schedule, requiring a payment of $200/year for all years in which water withdrawals are reported to the Supervisor of Wells.

3.2.4.2.3 Modify water withdrawal fee schedules

Instead of a flat-rate, annual reporting fee of $200 for all non-agricultural registered water withdrawal larger than 1.5 MGY, Michigan could institute a fee schedule similar to that used by the SRBC for all water users registering a new or expanded water withdrawal that take into account the volume of water withdrawn, whether the water is for a public or private project, the overall cost of the project, the vulnerability of the surrounding waters, etc.

Another way in which fees could be instituted is project planning fees. Planning fees could be levied against any project deemed to be in areas that are vulnerable to new or expanded water withdrawals. Such areas could include cold-transitional rivers (as defined by the WWAT) and subwatersheds that are in Zone C (or Zone B for cold-transitional rivers). The party that is proposing a new or expanded withdrawal in a vulnerable watershed would be required to pay for planning fees that would allow the DEQ and Michigan Department of Natural Resources (DNR) to conduct site-specific investigations of the expected impacts of the proposed withdrawal.

Another type of fee option would focus on large-scale projects, charging a water withdrawal fee for large-scale water withdrawals based on a percent of the total project's cost, as is done by the DRBC. This would provide the opportunity for additional oversight during and after the commercially viable operation periods of those projects most likely to have a major impact on water resources. These additional fees could thus be used to offset public costs associated with monitoring projects that have potential short and long-term risks to the public well-being.

HVHF APPLICABILITY: An across-the-board fee schedule would subject all registered and permitted water users to the new schedule, in addition to high volume hydraulic fracturing operations. This requirement could be set up through the Supervisor of Wells regulations, and either act in parallel with any fee schedule modification to the WWAP, or independently of it.

Planning fees would provide funds to defray the costs for the DEQ and DNR to address issues of water quantity and watershed vulnerability that are at the forefront of popular concern regarding water resources and HVHF. The completion costs for Chesapeake Energy's existing HVHF projects in various parts of the country ranged from $3,100,000 (in the Mississippian Lime of Northern Oklahoma) to $10,100,000 (in the Powder River Basin of Wyoming).[76] If Michigan were to implement planning fees in line with those of the DRBC, this could bring in as much as $404,000 per private HVHF project.

In contrast, capital-intensive projects that are expected to use large volumes of water, which may include HVHF operations, would be required to pay fees. In order to assure that costs for water withdrawal are not separated from costs for HVHF, the costs of the water withdrawal would be associated with the cost of the project for which the water withdrawals are proposed.

3.2.5 Modify water withdrawal permitting

In areas that use a regulated riparian framework—such as Michigan—the right to withdraw water is associated with property rights. However, those rights are contingent upon the rights of others to also withdraw and use commonly shared water resources. The issuance of a water withdrawal permit provides a guaranteed allowance by the state for a specified amount of water for a specified period of time and for a specified use (subject to certain responsibilities during periods of water shortage). The obtainment of a water withdrawal permit provides additional certainty in individual planning as well as additional governance responsibility under the legal framework that governs the permit.

3.2.5.1 Current regional standards

Various states around the Great Lakes region require water withdrawal permits for proposed withdrawal rates above 70 gpm. For example, in New York[77] and Wisconsin[78], a permit is required if water withdrawal rates exceed an average of 70 gallons per day over a 30-day period for users within the Great Lakes Basin[79] and an average of 1,388 gpm over a 30-day period statewide.[80] In Pennsylvania and New York, river basins that are part of other regional water compacts (i.e., the Susquehanna and Delaware River Compacts) use those compacts' standards (14 gpm[81,82] and 7 gpm,[83,84] respectively) to determine whether a water withdrawal permit is required.

The DRBC effectively enacted a ban on the issuance of water withdrawal permits for hydraulic fracturing operations until rules were made regarding water withdrawals for hydraulic fracturing.[85] As of the writing of this report, no new rules have been accepted by the DRBC, thus effectively halting hydraulic fracturing expansion within the Delaware River basin since 2010. This is an extreme example of a modification of water withdrawal permitting.

3.2.5.2 Michigan's current policy status

Currently, Michigan requires registration of all proposed water withdrawals with an average withdrawal rate larger than 70 gpm over a 30-day period[86] and requires a water withdrawal permit for water withdrawals greater than 1,388 gpm.[87,88] Water withdrawal permits are also required for withdrawals greater than 70 gpm if the water is moved between watersheds[89] or if the withdrawal is greater than 694 gpm in a Policy Zone C area.[90] One exception is if the withdrawal is less than 1,388 gpm and occurs in a period of less than 90 days[91] (which is considered a "seasonal withdrawal"). Water withdrawal permits can be obtained for withdrawals less than 1,388 gpm, if the property owner wishes to obtain a water withdrawal permit. At present, the issuance of a water withdrawal permit for its stated purpose is considered to not cause an ARI,[92] but permit holders are the first group that the DEQ can require

3.2.5.2.1: KEEP EXISTING MICHIGAN POLICY FOR WATER WITHDRAWAL PERMITTING

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Regulation of all HVHF water withdrawals and effectively all other water withdrawals greater than 70 gpm	
ECONOMIC		Little need to obtain a water withdrawal permit for most individual HVHF operations
COMMUNITY	All water permits governed by WWAP No water withdrawal use has preference	Very few cases of certain water withdrawal behaviors having precedence over others
GOVERNANCE	Mechanism for local water users to determine their own water uses	Little capacity for the DEQ to enforce behavioral changes among non-permitted users

3.2.5.2.2: PROHIBIT HVHF OPERATIONS FROM OBTAINING A WATER WITHDRAWAL PERMIT

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL		HVHF operators may "shop around" for sources of water; may increase overland transport of water. Registration process is less conservative than permit process.
GOVERNANCE	Will simplify water governance	Permit process would have placed HVHF water withdrawals under WWAP framework.

diminish their withdrawals if there is a determination of an ARI.[93]

Technically, HVHF operations are exempt from the provisions of the WWAP, unless they request a water withdrawal permit. HVHF operators must, however, use the WWAT to assess the potential impact of their water withdrawals, cannot create Zone B withdrawal in a cold-transitional waterway or a Zone C withdrawal elsewhere, and must report all water withdrawals to the Supervisor of Wells.[94] If a proposed HVHF withdrawal is expected to cause a Zone C or D impact (or Zone B or D impact in cold-transitional waterways), the operator can apply for a water withdrawal permit, and this would place such withdrawals under the WWAP.

Finally, individual riparian users in Michigan continue have a right to contest any finding of an ARI, SSR decision, or permitting decision under historic common law water rights and property rights.[95] At the present time, however, the use of the WWAP has not been tested in court.

3.2.5.2.1 Keep existing Michigan policy for water withdrawal permitting

Currently, Michigan requires obtaining a water permit for withdrawals greater than 1,388 gpm (or 694 gpm in a Policy Zone C area or 70 gpm for intrabasin water transfers), and allows property owners to seek permits for smaller large-quantity withdrawals.

3.2.5.2.2 Prohibit HVHF operations from obtaining a water withdrawal permit

Presently, an HVHF operator can obtain a water withdrawal permit if assessments of their proposed water withdrawals indicate a Zone C or Zone D impact. Setting a ban on HVHF operators from obtaining a water withdrawal permit could be seen as one way to protect watersheds that are approaching an ARI. Such a ban would require HVHF operations keep their water withdrawal rates below 1,388 gpm (or less in specific conditions; see Table 3.1), and register that withdrawal rate through the Supervisor of Wells. However, the requirements of obtaining a water withdrawal permit[96] are generally more rigorous than the mere use of the WWAT and potential SSR. The implementation of this policy option, while appearing to improve water conservation by setting an effective maximum cap, could result in reduced water conservation by removing a more conservative pathway of obtaining water (i.e., permitting) and leaving as the only available option the generally less rigorous registration process.

3.2.6 Transfer/sale/lease of water withdrawals

In order for HVHF wells to operate, they must have access to a supply of water. Due to possible hindrances that might arise in the legal/regulatory landscape as a public response to HVHF, companies might opt for obtaining water through a pre-existing registered withdrawal or permit. Given the concern surrounding the local impacts of water withdrawals associated with HVHF, providing rules for transferring, selling, or leasing registered water withdrawals or water withdrawal permits would give local water users the ability to negotiate with HVHF operators to coordinate water withdrawals so as to minimize local impacts. The state could use existing water assessment tools to ensure that local water users are provided with the publicly available tools to help make decisions using the best publicly available information.

Such negotiations could also be beneficial for HVHF operators, since they would not need to apply for additional water withdrawals, or the volumes of water withdrawals they apply for would be off-set by the volumes of use they negotiate with local users.

3.2.6.1 Current regional standards

Within the context of regulated riparianism (i.e., Eastern states), water rights are not privately held (as they are in prior appropriation/Western states). As such, the transfer, sale, or lease is not of the water, nor of the right to the water itself, but of the use of water through a registered or permitted withdrawal (and subject to the limitations placed on that registration or permit). The SRBC recognizes the possibility that a private water permit holder might sell a portion of their permitted water withdrawal to a hydraulic fracturing operation located on their lands.[97]

3.2.6.2 Michigan's current policy status

Michigan currently has no law about the transfer, sale, or lease of registered or permitted water withdrawals. However, under current Michigan law, the sale of unprocessed water is illegal. Furthermore, obtaining a water withdrawal permit (which is required for nearly all proposed water withdrawals larger than 1,388 gpm) requires that the use of the permit is "implemented so as to ensure that it is in compliance with all applicable local, state, and federal laws…,"[98] which may include a prohibition on transfers, sales, or leases of the permit.

3.2.6.2.1: KEEP EXISTING MICHIGAN POLICY FOR TRANSFER/SALE/LEASE OF WATER WITHDRAWALS

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL		Effectively no economic incentives for water conservation and water management
ECONOMIC		No water-use market exists
COMMUNITY		Communities do not have an economic means of managing their water resources
GOVERNANCE	Keeps water law simple	

3.2.6.2.2: PROVIDE A MECHANISM TO TRANSFER, SELL, LEASE REGISTERED/PERMITTED WATER WITHDRAWALS

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Provides an economic framework for water conservation	
ECONOMIC	Creates the opportunity for the creation of a water-use market	No previous experience with water or water-use markets The price for water-use is not set.
COMMUNITY	Provides communities with an additional mechanism for determining water uses	
GOVERNANCE		Need to continue to distinguish between water (a physical commodity that may not be sold) and water-use (a negotiated service that can be leased)

3.2.6.2.1 Keep existing Michigan policy for transfer/ sale/lease of water withdrawals

Throughout all the statutes associated with the WWAP, all responsibilities and liabilities associated with water withdrawals belong to the property owner.

HVHF APPLICABILITY: The Supervisor of Wells regulations refer to HVHF permittees, and the language implies that the permittees must register their withdrawals or obtain their own water withdrawal permit.[99] This means that they must be property owners where the water withdrawals take place.

3.2.6.2.2 Provide a mechanism to transfer, sell, lease registered/permitted water withdrawals

Although direct sales and trading of water in Michigan is not legal, since water as a natural resource cannot be owned, it could be possible to set up a system in which local water users negotiate—either monetarily or through other mechanisms—with other users in a common subwatershed (as delimited by the WWAT) as to acceptable levels and limits of water withdrawals. Since the WWAT effectively creates a "cap" within each delineated subwatershed in the state, it has effectively signaled the creation of an upper limit of usable water. Furthermore, Michigan's regulated riparianism structure of water law allows any water user "reasonable use" of the water. Given the cap created by WWAP and the simultaneous provision of reasonable use, such an outcome of a "water-use market" appears inevitable. Indeed, given the broad authorities of WUCs to negotiate mechanisms governing local water withdrawal behaviors, it is possible to that such committees could set up negotiated systems of water use based—in part or in whole—on market forces, so long as any transfer of a right to withdraw water also meets the water conservation requirements of the WWAP.

HVHF APPLICABILITY: The creation of a mechanism to transfer, sell, or lease a registered or permitted water withdrawal will provide local residents with options and opportunities to negotiate with HVHF operators to obtain water within a subwatershed unit over a relatively short period of time without implementing a new or increased water withdrawal. Due to the regulations of HVHF water withdrawals falling outside of the WWAP, specific rules would need to be included in the Supervisor of Wells regulations to allow for the use of water withdrawals registered under the WWAP.

3.2.6.2.3 Prohibit transfer or use of registered water withdrawals to HVHF operations

If Michigan were to provide a mechanism for transferring, selling, or leasing existing registered or permitted water withdrawals, then there could be a specific ban in the Supervisor of Wells regulations on transferring already existing registered or permitted water withdrawals to HVHF operations.

3.2.6.2.3: PROHIBIT TRANSFER OR USE OF REGISTERED WATER WITHDRAWALS TO HVHF OPERATIONS

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL		May create diffused water withdrawal operations, which will increase overland transportation May cause more watersheds to approach ARI status as HVHF operators seek to maximize withdrawals within a subwatershed
ECONOMIC		Removes a mechanism for creating economic incentives for water conservation
COMMUNITY	Removes the possibility of communities suffering from the negative consequences of making water-use contracts based on inherently constrained levels of information	Removes the possibility for direct community negotiation with HVHF operators over water resource access and use
GOVERNANCE	Each water user must obtain their own permit or registration Keeps water management simple	

3.2.7.1.1: KEEP EXISTING MICHIGAN POLICY FOR MONITORING

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	SSRs required for all cases where a potential for an ARI is high, thus improving water conservation regulations	All potential harms must be witnessed and observed in situ. Only neighbors can request an SSR from the DEQ.
COMMUNITY		Communities will only have self-reported annual numbers to indicate the condition of water resources.
GOVERNANCE		On-the-ground ARIs will not be assessed until after they have happened.

3.2.7 Additional monitoring

Public concern over potential impacts in much of the areas where HVHF will take place stems from concern that watersheds may be overallocated, due to errors in the predictions of water available made by WWAT.

3.2.7.1 Michigan's current policy status

At present Michigan has the SSR mechanism to deal with potential overallocation of and related impacts to water resources. SSRs are required when a subwatershed is determined to be in Zone C (or Zone B for cold-transitional systems).

In addition to a SSR, a complaint investigation can be initiated by existing registrants and permit holders if an ARI is suspected to already be occurring.[100] Petitions of suspected ARIs can be reported to the DEQ's Water Resources Division, which will conduct a field assessment. Following a field assessment, several things could happen. If no ARI is determined to exist, then a Policy Zone update may be required. If an ARI is determined to exist due to a non-registered well, then the well operator will be dealt with through the enforcement process.[101] The well operator could also potentially negotiate with the WUC in order to gain access to that water-scarce subwatershed. If an ARI is determined to exist due to a registered well that is withdrawing water at a rate exceeding its registered rate, it must be diminished.

3.2.7.1.1 Keep existing Michigan policy for monitoring

The current WWAP allows for an SSR to be conducted when an ARI is suspected, when a subwatershed unit is found to be in Policy Zone C, or

3.2.7.1.2: REQUIRE SITE-SPECIFIC REVIEWS FOR ALL HVHF WATER WITHDRAWAL PROPOSALS		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Increased numbers of SSRs can provide better environmental information among subwatersheds.	The requirement to complete all SSRs on a pre-determined deadline may negatively impact their quality.
ECONOMIC		Increases time requirement for starting HVHF operations
COMMUNITY	Provides assurances to the community that Zone C and ARI withdrawals are unlikely to happen	
GOVERNANCE	Can improve the data quality in regions where HVHF water withdrawals will take place	SSRs are only as good as the available data and time to conduct them; a lack of quality data or a lack of sufficient time will not lead to an improved assessment of water availability. Will increase the burden on the Water Resources Division to ensure that all SSRs are completed on schedule May incur additional labor costs for DEQ SSRs may cause revisions of some river classifications, thus causing changes in the Policy Zone determinations for those subwatersheds; this may affect existing registered and permitted users.

3.2.7.1.3: PROVIDE A MECHANISM TO USE PRIVATE MONITORING		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Use of private monitoring of water levels will improve water quantity assessments.	
ECONOMIC	No additional public costs for water monitoring	
COMMUNITY	Communities will have greater abilities to monitor the state of their water resources and to inform the state of any significant changes.	Costs for monitoring well installation and monitoring are borne by the community. Costs associated with ensuring data collection standards are borne by the community.
GOVERNANCE	Provides an additional source of water resources data	Will require the creation of data collection standards in order to have such data be used in official SSRs

when a proposed withdrawal would place a subwatershed unit into Policy Zones C or D (see Box 3.1). The applicant for the SSR may provide additional data to support its application. Additional data from non-applicants might be considered by the DEQ in its SSR process, but only if this data meets DEQ's data quality standards. Data that doesn't meet DEQ standards could still be used qualitatively to indicate areas where additional monitoring might be necessary.

3.2.7.1.2 Require site-specific reviews for all HVHF water withdrawal proposals

The process of the SSR involves the DEQ assessing the likelihood of a proposed water withdrawal causing an ARI, given the known data of the subwatershed from which the water is proposed to be withdrawn (see Box 3.1). Given that the majority of expected HVHF operations will take place in an area characterized by many groundwater-fed streams, requiring an SSR for all HVHF water withdrawal proposals can provide an additional assessment of the known condition of the water resources in a particular subwatershed. This requirement may cause additional and significant burdens for DEQ if there is a significant increase in HVHF water withdrawal applications, unless extra resources are given to DEQ or the statute requiring SSRs be completed within 10 days be extended. Such changes would give DEQ the resources necessary to ensure that a higher volume of SSR requests continue to be completed at their current quality.

3.2.7.1.3 Provide a mechanism to use private monitoring

The WWAP allows a water withdrawal applicant to provide data in assessing the condition of water resources in a subwatershed during the SSR process.[102] By expanding the sources of data and monitoring, the DEQ would provide a greater assessment of the impacts of a large-scale water withdrawal associated with HVHF. The DEQ should require similar standards for groundwater monitoring for these private monitoring wells as it does for other wells around the state in order to ensure that the data are measured consistently and objectively. Such standards could be assured through the requirement that specific monitoring well installation and observation are conducted by licensed companies and that reports of private monitoring wells be managed according to specified chains-of-command that mirror other groundwater monitoring activities around the state.

3.2.8 Public engagement on new water withdrawals

The topic of consumptive water withdrawals has historically been a contentious topic throughout the Great Lakes, and was one of the reasons for the passage of the Great Lakes Compact. Within Michigan, a recent public policy poll found that the majority of Michiganders were concerned about the impacts that HVHF would have on local and state water resources.[103] At the present time, water withdrawals below 1,388 gpm do not generally require any local, regional, or state-wide notification, let alone public input. However, without public notification and public engagement, local governance of a shared resource such as water cannot be equitably or openly pursued.

3.2.8.2.1: KEEP EXISTING MICHIGAN POLICY FOR PUBLIC ENGAGEMENT POLICY ON NEW WATER WITHDRAWALS		
	STRENGTHS	WEAKNESSES
COMMUNITY		No public notification of increased water use if nothing requires a permit
GOVERNANCE	Keeps the process simple.	Creates the possibility of surprises, and increased mistrust of the established water withdrawal process Unclear how WUCs would work in conjunction with the Supervisor of Wells regulations

3.2.8.2.2: INCLUDE HVHF OPERATIONS IN WATER USERS COMMITTEES		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Better informed decisions can lead to better environmental outcomes.	
COMMUNITY	Provides community water users with the ability to make further decisions about water uses	There is no existing model of WUCs.
GOVERNANCE	Keeps the management of registered water uses at the local level	There is no existing model of how the DEQ will operate within a WUC. Would provide opportunity for HVHF operators to implement water conservation measures that would be required to operate in an area under Zone C (or Zone B for cold-transitional rivers)

3.2.8.1 Current regional standards

Outside of public notification procedures existing with any public works project, no public notifications are required for new water withdrawal wells that do not require permitting. However, in cases of the issuance of a permit public notification may be pursued. For example, Wisconsin provides online reporting of the permit application process,[104] while New York may require public hearings on major water withdrawal project, based on the state's Uniform Procedures Act.[105]

3.2.8.2 Michigan's current policy status

Similar to other states, Michigan provides public notification for major water withdrawal projects (i.e., larger than 1,388 gpm), but does not require public reporting or engagement when registering new large-quantity water withdrawals (i.e., larger than 70 gpm and less than 1,388 gpm), unless the local subwatershed unit moves into a "Zone C" status (or a "Zone B" status for cold-transitional systems). In such a case, the registered water users can establish WUCs, made up of registered and permitted water users, who will deliberate voluntary measures to prevent an ARI.[106] The DEQ can—if no agreement is reached by the WUC within 30 days—propose a solution, but water users are not required to follow it. Finally, the DEQ director can order permit holders (save for baseline capacity users) to restrict their water use to ensure that an ARI does not occur, although this decision can be contested legally.

In addition to the provision to create WUCs, the registered water users, local governmental units and interested parties can create water resources assessment and education committees (WRAECs) when it issues a registration or permit for a "Zone B" or "Zone C" withdrawal.[107] These committees are to be open to the public and are meant to assist with the provision of educational materials and recommendations concerning a variety of local water-use topics, with the DEQ providing technical information about regional water use and availability.

It is important to note that, at the time of this writing, no water users or other interested parties have requested the DEQ's assistance in forming any WUCs or WRAECs. It is also unclear how the WUCs would operate in determining water uses that are governed by the Supervisor of Wells regulations and not by the WWAP.

3.2.8.2.1 Keep existing Michigan policy for public engagement on new water withdrawals

Unless a water permit is being obtained, no public notification for a water withdrawal registration needs to be made.

HVHF APPLICABILITY: If an HVHF operation does not cross the threshold of requiring a permit (i.e., 1,388 gpm), then there is no requirement to notify the public about the proposed water use.

3.2.8.2.2 Include HVHF operators in water users committees

The requirement under the WWAP is that WUCs be established whenever a local subwatershed unit moves into a Zone C status (or Zone B for cold-transitional systems). The current lack of any WUCs in Michigan means that there is no formalized local water governance structure available in which the state has input. If or when a WUC is formed that has the DEQ's input, the members of those WUCs could include HVHF water withdrawal operators.

HVHF APPLICABILITY: WUCs are meant to be formed only in areas under Zone C (or Zone B in cold-transitional systems), but HVHF water withdrawals are not allowed to cause this level of impact, as per the Supervisor of Wells regulations.[108] Furthermore, HVHF operators are not part of the WWAP, and thus not a part of WUCs. However, by incorporating the WUC mechanism into the Supervisor of Wells regulations, local water users can work with HVHF operators in areas that are Zone C (or Zone B for cold-transitional systems) in order to implement the necessary water conservation measures that would otherwise be necessary for operating in a Zone C (or Zone B in cold-transitional systems).

3.2.8.2.3 Incentivize the organization of water resources assessment and education committees

WRAECs can be created whenever a subwatershed enters a Zone B or Zone C designation in order to increase the technical understanding of available water resources in a subwatershed area as well as providing recommendations for assessing competing water uses. These committees would be public, receive technical input from the DEQ, and can provide educational materials and recommendations about long-term planning, conservation measures, and drought management activities.[109] The current lack of any WRAECs in Michigan means that local decision making about reallocation of water resources may be occurring in a setting of unequal information or even a lack of potentially knowable information. The DEQ could provide additional incentives to form WRAECs, or notify a greater set of organizations about the possibility of forming WRAECs, in order to assist communities in making their own water management plans.

3.2.8.2.3: INCENTIVIZE THE ORGANIZATION OF WATER RESOURCES ASSESSMENT AND EDUCATION COMMITTEES		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Better informed decisions can lead to better environmental outcomes.	
COMMUNITY	Provides local water users with scientific advice and tools to determine the existing water uses, the remaining water resources, and implications for different water management strategies	There is no existing model of WRAECs in Michigan.
GOVERNANCE	Provides direct advice to local users Maintains a devolved governance structure	There is no existing model of how the DEQ should operate within a WRAEC. Will require additional funds to conduct WRAEC studies and analyses

3.2.8.2.4: REQUIRE NOTIFYING THE PUBLIC ABOUT NEW HIGH-CAPACITY WELLS		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Better informed decisions can lead to better environmental outcomes.	
ECONOMIC		Additional minor costs of public notice
COMMUNITY	Greater level of information about water withdrawals in a community	May create "information overload" Depending on the mode of notification, there may be disparities in public awareness of projects.
GOVERNANCE		Will create additional obligations for DEQ

HVHF APPLICABILITY: WRAECs provide a means by which technical knowledge about available local water resources and likely impacts from various water uses, including HVHF, can be explored.

3.2.8.2.4 Require notifying the public about new high-capacity wells

This policy option would require disseminating information about new high-capacity well registrations and permit allocations and would expand the current requirement of notifications following an SSR (see Box 3.1) or the acquisition of a permit (public notification upon receipt of a permit request; 45 days of public comment).[110] The dissemination of information about new high capacity wells could be initiated automatically through the WWAT to send regular dispatches of new water registrations. Such dissemination could provide updated information about the condition of registered local water extraction and provide information that would be useful for local water governance decisions.

HVHF APPLICABILITY: Arguably concerns over water quantity security may arise from a perception of a problem, even if the perception may be an overestimate. Concerns surrounding water use associated with HVHF deal heavily with the expected local impacts to the availability of local water resources due to the projected volumes of withdrawal. Publicizing the information of all water withdrawals, including HVHF, can provide comparative judgments of water use. At the same time, local residents and governmental units will have a means of assessing projected impacts of publicly disclosed, registered withdrawals, thus increasing transparency.

3.2.9 Summary of HVHF water withdrawal regulation

HVHF requires large quantities of water for its operation (Table 3.2), and these numbers are often a source of concern for many citizens when it comes to thinking about the potential impacts of HFHV. Michigan has a well-developed system for the management of water withdrawals, the WWAP, which was developed as part of the Great Lakes Compact, and instituted in 2009[111] (see Box 3.1).

The WWAP offers a unified mechanism of managing HVHF operations, by managing the water resources of the state. Currently, the state regulates HVHF water withdrawals along a parallel regulatory pathway. While HVHF water withdrawals are not governed by the WWAP, such water withdrawals are required to be assessed using the same online assessment tool and are not allowed to cause Zone C conditions (or Zone B conditions in cold-transitional systems). Furthermore, HVHF water withdrawals must identify existing water withdrawal wells nearby, install their own groundwater monitoring wells, and must report all water withdrawal activities to the Supervisor of Wells. The management of water resources as a central means of managing HVHF operations is currently utilized by both the DRBC and the SRBC, and the Supervisor of Wells regulations in Michigan provides a system for managing HVHF operations that operates in parallel to the WWAP.

The parallel structure of governing water withdrawals in the state (through the Supervisor of Wells in the case of HVHF water withdrawals and through the WWAP for almost all other large scale water withdrawals) rests upon the common use of the WWAT. However, since the water itself doesn't recognize regulatory boundaries, it is necessary to assess different parts of the WWAP in response to the additional physical and public perception challenges that HVHF brings to the table.

One of the major policy options presented here was to update the WWAT, upon which both the WWAP and HVHF water withdrawals rest. Updates to the WWAT would allow for greater precision and accuracy in assessing the impacts of large-volume water withdrawals from HVHF as well as other large water withdrawals across the state. Updates to the WWAT could take the form of using the results of SSRs to increase the local precision of the tool, building the required tools to assess the impacts of large-scale water withdrawals on lakes and wetlands, or updating the groundwater component of the WWAT itself to better reflect the local groundwater conditions throughout the state. Such updates would go a long way in addressing the fundamental tool used in the state's water withdrawal regulations. 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 WRAECs—can help develop local water use governance, ***especially in cases where water resources approach an ARI designation.***

Another major policy option revolves around water withdrawal permitting, the fees for such permitting, and the question of whether such permits might be transferrable. Such changes could provide local water users greater ability to make their own decisions about water use. However, such changes would significantly alter the fundamental basis of water governance in the state, moving it more deeply into a regulated riparian system. Options such as fee schedules, like those used by the SRBC and DRBC, 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, the 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.

Other options include altering the thresholds for enacting regulation. Enacting parallel measures within the WWAP and the Supervisor of Wells regulations could likely have negative consequences on certain types of water users but would also increase the strength and quality of water conservation throughout the state.

The future of water uses in 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 Supervisor of Wells regulations on HVHF water withdrawals form a parallel to the WWAP and appear to provide a unique mechanism for addressing many water conservation decisions through the automated, online WWAT as well as a system of human-based reviews for areas with heightened scrutiny. Other tools exist, such as those within FracFocus, but these can best be used to operate in addition to tools available to the state in order provide better assurances that industry oversight matches state regulations. In the end, HVHF presents a new challenge for water governance in the state, but it is one that can—with sufficient applications of policy options—be addressed effectively without building a completely new water governance structure.

3.3 WASTEWATER MANAGEMENT AND WATER QUALITY

Management of wastewater produced through HVHF—i.e., flowback fluid—is an issue of wastewater management, since 10% to 70% of the water used can return to the surface, with the historic average in Michigan being 37%.[112] This fluid contains fracturing chemicals in addition to dissolved compounds brought up from the fractured geological layer, and is no longer suitable for human consumption,[113] with many possible human health impacts due to potential cumulative and synergistic effects that complex chemical mixtures may have.[114] Furthermore, it may have significant negative environmental impacts.[115] Therefore, while a significant portion of fluid might be recovered during the stimulation of a well, such liquids must be handled appropriately to ensure the quality of other water sources. There are two periods of time when hydraulic fracturing wastewater can impair local water quality: during surface storage and handling and during disposal through deep well injection.[116] While concerns over surface storage and handling are important, surface storage is not permitted in Michigan, and so this chapter will focus on policy structures and options associated with disposal of wastewater.

Water quality and governance of quality standards is a multifaceted issue. Laws concerning water quality encompass federal, interstate, and state levels, making water quality a specifically complex parameter to manage. At the federal level, there are many laws concerning water quality, the foremost being the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA).

3.3.1 The Clean Water Act

The CWA provides the basis for a permit program called the National Pollutant Discharge Elimination System (NPDES), which regulates the discharge of pollutants from point sources. The goal of this law is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[117]

Section 301 of the CWA specifically addresses effluent limitations for point source pollution. This section deems "the discharge of any pollutant by any person" to be "unlawful" except for "publicly owned treatment works" (POTWs).[118,119] Effluent limitations for point sources from these POTWs "require the application of the best practicable control technology currently available as defined by the Administrator pursuant to section 304(b) of [the CWA]").[120] Furthermore, CWA Section 302 addresses water quality related limitations on point-sources of effluent, requiring protection of public health and public water supplies.[121] However, the CWA has its limitations. There are no specific requirements for the disposal of HVHF wastewater, let alone specific requirements for deep well injection of HVHF wastewater. In effect, the CWA disallows the disposal of HVHF wastewater into surface waters directly. This presents a possibility of sending wastewater to POTWs and having them manage the wastewater. This process was indeed tried in Pennsylvania, but studies demonstrated that POTWs were unable to adequately treat HVHF wastewaters,[122] and recently a lawsuit forced a Pennsylvanian POTWs to stop accepting hydraulic fracturing wastewaters until it constructed a wastewater treatment system that could remove 99% of contaminants from the water.[123] Indeed, the volumes of water produced through HVHF operations in the Marcellus shale since 2004 have been far greater than the treatment capacity of POTWs.[124] At the time of writing this report, the EPA was preparing to release rules that would prevent discharging wastewater from shale drilling operations into POTWs.[125]

Furthermore, in Section 310 of the CWA, which addresses effluent limitations, neither groundwater resources nor discharge limits into groundwaters are discussed. This is significant, because deep well injection is the means by which HVHF fluids are disposed of in Michigan.

3.3.2 The Safe Drinking Water Act

The SDWA is another federal law managing water quality. Hydraulic fracturing is exempt from the definition of "injection" under the SDWA, meaning that injection of hydraulic fracturing fluids is exempt under the SDWA for the purposes of conducting a hydraulic fracturing operation. However, the wastewater from oil and gas operations, including flowback and produced water, is not exempt if disposed of in deep injection wells under Part 144 of the Federal Underground Injection Control Program (UIC) regulations.[126]

3.3.3 Interstate laws: The Great Lakes Compact

At the interstate compact level, the Great Lakes Compact addresses water quality in the Great Lakes region, but only tangentially. This agreement observes the interests of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Wisconsin, and Pennsylvania with regard to the waters of the Great Lakes, which include water quality maintenance as well as "the maintenance of fish and wildlife habitat and a balanced ecosystem."[127] The Compact requires that all water withdrawn from the Basin shall be eventually returned and disallows surface or ground waters to be transferred into the Great Lakes Basin, unless the water "is treated to meet applicable water quality discharge standards," or "is part of a water supply or wastewater treatment system that combines water from inside and outside of the [Great Lakes] Basin."[128,129] If a water source is suspected to have significant adverse impact to quantity of quality of waters and water dependent natural resource of the Great Lakes Basin, it is dis allowed from entering the Great Lakes Basin.[130] However, the major purpose of the Great Lakes Compact is water quantity conservation and control over diversions out of the Great Lakes. As such, it only addresses water quality issues through a water quantity framework. Unlike the CWA, which regulates the quantities of *pollutants* entering the nation's waterways, the Great Lakes Compact only addresses the quantity of *water* into which the pollutants enter.

3.3.4 Michigan laws

In Michigan, the Water Resources Division of the DEQ regulates wastewater discharge to surface waters through the NPDES permit program, which is delegated to the state's authority by the EPA under Michigan's Natural Resources and Environmental Protection Act of 1994, as amended.[131] Furthermore, the DEQ is in charge of responding to surface water spills of hazardous waste.[132] In addition, the DEQ also implements permits to regulate groundwater discharge.[133]

The handling and disposal of wastewater associated with HVHF is governed through various regulations associated with the Supervisor of Wells. Since much of the wastewater associated with HVHF is contaminated with salts and fracturing chemicals, and since discharge and land application[134] of flowback fluids is forbidden in Michigan, deep well injection is the method favored in the state.[135]

3.3.5 Deep well injection

Deep well injection is defined as liquid waste disposed of through the pumping of waste into or allowing it to flow through a specifically designed and monitored well.[136] Under the UIC Program set up by the SDWA, there are six classes of disposal wells (Class I–Class VI), each with its own disposal purposes and requirements. In the case of hazardous waste, Class I injection wells are determined to be the safest and most effective for disposal. Class I wells are supposed to inject waste materials to a depth below the lowermost underground source of drinking water. However, while HVHF wastewaters could be considered hazardous waste from a public health and environmental health standpoint,[137] HVHF wastewaters are exempt from the legal definition of hazardous wastes and are statutorily defined as "non-hazardous," which means that oil and gas wastes can be injected into Class II disposal wells. Class II wells are subject to fewer safety requirements and potentially pose a greater risk of contaminating groundwater.[138] There are three types of Class II wells: disposal wells, enhanced recovery wells, and hydrocarbon storage wells. Class II disposal wells are used for the disposal of brines and wastewater associated with oil and gas recovery. Enhanced recovery wells can be used in secondary and tertiary recovery that use diesel fuels in the fluids or in propping agents, although this practice has seldom occurred in Michigan. These are the most numerous type of Class II well nation-wide. Finally, hydrocarbon storage wells are used for the injection of liquid hydrocarbons, generally as part of the U.S. Strategic Petroleum Reserve.[139]

Reports suggest the greatest hazards of deep well injection are the contamination of surface soil, surface water, shallow groundwater by accidental spillage at the wellhead, and contamination of underground source of drinking water by migration or escape of waste components and displaced formation water.[140] The transport of waste to the disposal site poses some potential threats to surface environments,[141] even if conducted via pipeline.[142] However, subsurface injection has been shown to have low potential impact on underground sources of drinking water in Class I wells[143] as well as historically in Michigan's Class II wells.[144]

There is a small amount of historical evidence to suggest that wastewater injection into these wells has caused increased hydraulic conductivity in wells in Pennsylvania.[145] However, during the five decades of hydraulic fracturing operations in Michigan, there has been no report of such occurrences in the state,[146] and a recent study of migration of water from HVHF operations in the Marcellus Shale indicates that migration from the fractured layer to the groundwater layer is not happening.[147]

Wells can also fail, posing contamination issues for groundwater (see Chapter 4, Chemical Use). Well failure can arise from lack of consideration of all fluid movements, human error, and failure of well design, construction, or operation. Recent studies from outside of Michigan—specifically the Marcellus and Barnett shales—have indicated that some examples of groundwater contamination may have been caused by casing failure in production wells,[148] and while the study examined production wells and not disposal wells, the findings do appear to confirm that groundwater contamination was a result of well-failure in these cases, and not of migration of hydraulic fracturing fluids from the fracturing zones. Such errors and subsequent consequences can be avoided by designing wells so that local freshwater supplies are protected from contamination by using a separate casing set into the top of the underlying confining layer and cemented back to the land surface, since the confining layer is breached during construction,[149] and such changes have been seen within the industry in recent years. Michigan also has specific regulations concerning well construction. (See Chapter 4 for more information about casing and cementing requirements.)

3.3.5.1 Michigan's current policy status

In Michigan, the disposal of flowback fluids is governed by both EPA regulations as well as Michigan regulations. Briefly, wastewater from HVHF is not allowed to be sent to POTWs, and is required to be injected "into an approved underground formation in a manner that prevents waste. The disposal formation shall be isolated from fresh water strata by an impervious confining formation."[150] Michigan requires a permit and testing in order to practice deep well injection. During operation, thorough records of various parameters are to be kept and reported to well supervisors.[151]

Permitting for the deep well injection[152] of all hydraulic fracturing wastewater in Michigan is the responsibility of the DEQ. Within Michigan state law, Part 615 addresses regulations associated with waste injection wells in Michigan, including produced waters associated with HVHF,[153] which the DEQ regards as a form of brine.

Although the DEQ is considering submitting a petition for obtaining primary authority over the state UIC program,[154] it currently does not have that authority.[155] Therefore, the EPA regulates disposal wells through its UIC program in addition to the state regulation. This means that, in addition to an application to the DEQ, a well operator must also apply to the EPA under its UIC program. Class II wells are the well-type regulated by the DEQ Supervisor of Wells at the state level for use in the disposal of all hydraulic fracturing wastewaters.[156] Currently, Michigan has 1,460 Class II wells.[157]

Under Part 615, persons may not begin the drilling or operation of a well until they have complied with specific requirements. These requirements include disclosure of well location, explanation of how the well is to be reached, and information of approximate distances and directions from the well site to special hazards or conditions. These special conditions include surface water and environmentally sensitive areas, floodplains, wetlands, rivers, critical dune areas, threatened or endangered species, public water supplies, buildings, and local zoning considerations. Information including daily injection rates, pressures, types of fluids to be injected, geological name as well as depths of freshwater strata and more are required to be disclosed during permitting, as well.[158] A permit issued under Part 615 is for the life of the disposal well.

3.3.5.2.1: KEEP EXISTING MICHIGAN POLICY FOR DEEP WELL INJECTION

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Wastewater is injected into Class II disposal wells.	
HEALTH	Wastewater should be injected below any groundwater drinking source.	Well casings may fail, causing pollution of groundwater drinking source.
GOVERNANCE	Maintains the current system in which no reported groundwater contamination has yet occurred in the State	

3.3.5.2 Analysis of policy options

3.3.5.2.1 Keep existing Michigan policy for deep well injection

The DEQ and the EPA manage Class II disposal wells for the disposal of flowback fluids associated with all hydraulic fracturing. These flowback fluids are injected below the layers of groundwater associated with drinking water supply and environmental connectivity. During the long history of hydraulic fracturing in far shallower shale formations than where HVHF will operate, there have been no reported groundwater contamination issues in Michigan,[159] even though Class II wells have failed in other States.[160]

3.3.5.2.2 Increase monitoring and reporting requirements

The presence of public concern over the volumes of wastewater being produced and disposed implies a need for greater transparency and expansion of wastewater disposal information. Reports of the volumes of wastewater injected should be made easily available to the public so that they can to ensure that the volumes reported by drillers are the same as the volumes that are being disposed. Furthermore, a publicly accessible statewide database with wastewater management information could be developed to monitor changes in the sources and volumes of wastewaters.

3.3.5.2.3 Obtain primary authority over Class II well oversight by the state

Michigan is seeking to obtain primary authority over Class II wells in the state. Such a change in oversight could be seen as a useful thing for managing deep well injections within the state. By obtaining primary authority, the DEQ would be in charge of collecting all information about wastewater disposals within the state. This would decrease the reporting burden on HVHF operators, while increasing the possibility of integrating information of wastewater disposal with other water information.

3.3.5.2.4 Require use of Class I hazardous industrial waste disposal wells

There is a fair deal of public concern over the disposal of wastewater through deep well injection, both throughout the U.S. and within Michigan, despite a record of 50 years without incident. The fact that injection of wastewater into a Class II injection wells could lead to contamination of drinking water resources is enough to raise public concern, and some people point out that hydraulic fracturing wastewaters are allowed to be disposed of using Class II wells only due to a legal exemption, and ought to be treated as a hazardous industrial waste. One way of addressing this concern is to look for other ways of disposing of HVHF wastewaters. If HVHF wastewaters were to be considered a hazardous industrial waste, which it is from a human and environmental health point-of-view,[161] such a recognition would require using Class I disposal wells, which are meant to handle the disposal of hazardous and non-hazardous industrial wastes. At present, there are relatively few Class I wells in Michigan. Of the 30 Class I wells, 7 are for the injection of hazardous waste, and only 2 of these are commercial facilities.[162] In contrast, there are currently 1,460 Class II wells. Therefore, is quite likely that more Class I wells would need to be constructed to receive HVHF wastewaters if this approach were taken.

One additional caveat is that this would either require a definitional change of oversight of these wells by EPA or the creation of a new category of waste disposal to supersede the EPA regulation and to be overseen by the DEQ. (Note that this is the only policy option presented in this report that includes possible requisite action to be taken by the federal government.)

3.3.5.2.2: INCREASE MONITORING AND REPORTING REQUIREMENTS

	STRENGTHS	WEAKNESSES
ECONOMIC		Increased costs
COMMUNITY	Increased monitoring will ease concerns over groundwater contamination.	
GOVERNANCE	Will provide a better understanding of groundwater quality and quantity, building on baseline monitoring already required in the existing regulations for HVHF water withdrawals	

3.3.5.2.3: OBTAIN PRIMARY AUTHORITY OVER CLASS II WELL OVERSIGHT BY THE STATE

	STRENGTHS	WEAKNESSES
ECONOMIC	Decreased costs	
GOVERNANCE	Will have direct oversight over Class II wells	Will increase costs associated with oversight

3.3.5.2.4: REQUIRE USE OF CLASS I HAZARDOUS INDUSTRIAL WASTE DISPOSAL WELLS

	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Uses the type of disposal well required for hazardous wastes	Is not proof-positive against faulty wells Increased potential of spills due to requirement of overland transport of wastewater
ECONOMIC		Increased costs of establishing Class I disposal well facilities Increased cost of transporting wastewater to existing Class I wells
COMMUNITY	Greater confidence in disposal of HVHF wastes at the State level	Greater concern of potential problems by local community Need to build more Class I wells in the State
GOVERNANCE		Would require a redefinition of HVHF wastewaters under the SDWA, which Michigan cannot do

3.3.6.3.1: KEEP EXISTING MICHIGAN POLICY FOR WASTEWATER RECYCLING		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Minimizes the possibility of surface spills during wastewater processing	Does not conserve water resources
HEALTH	Minimizes the chances of surface spills due to increased transport and transfer of polluted waters	
GOVERNANCE	Maintains the current regulatory system	

3.3.6.3.2: PROVIDE OPTIONS FOR WASTEWATER RECYCLING		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Water recycling means less pristine water withdrawn from groundwater sources.	Creates the possibility of surface spills during wastewater processing.
ECONOMIC	Diminishes costs of withdrawing and transporting waters Diminishes the volumes (and costs) of disposing wastewater.	Increases costs associated with recycling (cost of treatment, costs of using treated HVHF fluids, etc.)
HEALTH		Creates the possibility of exposure to wastewaters and treated waste products during processing
COMMUNITY	Diminished water withdrawals maintain an increased amount of water withdrawals available for local communities	Increased trucking of treated waste products
GOVERNANCE		Need regulatory mechanisms to assess performance of current and future technologies in this developing field Need rules to determine how to dispose of the waste products of treatment

3.3.6 Wastewater recycling

HVHF operations in the Utica-Collingwood can produce enormous quantities of polluted water per well. In Michigan, all water utilized in the process of HVHF is essentially lost to the water cycle, since wastewater is stored away from existing water supplies and is generally not reused before it is disposed of through deep well injection. The opportunity of treating and re-using this polluted water means that the volume of water withdrawals can be lower, which will reduce any local water stresses that would otherwise occur if wastewater recycling were not allowed.

There are many ways that hydraulic fracturing wastewater can be recycled. For example in some states, wastewater is used for dust control on roads, deicing roads during the winter, and sold back to local governments for treatment.[163] Except in certain conditions,[164] this practice is prohibited in Michigan, and thus isn't the best example of recycling, despite it being the only option provided by the state. It is important to note, though, that Michigan does not currently provide any preferred options for the recycling of hydraulic fracturing wastewaters. Despite the concerns about potential contamination associated with spills, the technique of on-site recycling is becoming a viable option for some hydraulic fracturing facilities.

A variety of wastewater treatment technologies exist, with some on-site technologies capable of recycling more than 245,000 barrels of both produced and flowback water.[165] Centralizing wastewater recycling operations could save approximately $1.2 billion over five years for a 1,400-well operation the Eagle Ford Shale[166] and could save 10% of the operating cost per well in the Marcellus Shale.[167] These technologies are done on site of the hydraulic fracturing operation. The recycling of water through this option diminishes both the demand for freshwater as well as the volumes of wastewater.[168, 169]

It is important to recognize, however, that wastewater recycling is not a panacea for all water conservation and water quality issues. Since only a portion of the total volume of water withdrawn returns as flowback fluid (historically 37% in Michigan[170]), supplemental water will always be required to maintain or expand development. Furthermore, there are limitations associated with recycling the produced water, including increased salinity and viscosity, which makes recycling expensive.[171] Furthermore, wastewater recycling requires increased transfer, transport, and treatment; each of these processes bring with it additional possibilities of worker exposure and surface spills, in addition to the burdens of increased energy use, waste disposal, and government oversight.[172]

3.3.6.1 Current regional standards

Hydraulic fracturing wastewater recycling has historically not been a popular management choice, due to additional costs associated with separation and filtration[173] as well as increased costs associated with disposal of flowback fluids.[174] Additionally, increased handling of these fluids increases the possibility of spills, invoking spill reporting (see Chapter 4) and associated public concern (see Chapter 2). However, wastewater recycling is increasingly being used in the Marcellus Shale because traditional off-site disposal methods are not often available in close proximity to hydraulic fracturing wells.[175] Currently in Pennsylvania, the operator must submit a report to the Department of Environmental Protection after the completion of a well, listing—among other things—the volume of recycled water that was used during the drilling of the well.[176] Further afield, Texas recently changed its laws to allow operators to recycle hydraulic fracturing wastewater without a permit and sell or purchase wastewater from other operators, as long as the recycling takes place on land leased by the operator.[177]

3.3.6.2 Michigan's current policy status

The DEQ notes that on-site wastewater recycling *in general* can be a good technique to ensure that wastewater will not contaminate drinking water supplies, ground or surface waters, and will not be a risk to public health or safety hazards.[178] However, surface spills during the process of wastewater recycling of flowback fluids remain a concern to the DEQ.

Michigan legislation does not currently provide any options for on-site recycling of wastewater from hydraulic fracturing processes, unless the wastewater meets specific quality conditions allowing it then to be used for ice or dust control.[179] If the wastewater does not meet these specific requirements, then current regulations covering wastewater provide deep well injection as the

3.3.6.3.3: USE ALTERNATIVE WATER SOURCES FOR HVHF		
	STRENGTHS	WEAKNESSES
ENVIRONMENTAL	Diversion of low-quality POTW discharge to HVHF operations can improve the water quality in some systems, especially those with higher natural water yield.	Improvements will only be temporary; when POTW discharges return to normal, any gains to water quality will be lost. May diminish water quality in river systems with low natural water yield Will require overland transport from POTWs to the HVHF site
ECONOMIC	Collecting and transporting treated POTW discharge may be cheaper than digging and operating a water withdrawal well.	Will require additional costs associated with using non-pure water sources May require additional treatment before use
COMMUNITY	Diminished amounts of water withdrawals maintain an increased amount of water withdrawals available for local communities.	Will increase trucking of water resources from POTWs to HVHF site
GOVERNANCE		Will need to draft new rules associated with using treated POTW discharge

default regulatory option.[180] However, wastewater recycling can offer significant environmental benefits, with well operators reducing freshwater consumption and decreasing the amount of wastewater to be disposed. Whether these practices are associated with significant cost benefits, as seen in some other places around the nation, are yet to be tested locally.

3.3.6.3 Analysis of policy options

3.3.6.3.1 Keep existing Michigan policy for wastewater recycling

There are no specific regulations about wastewater recycling of flowback fluids, leaving deep well injection of all flowback fluids as the sole defined regulatory option for wastewater management from fracking operations.[181]

3.3.6.3.2 Provide options for wastewater recycling

With the recognition that wastewater treatment and recycling can provide benefits in diminished water withdrawals, wastewater recycling in Michigan would provide water conservation opportunities and would reduce the total volume of wastewater to be injected.

Instead of being injected into disposal wells, wastewater could be treated and reused for gas development. Treatment of wastewater to be reused for hydraulic fracturing operations should focus on the removal of organic contaminant and inorganic constituents. However, treatment of wastewater can be expensive and energy intensive.[182] Still, an estimate of the economic benefits of 100% wastewater treatment and recycling in the nearby Marcellus shale ran an estimated $150,000 per well (or roughly 10% of total costs).[183] Furthermore, wastewater recycling minimized the transport of wastewater across state lines, which obviated other potential costs and risks (See Box 3.5).

Box 3.5 Importation of Hydraulic Fracturing Waste into Michigan

Recently, a *Detroit Free Press* article revealed that hydraulic fracturing waste from the outside the state was being imported for disposal.[185] This hydraulic fracturing waste is associated with naturally occurring radioactive materials (NORM) generated in hydraulic fracturing operations outside of Michigan. As such, the question of the management of this hydraulic fracturing waste should be considered in the context of trade and importation policy rather than that of hydraulic fracturing policy.

Finally, if regulations regarding disposal of HVHF wastewater through deep well injection were to be changed, operators would be looking for existing rules or guidelines for wastewater recycling. In Colorado, recent concerns over seismicity changed the rules for deep well injection, thus causing greater interest in wastewater recycling. Although seismicity is not expected to be a concern in Michigan,[184] changes to rules over deep well injection (caused by any reason) would likely increase the interest in wastewater recycling, especially if guidelines are already in place.

3.3.6.3.3 Use alternative water sources for HVHF

Providing alternative, non-potable water sources for HVHF operations would diminish the amount of water removed from the local environment. Alternative sources could include treated municipal sewage water or treated wastewater used in conventional mining. In some areas, the diversion of treated sewage or mining waters could also improve local freshwater conditions. However, in more water-stressed regions, the diversion of municipal wastewater may further stress local rivers and streams.

3.3.7 Summary of wastewater management and water quality policy options

Presently, the wastewater management and water quality policies of Michigan have been 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 HVHF, it is not clear whether the laws and regulations written at a time of small-scale, shallow hydraulic fracturing options will be adequate (see Table 3.2 for relative scales of water use). Where there once were thousands of gallons of wastewater being created by a single hydraulic fracturing well, a future with HVHF will be one where each well potentially creates hundreds-of-thousands of gallons of wastewater, several hundred times more than a historic hydraulic fracturing well.

A future with HVHF in Michigan should be met with the understanding of the vastly different scales of water use and wastewater production associated with each HVHF well. Providing additional safeguards could 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 could provide well operators with an option 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 Michigan is deep well injection. The UIC program, which is the national governing framework for deep well injection, is managed by the EPA, and, together with Michigan law, it requires the disposal of hydraulic fracturing fluids into Class II wells.[186] Although Class II disposal wells are supposed to keep underground drinking water supplies safe from contamination, there have been well casing failures in production wells in other states due to high pressure that have caused groundwater contamination. In addition, the public often perceives groundwater resources as vulnerable to hydraulic fracturing operations in general. Given these concerns additional options for managing and monitoring wastewater disposals are presented. One presented option is to increase the amount of groundwater monitoring around deep well injection sites. Another option is to specifically require that hydraulic fracturing fluids be disposed of in Class I wells, which are designed to handle hazardous industrial wastes.

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, Michigan provides 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. 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 panacea, as they both carry associated environmental risks.

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14 WWAT and SSR assessments from a DEQ database were used to develop a map of subwatershed Policy Zone determination. If the DEQ database indicated that a subwatersheds had one or more proposed water withdrawals that would cause an ARI and that an SSR was also conducted that indicated a potential ARI, that subwatershed was indicated as Zone D. NOTE: This determination of Zone D does not indicate that DEQ allowed the proposed water withdrawals that were determined to cause an ARI. The indication of Zone D on the figure is to indicate subwatersheds that are effectively at their legally allowed limits with regards to large-scale water withdrawals, but which still have additional water withdrawal proposals being sent to the DEQ.

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19 When calculating each Policy Zone, the total number of registered withdrawals was calculated. Values for Zones B were added to the total for Zone A, and the same was done with Zone C, in order to evaluate the impacts of cumulative withdrawals. Policy Zone D was calculated by using the smallest proposed withdrawal that caused a determination of Zone D; if only one value was listed, the evaluation used that value. As such, this is an indication of the cumulative impacts of registered water withdrawals. It is not an indication of the actual volumes of water withdrawal, since the reported withdrawal capacities represent maximum limits of allowable water withdrawal; most withdrawals will be lower than this stated capacity, and—since these withdrawals are associated with agriculture—most are likely intermittent.

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25 Mich. Admin. Code r.324.61501 et seq.

26 Delaware River Basin Commission. Meeting of May 5, 2010 Minutes. 2010 [accessed 2014 Nov 20]. http://www.state.nj.us/drbc/library/documents/5-05-10_minutes.pdf.

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30 58 Pa. Cons. Stat. Ann. § 3211(m).

31 58 Pa. Cons. Stat. Ann. § 3211(m).

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39 Mich. Admin. Code r.324.1402.

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47 Minn. Stat. § 103G.271.

48 N.Y. Comp. Codes R. & Regs. tit. 6, § 601.

49 Wis. Stat. § 30.18.

50 Wis. Stat. § 281.346.

51 Wis. Stat. § 281.346.

52 Susquehanna River Basin Commission 18 C.F.R. § 806.4.

53 The regulation of the Susquehanna River Basin Commission refers to a *pumping rate* of 20,000 gallons per day. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per minute (20,000 gpd = 13.8888 gpm; 14 gpm = 20,160 gpd).

54 Delaware River Basin Commission 18 C.F.R. § 410.1, *available at* http://www.nj.gov/drbc/library/documents/watercode.pdf (2 Del. River Basin Water Code § 20.7).

55 The regulation of the Delaware River Basin Commission refers to a *pumping rate* of 10,000 gallons per day. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per minute (10,000 gpd = 6.9444 gpm; 7 gpm = 10,080 gpd).

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78 Wis. Stat. § 30.18.

79 Wis. Stat. § 281.346.

80 Wis. Stat. § 281.346.

81 Susquehanna River Basin Commission 18 C.F.R. § 806.4.

82 The regulation of the Susquehanna River Basin Commission refers to a ***pumping rate*** of 20,000 gallons per day. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per minute (20,000 gpd = 13.8888 gpm; 14 gpm = 20,160 gpd).

83 Delaware River Basin Commission 18 C.F.R. § 410.1, *available at* http://www.nj.gov/drbc/library/documents/watercode.pdf (2 Del. River Basin Water Code § 20.7).

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88 The regulation in Michigan refers to a pumping rate of 2,000,000 gallons per ***day***. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per ***minute*** (2,000,000 gpd = 1,388.9 gpm).

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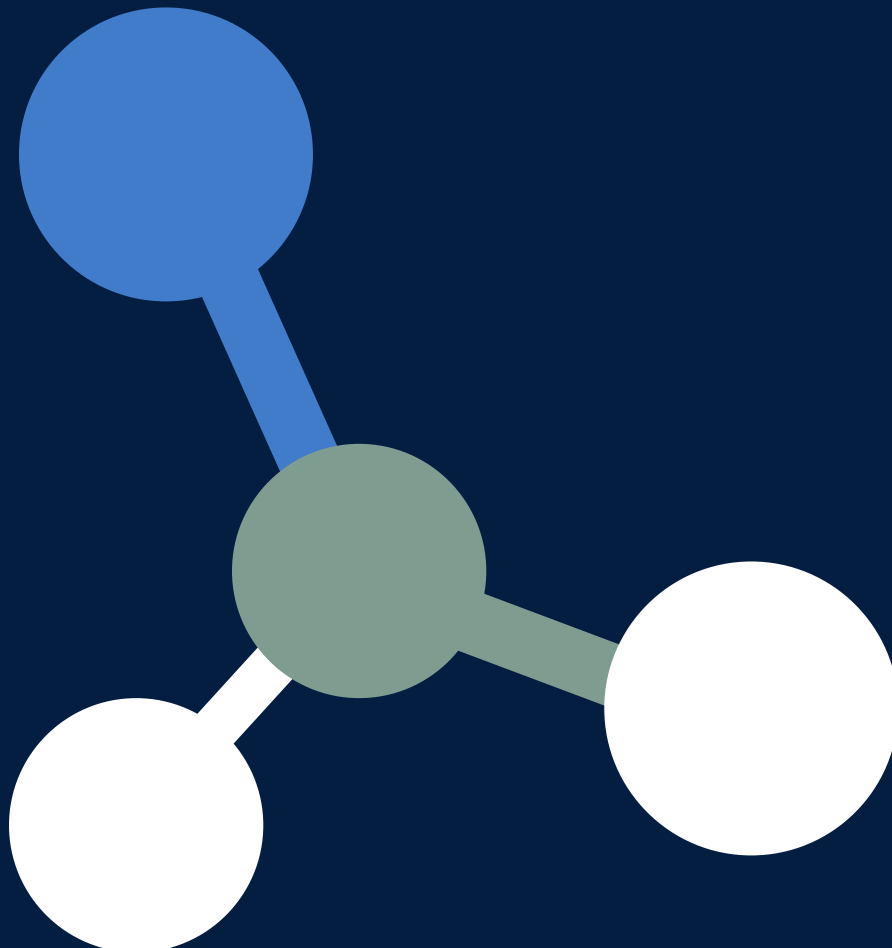

CHEMICAL USE

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Chapter 4

4.1 INTRODUCTION

The chemical substances associated with high volume hydraulic fracturing (HVHF) activities are numerous and may be found at every point in the process. For example, between January 2011 and February 2013, the Environmental Protection Agency (EPA) identified approximately 700 different chemicals that were used in fracturing fluids. The fracturing fluid for each well contained a median of 14 chemical additive ingredients, with a range of 4 to 28 ingredients.[1] 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,[2–5] as well as in other jurisdictions currently engaging in HVHF.[6,7]

These chemicals are either intentionally used, or by-products of, HVHF operations. For example, acetic acid (function: reduces fluid volume), ethylene glycol (function: prevents mineral scale formation in the wellbore), and silica sand (function: props open fractures to allow gas to escape from the shale) have traditionally been used among various other chemicals at well sites across the U.S., including Michigan.[8] Other chemical by-products of HVHF include various naturally occurring minerals and metals that may contaminate flowback water. These chemical by-products have the potential to give rise to a number of adverse human health effects. Animal health may also be adversely impacted by the release of chemicals associated with HVHF activities into the surrounding environment.[9] A more comprehensive discussion of the chemicals associated with HVHF operations and their potential human and ecological health implications may be found in the Public Health Technical Report.[10]

Nearly all chemical substances are characterized by one or more ecological and/or human health *hazards* (i.e., the potential to do harm). However, it is the conditions surrounding the presence of that chemical that determine the ecological and/or health *risks* (i.e., the probability of causing harm). For example, the consumption of ethanol in the form of alcoholic beverages carries with it a series of hazards (e.g., intoxication, liver cirrhosis, death), but it is the concentration of the ethanol, frequency of consumption, and time-frame over which consumption takes place that largely determine the risks.[11] In the same light, the chemicals associated with HVHF may have one or more ecological and/or health hazards, but it is the *circumstances of their interactions* (i.e., concentration, route, duration, and frequency of exposure) with humans and other life forms that dictate the risks.

Although HVHF activities are prevalent within the State of Michigan and other areas of the U.S., information on the ecological and/or health risks posed by the chemicals associated with this activity is currently limited. This is especially true in relation to the long-term ecological and human health impact of high-volume chemical use. The New York Department of Environmental Conservation recently concluded that "significant uncertainty remains regarding the level of risk to public health and the environment that would result from permitting high-volume hydraulic fracturing . . . . In fact, the uncertainty regarding the potential significant adverse environmental and public health impacts has been growing over time."[12]

Much of the information available to date is derived from methods that are not widely accepted by the scientific community (e.g., anecdotes, non-peer-reviewed reports).[13] Several factors challenging our progress in this domain include the relatively recent development of HVHF, latency issues (i.e., time delay between exposure and disease, especially those diseases known to have a long latency period), limited monitoring data, limited baseline health data, and a lack of complete chemical disclosure (e.g., trade secret exemptions) among others.[14] For example, EPA's recent study found that well operators withheld 11% of ingredients as confidential business information.[15] From a public health perspective, epidemiology studies using widely accepted scientific methods are greatly needed, as well as scientifically sound data on the impact of HVHF activities on the ecology surrounding the sites. However, due to the complex mixture of HVHF chemicals, the multi-causal nature of reported health outcomes (e.g., headaches, rashes, asthma), and the absence of systemic data collection on human or ecological impacts, assessing the associations is problematic.[16]

Nevertheless, the coming years are expected to bring a wealth of information on potential risks and/or hazards posed by the chemicals commonly used in HVHF given increasing HVHF activity; interest in the potential associated risks from the general public, industry, and epistemic and regulatory communities; and continuing advances in scientific research. For example, the potential endocrine-disrupting[17] and developmental effects[18] associated with commonly used HVHF chemicals and the potential health risks associated with airborne occupational exposures to silica during the transportation and handling of silica sand[19] have generated concern among stakeholders recently. So, too, have airborne exposures to volatile hydrocarbons during flowback operations,[20] and human and ecological risks associated with exposure to HVHF chemicals that could contaminate drinking water and other water resources.[21,22] Given the current dearth of publicly available scientific data and their potential risks, it is anticipated that research into such chemicals when associated with HVHF activities shall be a priority in the short to medium term.

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.[23] In its strongest form, the precautionary approach would counsel

TABLE 4.1: PRODUCTION CHARACTERISTICS OF STATES SURVEYED

STATE	NATURAL GAS PRODUCTION RANKING (2013)[31]	SHALE GAS PRODUCTION RANKING (2013)[32]	CRUDE OIL PRODUCTION RANKING (2014)[33]	YEAR CONVENTIONAL PRODUCTION BEGAN[a]
Arkansas	8	4	20	1921[34]
Colorado	6	13	7	1862[35]
Illinois	26	None	15	1905
New York	22	None	28	Gas: 1821[36] Oil: 1881[37]
North Dakota	14	7	2	Gas: early 1900s[38] Oil: 1951[39]
Ohio	16	9[b]	14	1860[40]
Pennsylvania	2	2	19	1859[41]
Texas	1	1	1	1866[42] – 1894[43]
Michigan	**18**	**9[b]**	**17**	**1925[43]**

[a] Unless otherwise noted, dates in this column refer to oil production, which pre-dates gas production.

[b] Michigan and Ohio both produced 101 billion cubic feet of shale gas in 2013, so they are tied in the ranking.

TABLE 4.2: DEMOGRAPHIC CHARACTERISTICS OF STATES SURVEYED

STATE	POPULATION (MILLION, 2010)[45]	POPULATION DENSITY (PERSONS/ SQUARE MILE, 2010)[46]	MEDIAN INCOME (2011–2013)[47]	GEOGRAPHIC LOCATION
Arkansas	2.92	56.0	$40,760	South
Colorado	5.03	48.5	$60,727	West
Illinois	12.83	231.1	$54,044	Midwest
New York	19.38	411.2	$51,554	East
North Dakota	0.67	9.7	$55,946	West
Ohio	11.54	282.3	$45,887	Midwest
Pennsylvania	12.70	283.9	$52,768	East
Texas	25.15	96.3	$52,169	South
Michigan	**9.88**	**174.8**	**$50,056**	**Midwest**

banning an activity that could potentially result in severe harm.[24] The second is to adopt an adaptive approach. Policymakers may choose to take some regulatory action at the outset, then refine the policy as more information becomes available.[25] As discussed in chapter 5 of this report, adaptive management may use several mechanisms, including automatic adjustments in response to predicted conditions and formal review in response to new or unanticipated events. The third is to adopt a remedial—or post-hoc—approach. Policymakers may decide to allow the activity and rely on containment measures and liability to private and public actors to address any harm.[26]

Thirty states have adopted policies governing HVHF and associated oil and gas production.[27] Of these, twenty-seven states allow HVHF with varying levels of regulation; three states do not allow the practice.[28] Two more states are considering taking action.[29] This chapter will focus on the policies of eight of these states: Arkansas, Colorado, Illinois, New York, North Dakota, Ohio, Pennsylvania, and Texas. The states were chosen to reflect a range in the characteristics of production, demography, and policy.[30] Although New York has chosen to ban HVHF rather than proceed with a rulemaking, the state's proposed rules are included in this chapter because they represent a qualitatively different policy approach. (For simplicity's sake, the report treats the proposed rules the same as the policies adopted by the other states.) A summary of key characteristics of the surveyed states is in Tables 4.1, 4.2, and 4.3.

In this chapter, we examine 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 to reduce risk or set a performance standard; and response policies manage any contamination through emergency planning, cleanup, and liability requirements. For each type of tool, and building on the approaches to uncertainty, we present the range of state policies and describe Michigan's current policies. We then offer three combinations of policy options the state could adopt, including returning to its previous policies. Summary tables comparing the key components, relative to the current Michigan policy and including strengths and weaknesses, are set out at the end of each section.

4.2 INFORMATION POLICY

4.2.1 Introduction

U.S. states have focused much of their policy attention on gathering information about chemical use in hydraulic fracturing through reporting and monitoring requirements. These policies build on existing laws that require well operators to submit reports on the methods used for completing a well. Mechanisms for regulating the provision of information by HVHF operators vary. Moreover, such mechanisms may or may not be specific to HVHF activities, but rather capture HVHF activities by their scope. Variation is evident in terms of their objectives, obligations, penalties, and audience. Yet despite the differences in design, the overarching goal of such mechanisms is to increase transparency of otherwise private information. While the focus may be on increasing transparency between the operator and the state, information policies may also increase transparency between all relevant stakeholders, including the public at large. In doing so, these policies may enhance public participation in the decision-making process. As this section illustrates, the mechanisms and/or tools adopted by the state will therefore depend on their overall policy objective around access to, use of, and availability of information.

TABLE 4.3: POLICY CHARACTERISTICS OF STATES SURVEYED			
STATE	PRIMARY POLICY ACTOR	FORM OF POLICY	YEAR ADOPTED
Arkansas	State agency	Rules	2010
Colorado	State agency	Rules	2012
Illinois	Legislature	Statute; rules	2013; 2014
New York	State agency	Proposed rules; imposed ban	2011; 2014
North Dakota	State agency	Rules	2012
Ohio	Legislature	Statute	2012
Pennsylvania	Legislature and state agency	Statute; rules	2012; 2011
Texas	State agency	Statute; rules	2011; 2011
Michigan	**State agency**	**Instruction; rules**	**2011; 2015**

4.2.2 Range of policies

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.

4.2.2.1 Information on chemical additives

The most common information policy is disclosure of the chemicals used in hydraulic fracturing fluid. Since 2010, twenty-six states, including Michigan, have adopted such policies.[48] All of the states surveyed require some form of chemical disclosure, and the American Petroleum Institute recommends disclosure in its guidelines.[49] Each policy can be broken down into four elements: (1) the substance of the disclosure; (2) the means of disclosure; (3) the timing of disclosure; and (4) the exceptions to disclosure.

Chemical disclosure policies require the well operator to disclose specific information on the chemical additives in the hydraulic fracturing fluid and on the chemical constituents that comprise each additive.[50] The most common pieces of information are: the identity of each chemical constituent, including the name and the number assigned by the Chemical Abstract Service (CAS) Registry[51]; the concentration of each constituent in the additive and in the total fluid[52]; the trade or product name of each additive[53]; the supplier or vendor of each additive[54]; and the intended use or function of each additive.[55] Six states expressly limit the required disclosures to chemicals that are intentionally added to the base fluid.[56] Less common are the additive volume[57] and the Material Safety Data Sheet (MSDS), a type of hazard communication required by federal worker safety law, for each additive.[58]

The means and timing of disclosure are closely linked. The primary mechanism for disclosure is posting of the information on a website called FracFocus within thirty to sixty days after hydraulic fracturing. State officials in the Groundwater Protection Council and the Oil and Gas Compact Commission created the website in 2011, initially as a means of voluntary reporting by industry. Well operators submit the information for each well online, and the public can then view a standardized form through a map-based interface or search by location, operator, chemical name, or CAS number (see Figure 4.1). The most recent version, FracFocus 3.0, allows interested members of the public to download all of the well data in machine-readable format. State officials have also announced that this version will include more search criteria. Six of the eight surveyed states require or allow operators to use FracFocus.[59] The remaining states require disclosure directly to the state regulatory agency.[60] Illinois plans to post the information on its own website.

A less common mechanism of disclosure is requiring the well operator to disclose the proposed chemical additives and constituents in the application for a well permit, before hydraulic fracturing occurs. The public may have access to the information through a state website or information requests under state records laws. Two of the surveyed states have this type of disclosure in addition to post-hydraulic fracturing reporting.[61] In a unique variation, Arkansas and Illinois require each provider of hydraulic fracturing services to disclose a master list of all chemicals that will be used in the state prior to servicing any wells.[62]

All of the surveyed states allow well operators to protect the identity of a chemical from public disclosure on behalf of product suppliers and service companies if the identity is deemed a trade secret. Seven states specifically grant an exception for trade secrets[63]; North Dakota relies on the reporting requirements of FracFocus, which provide that operators can protect information considered to be a trade secret under federal worker safety law.[64] In addition to the name and CAS number of a chemical, many states allow operators to withhold the concentration or volume of a chemical.[65] Several states require operators to disclose the chemical family, such as polymers, in place of the withheld identity.[66]

The states vary in their treatment of the trade secret claim. Some require written statements, affidavits, or justifications[67]; others require that the information itself be submitted for review.[68] Yet others allow certain members of the public to contest a claim.[69] In Texas, for example, the surface landowner or adjacent landowner may submit a challenge to the state within twenty-four months of the date a well completion report is filed, and the state must investigate.[70] However, because the operator need not provide a basis for the claim, it is not clear how effective the right is. As of July 2015, there have been a few inquiries but no challenges have been filed.[71] Six of the eight states require disclosure of chemicals to healthcare professionals under certain conditions.[72]

Michigan's current policy uses a combination of pre-HVHF disclosure through permit applications and post-HVHF disclosure through FracFocus. Each applicant for a well permit who intends to utilize HVHF must disclose a list of constituents the applicant anticipates will be used in the HVHF fluid, including the specific identity and CAS number.[73] Well operators are allowed, however, to use other chemical constituents in the actual HVHF operation.[74] Operators are also required to disclose information on all chemical constituents of HVHF fluid within thirty days after well completion on the FracFocus site.[75] Such information includes the specific trade name, supplier, and type of each chemical additive; and the specific identity, CAS number, and maximum concentration in the total fluid of each chemical constituent intentionally added.[76] An operator may withhold the identity and CAS number of a chemical constituent if they are trade secrets, but the operator must provide the chemical family name or "similar description," and a statement that a claim of trade secret protection has been made.[77]

4.2.2.2 Information on well integrity

While chemical disclosure has garnered the most attention, states also require operators to gather information on the integrity of well construction and report the results. Before hydraulic fracturing may commence, five states require mechanical integrity tests of both the internal and external integrity of some wells; these tests ensure that the steel casing and cement form a tight barrier between substances inside of the well and the surrounding environment.[78] In addition, seven states require operators to monitor pressures during hydraulic fracturing to ensure that there are no leaks in the well.[79] Most commonly, operators must monitor pressures at the surface and in the space between casings,

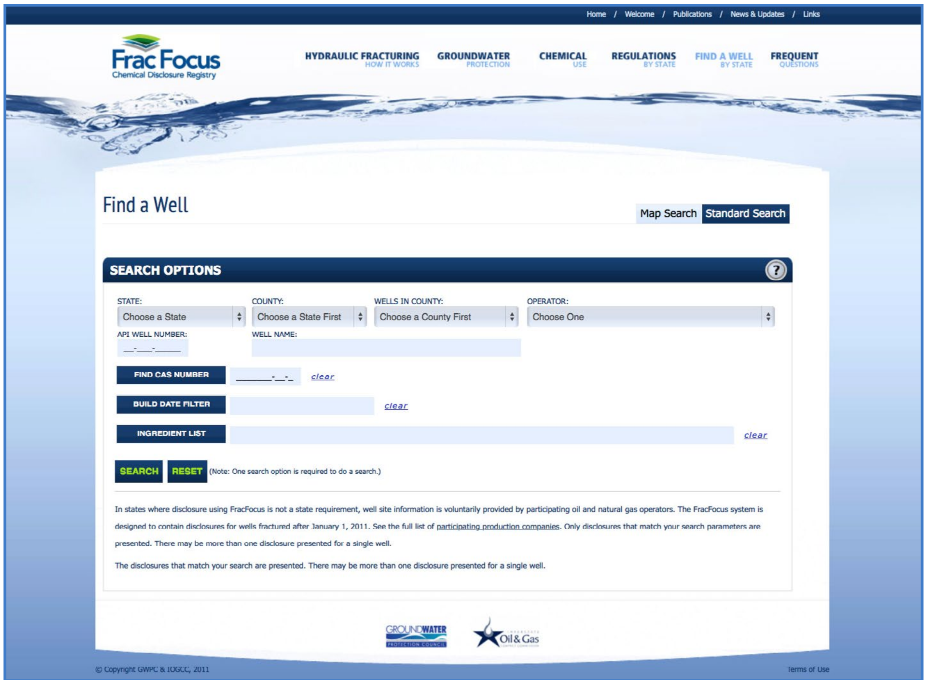

FIGURE 4.1: FracFocus chemical disclosure registry search page.

known as the annulus (for an overview of the technology involved with HVHF, please see the Technology Technical Report[80]). Once in operation, Pennsylvania requires operators to inspect the wells at least quarterly for mechanical integrity.[81] Colorado requires operators of wells in certain areas to monitor pressures when nearby wells are being hydraulically fractured.[82]

Some states direct the operator to take certain steps if these tests indicate a possible leak. For example, North Dakota requires the owner or operator to verbally notify the director if a certain pressure exceeds 350 pounds per square inch during hydraulic fracturing.[83] Ohio requires the operator to notify the state if it discovers any inadequacy in the well's construction and to immediately correct the problem.[84] Similarly, New York's proposed rules require operators to suspend hydraulic fracturing and notify the state if any anomalous pressure or flow condition occurs.[85]

Michigan's current policy requires operators of an HVHF well to monitor well integrity by recording well pressures during HVHF operations.[86] Operators must then report the data to the state within sixty days of completing operations.[87] If pressures during hydraulic fracturing indicate a lack of well integrity, the operator must immediately cease operations, notify the state, and submit a corrective action plan for approval.[88] The state does not require operators to test the mechanical integrity of a well prior to HVHF; however, the Department of Environmental Quality (DEQ) may direct an operator to conduct such a test as part of a corrective action plan.[89]

4.2.2.3 Information on water quality

Finally, states have responded to concerns about water contamination by requiring operators to gather information on the quality of water resources around the well. Five of the surveyed states mandate some form of water quality testing.[90] Pennsylvania does not require testing, but strongly encourages it through a presumption of operator liability for groundwater contamination that can be rebutted by showing that the contamination was present before hydraulic fracturing.[91] Reflecting the concern about groundwater contamination from HVHF, states most commonly require testing of groundwater wells that supply drinking water.[92] Illinois, however, includes both surface and groundwater.[93]

These policies vary by timing, the size of the testing area, the types of substances tested, and the extent of reporting. Some states require baseline testing;[94] others require operators to monitor water quality after hydraulic fracturing by testing at regular intervals.[95] In Illinois, for example, operators must test water quality at six, eighteen, and thirty months following completion of the oil or gas well.[96] The radius of testing may be from 1,500 feet to one mile from the well pad[97] and depends on the availability of water sources and the permission of landowners.[98] Some states specify the testing parameters in the policy,[99] and others do not.[100] The operator is usually required to report the results to the state regulatory agency or the (surface) property owner.[101] In a unique variation, New York's proposed rules require the operator to report any "significant deviation" from the baseline results to the state environmental agency within five days, in addition to regular reporting to the state and the landowner.[102]

Michigan's current policy requires a permit applicant to conduct baseline tests of no more than ten "available" groundwater sources within one-quarter mile of the proposed HVHF well to establish local background water quality.[103] The sampling must occur between seven days and six months before the well is drilled.[104] In contrast to surface facilities that store brine or hydrocarbons, there is no requirement that an applicant monitor groundwater or the well site over time for contamination.[105]

At a minimum, the state's policy requires the applicant to test for chloride and total dissolved solids (indicators of general water quality), methane (a flammable gas), and certain carcinogens.[106] The applicant must notify the state immediately if carcinogens are detected in a sample; otherwise, the applicant is required to report the results to the state and freshwater well owner or landowner within 45 days.[107] If methane is detected, the applicant must conduct additional testing to determine whether the gas originated in deep formations, and thus could be attributed to HVHF well development.[108] Once baseline tests are conducted for one well on a well pad, the operator can rely on the tests for additional wells drilled within three years on the same pad or an adjacent pad.[109] Operators with well permits who intend to re-fracture an existing well must also comply with the policy.[110]

4.2.3 Policy approaches

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 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. Adequate resourcing of the state agency to perform this ongoing function is crucial to the approach. Under a remedial approach, states collect information 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 deciding whether to continue to drink water

TABLE 4.4: SUMMARY OF INFORMATION POLICY OPTIONS FOR MICHIGAN					
POLICY AREA	POLICY ELEMENTS	CURRENT POLICY	OPTION A (PREVIOUS APPROACH)	OPTION B (ADAPTIVE APPROACH)	OPTION C (PRECAUTIONARY APPROACH)
CHEMICAL USE	SUBJECT OF DISCLOSURE	All constituents	Hazardous constituents	All constituents; plain-language description	All constituents; plain-language description of risks and alternatives; studies
	MEANS OF DISCLOSURE	Permit application; FracFocus	MSDS on state website	Master list; state website; FracFocus	Permit application; state website
	TIMING OF DISCLOSURE	Before HVHF and within 30 days after HVHF	Within 60 days after HVHF	No change	Before HVHF
	TRADE SECRET CLAIM REVIEW	Statement of claim; must use family name or other description	None	Careful scrutiny of trade secret claims	Full information provided to state
WELL INTEGRITY	PRESSURE MONITORING	Monitored during HVHF and reported immediately to state if problem; HVHF ceases until plan of action implemented	Monitored during HVHF and reported within 60 days	Monitored during HVHF and reported immediately to state and nearby landowners if problem; status placed on website; HVHF ceases until plan of action implemented	Monitored during HVHF and reported immediately to state and nearby landowners if problem; status placed on website; operator must demonstrate integrity before continuing
	MECHANICAL INTEGRITY TEST	When monitoring during HVHF indicates problem	None	Periodic tests through life of operating well	Prior to approval of HVHF; when monitoring indicates a problem
WATER QUALITY	WATER SOURCE	Groundwater	None	Groundwater and surface water	Groundwater and surface water
	AREA AROUND WELL	¼-mile radius around well		Based on characteristics of aquifer/watershed	Based on characteristics of aquifer/watershed
	NUMBER OF SOURCES TESTED	Up to 10		Part of larger monitoring system in area	Based on importance of sources to be protected
	FREQUENCY OF TESTING	Baseline test, >7 days but <6 months prior to drilling of new well or HVHF of existing well		Baseline test; long-term regular monitoring	Baseline test; long-term continuous monitoring of critical sources
	TEST RESULTS	Within 45 days to state and owner; immediate report of BTEX to state		Within 10 days to state, owner, and public; immediate report of contaminants of concern	Prior to approval of well and within 10 days to state, owner, and public; immediate report of all contaminants

from wells. Under a remedial approach, members of the public use information to participate in enforcement actions and also to minimize their exposure to contamination and decide whether to seek compensation.

Of the states surveyed, the most common approach to chemical use information is remedial: five states require the information only after hydraulic fracturing has occurred, a policy that is useful in helping to identify the source of any contamination. Two states have adopted a precautionary approach: information on all chemicals is collected as part of the permitting process so that the states can decide whether the HVHF well should be permitted, and if so, which conditions should be imposed on the activity. And one state has adopted an adaptive approach: chemical use is monitored over time through a master list of chemicals submitted prior to hydraulic fracturing and disclosure afterwards. While the intent of chemical disclosure is often to inform the public, it is unlikely that members of the public will be able to use the technical information to either participate in public discourse or make individual decisions.[111] The primary mechanism for disclosure, FracFocus, also fails to provide full information.[112]

The most common approach to well integrity information is also remedial: seven states require pressure monitoring during hydraulic fracturing to detect leaks and minimize harm. Notably, five of the same states also take a precautionary approach to certain wells or casing strings that are more likely to fail: operators must conduct tests before hydraulic fracturing to ensure that there are no preventable leaks. And one other state has adopted an adaptive approach: the integrity of operating wells is monitored over the life time of the well, giving the state and operators information on the long-term probability of contamination.

Finally, the most common approaches to water quality information are adaptive and remedial. Three states have taken an adaptive approach: operators are required to monitor water quality both before and after hydraulic fracturing. This information provides the state with an ongoing assessment of exposure through the water sources tested, and owners with a basis to make adaptive decisions about water use. Meanwhile, three states have taken a remedial approach: operators must conduct a baseline test or are incentivized to do so, creating information that can be used by the state and owners in determining liability for contamination.

Michigan's information policies primarily adopt a remedial approach to uncertainty, the most common approach of the other states surveyed. Michigan gathers information about well integrity through pressure monitoring during HVHF and information about water quality through a baseline test; both are remedial policies that use the information to address contamination and liability. The exception is the state's chemical disclosure policy, which takes a precautionary approach. By requiring operators to provide information on chemical constituents prior to HVHF, the state can take preventative actions in permitting. These actions are limited, however, by the incomplete nature of the chemical information: operators may withhold the identities of chemical constituents considered to be a trade secret and may use other chemicals in HVHF that are not disclosed in the permit application.

The intent of Michigan's chemical disclosure policy, as in other states, is to give more information to the public by collating the data and making it accessible through a permit application and a map-based website. But because the data is not translated into an easy-to-understand form, it is unclear how members of the public can participate in policy decisions or use the information to change their own behavior. The information, when combined with water quality testing, could serve the remedial purpose of determining whether HVHF is a possible cause of future contamination. If later testing detected a contaminant used in HVHF fluid, the baseline test would demonstrate whether the contaminant was present in groundwater prior to HVHF. But the policy relies on freshwater well owners to test for the correct contaminants.

4.2.4 Analysis of policy options

The tools available to the state to enhance, or hinder, access to information relating to HVHF vary significantly. Multiple mechanisms for the supply, and use, of information shall, however, be required by the state in order to deal with HVHF activities. As such, the state will be required to retain the status quo, return to former policies, examine how current policies may be amended to specifically address the desired objective, or look to new policy tools. With this in mind, this section presents a series of policy options available to policy makers and relevant regulators. Rather than identify each individual mechanism, the following section presents policy tools within the context of a suite of tools; each suite focuses, and addresses, the policy response to uncertainty that the state may wish to pursue in relation to information provision. Importantly, the purpose of the following options analysis is not to recommend or suggest one policy objective, and suite of policy tools, over another. Rather, it is to illustrate what policy tools, and in what combination, shall be needed in order to address a specified policy objective relating to information provision.

4.2.4.1 Option A: Information policy employing Michigan's previous approach

Michigan's previous information policies responded to uncertainty through a remedial approach. Information on hazardous chemicals, when combined with well pressure records, were primarily useful in helping the state to identify the source of any contamination. While employing the previous policies would impose fewer costs on industry and provide greater protection for intellectual property, lack of information would make it difficult for the state to take precautionary actions or refine policies over time through adaptive management.

Information on chemicals

Unlike Michigan's current precautionary policy, the state's previous remedial policy required HVHF well operators to submit a MSDS and the volume of each chemical additive used in HVHF to the state within sixty days after well completion.[113] The state then posted the MSDSs on the state's website, sorted by well.[114] A MSDS provides health and safety information on hazardous chemical products under worker safety law. Each MSDS includes a list of hazardous constituents in the product; the maximum concentration of each constituent; information on potential human health harms if workers are exposed; and safety precautions. Suppliers can withhold the identity of proprietary chemical constituents from the MSDS in accordance with federal law.[115]

If the state returned to the previous policy, it would focus attention on hazardous chemicals and make it easier for industry to accurately report chemical use. It could also help individuals understand more about the effects of specific chemicals through a readily available document. And it would provide maximum protection to product suppliers' and service companies' intellectual property. But the state would no longer be able to take preventative actions prior to HVHF using the information it collected through permitting. The slower release of information could also lead the state to invest less in infrastructure and response measures. The policy would decrease transparency about chemical use, which could weaken partnerships and trust between industry and the public. Finally, the policy would prevent members of the public from determining whether or not they want to challenge claims of trade secret protection.

Information on well integrity

Like Michigan's current policy, the previous policy took a remedial approach by requiring operators to monitor well pressures during HVHF and report them within sixty days of well completion.[116] The policy did not, however, direct operators to cease operations or take any specific action when monitoring indicated a problem. Adopting the previous policy would give operators more flexibility in responding to monitoring data and reduce the costs of compliance for industry. But without specific supplementary measures, the policy could lead to poor well integrity and increased potential public health and environmental risks.

Information on water quality

Prior to the current remedial policy, Michigan did not have a specific policy governing water quality testing near HVHF wells. Rescinding the state's baseline sampling requirements would reduce the costs to industry and avoid duplication of private testing by freshwater well owners. But without mandatory testing, it would be more difficult to determine if contamination occurred and remedial action is needed. In addition, there would be less data to judge whether or not current conditions pose unacceptable public and environmental risks.

4.2.4.2 Option B: Information policy employing an adaptive approach

Option B is concerned with increasing the availability of, and access to, information relating to aspects of HVHF activities so as to ensure that best practices may be followed at all times. Policy makers may adopt such an approach in order to ensure that evolving science informs the state's decision making about HVHF activities and the operation of HVHF sites. A key strength of Option B, when compared to the current policy, is that this approach, by virtue of increasing the amount of information collected and disclosed, may facilitate greater awareness by all impacted parties regardless of their knowledge of HVHF, and may strengthen public health and environmental preparedness. While continuing to employ the current policy would, relative to Option B, impose fewer monitoring and reporting requirements and financial costs on industry, it would also be difficult for the state to identify, and adapt, its practices in a timely manner.

4.2.4.1: OPTION A: INFORMATION POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH

POLICY AREA	POLICY ELEMENTS	CURRENT POLICY	OPTION A (PREVIOUS APPROACH)		
			PREVIOUS POLICY	RELATIVE TO CURRENT POLICY	
				KEY STRENGTH	KEY WEAKNESS
CHEMICAL USE	SUBJECT OF DISCLOSURE	All constituents	Hazardous constituents	Focus is on chemicals that pose hazards	Decreased transparency of chemicals used during HVHF can weaken partnerships and trust between industry and the public
	MEANS OF DISCLOSURE	Permit application; FracFocus	MSDS on state website	MSDS is readily available and content may be better understood by the public.	State does not have information on chemicals prior to HVHF; public cannot access multistate information in one place
	TIMING OF DISCLOSURE	Before HVHF and within 30 days after HVHF	Within 60 days after HVHF	Easier for industry to accurately report when HVHF has occurred	State cannot impose permitting requirements related to chemicals; less preparedness (e.g., infrastructure and response measures) through slower release of information
	TRADE SECRET CLAIM REVIEW	Statement of claim; must use family name or other description	None	Ensures broad protection of intellectual property	Less disclosure decreases awareness and keeps individuals from determining whether or not they want to challenge trade secret claims
WELL CONSTRUCTION	PRESSURE MONITORING	Monitored during HVHF and reported immediately to state if problem; HVHF ceases until plan of action implemented	Monitored during HVHF and reported within 60 days	More flexibility for industry when responding to data	Without supplementary administrative measures to ensure remedial action, poor well integrity can increase potential public health and environmental risks.
	MECHANICAL INTEGRITY TEST	When monitoring during HVHF indicates problem	None	Reduced financial cost to industry for mechanical integrity tests	
WATER QUALITY	WATER SOURCE	Groundwater	None	Reduced financial cost to industry for baseline tests, and avoids testing duplication	More difficult to determine whether or not contamination occurred and remedial action is needed; less data to judge whether or not current conditions pose unacceptable public and environmental risks
	AREA AROUND WELL	¼-mile radius around well			
	NUMBER OF SOURCES TESTED	Up to 10			
	FREQUENCY OF TESTING	Baseline test, >7 days but <6 months prior to drilling of new well or HVHF of existing well			
	TEST RESULTS	Within 45 days to state and owner; immediate report of BTEX to state			

4.2.4.2: OPTION B: INFORMATION POLICY EMPLOYING AN ADAPTIVE APPROACH

POLICY AREA	POLICY ELEMENTS	CURRENT POLICY	OPTION B (ADAPTIVE APPROACH)		
			ADAPTIVE POLICY	RELATIVE TO CURRENT POLICY	
				KEY STRENGTH	KEY WEAKNESS
CHEMICAL USE	SUBJECT OF DISCLOSURE	All constituents	All constituents; plain-language description	Information on chemicals is communicated in a way that is understood by the lay public; can facilitate awareness by all impacted parties regardless of their knowledge of HVHF	Increased reporting for industry and financial costs; information may not be accurate
	MEANS OF DISCLOSURE	Permit application; FracFocus	Master list; state website; FracFocus	State and public have information on statewide chemical use by operators before HVHF, which is updated over time	State cannot limit chemical use in individual wells
	TIMING OF DISCLOSURE	Before HVHF and within 30 days after HVHF	No change	None	None
	TRADE SECRET CLAIM REVIEW	Statement of claim; must use family name or other description	Careful scrutiny of trade secret claims	More information can strengthen public health and environmental preparedness	Could discourage innovation and investment in HVHF activity
WELL CONSTRUCTION	PRESSURE MONITORING	Monitored during HVHF and reported immediately to state if problem; HVHF ceases until plan of action implemented	Monitored during HVHF and reported immediately to state and nearby landowners if problem; status placed on website; HVHF ceases until plan of action implemented	Prompt information to owners and public about poor well integrity can reduce exposure	Increased action and reporting requirements for industry
	MECHANICAL INTEGRITY TEST	When monitoring during HVHF indicates problem	Periodic tests through life of operating well	Risks to public health and environment of operating wells can be identified earlier	Financial cost to industry for mechanical integrity tests
WATER QUALITY	WATER SOURCE	Groundwater	Groundwater and surface water	Groundwater and surface water data can be used to determine whether or not contamination occurred and remedial action is necessary throughout use of HVHF well, based on comparison against water quality standards that are intended to protect the public and environment from unacceptable risks	Financial cost to industry for monitoring groundwater *and* surface water
	AREA AROUND WELL	¼-mile radius around well	Based on characteristics of aquifer/watershed		
	NUMBER OF SOURCES TESTED	Up to 10	Part of larger monitoring system in area		
	FREQUENCY OF TESTING	Baseline test, >7 days but <6 months prior to drilling of new well or HVHF of existing well	Baseline test; long-term regular monitoring		
	TEST RESULTS	Within 45 days to state and owner; immediate report of BTEX to state	Within 10 days to state, owner, and public; immediate report of contaminants of concern	Faster reporting of more contaminants and notification of the public can limit exposure	Increased reporting requirements for industry

Information on chemical use

Option B would require all well operators in Michigan to disclose information on the chemical constituents they use in the state in a master list, prior to HVHF activities. This policy is similar to the policies in Arkansas and Illinois, but Option B would also require well operators to provide, where possible, plain-language descriptions of the constituents (i.e., understandable by the lay public)[117] prior to HVHF activities. The information on constituents would be regularly updated as operators alter their use of chemical additives. The disclosure would be through a dedicated state website; importantly, the information would be tied to other information about the operator, such as permit applications, permits, results of water quality tests, and enforcement history. Operators would also be required to disclose the actual constituents used, with plain-language descriptions—where possible—within thirty days after well completion. The information would be disclosed on the state website and through FracFocus, if it becomes fully searchable.

In order to comply with the policies forming Option B, operators would have the ability to assert trade secret protection on behalf of product suppliers and service companies with regard to the specific identity of a chemical constituent. The state would carefully scrutinize claims to ensure that information is not unnecessarily withheld from the public. When needed for public health purposes, the information would be required to be disclosed.

Because full information is necessary for adaptive management, failure to disclose accurate chemical information would carry a maximum penalty of $1,000 per day of violation.

Option B would enable experts and the lay public to assess chemical constituent use over time across the country, and facilitate greater awareness of HVHF more generally. Relative to the current policy, this approach would increase the amount of information available to the public regarding chemical use in HVHF activities, and strengthen public health and environmental preparedness. Even with a penalty for failure to report accurate information, however, there may be some challenges in assuming that all companies will in fact disclose the information they are expected to, and do so in a timely way.[118] Moreover, inclusion of a plain-language description under this policy would place a financial burden on all operators and increase reporting and financial costs. While states would protect valid trade secret information, the scrutiny could discourage innovation and investment in HVHF activity in the state.

Information on well construction

Option B would assist the state to refine its policies by collecting monitoring data on well pressures during HVHF. As with Michigan's current policy, the data would be reported to the state within sixty days after well completion. If pressures during hydraulic fracturing indicate a lack of well integrity, this information would be reported to the state immediately. And as in the current policy, the operator would be required to cease hydraulic fracturing, notify the state, and submit a corrective action plan.

Option B differs from Michigan's current policy in that it would also require the well operator to immediately notify surrounding landowners of the problem and keep them informed of the status of the well. Information about the status of the well would be incorporated into the state website. Prompt provision of information about well integrity could reduce exposure, and lead to decreased potential public health and environmental risks. Such requirements would, however, come at a cost to industry due to the increased action and reporting requirements.

Rather than a single mechanical integrity test in the event of a problem during HVHF, as required under Michigan's current policy, Option B would require the operator to periodically test the mechanical integrity of the operating well. This would enable the operator to identify, at an early stage, any potential risks to the public and/or the environment in relation to the well. The additional mechanical integrity testing would impose additional financial costs on industry. This may be a limitation for small operators, and could adversely impact competition within the state.

Information on water quality

Under Michigan's current policy, operators of HVHF wells are required to conduct a baseline test of groundwater quality. The adaptive approach proposed under Option B would seek to gather more information by requiring ground and surface water monitoring of sources that could be contaminated by an HVHF well, at regular intervals. This monitoring would be part of a larger effort to monitor the water quality of the aquifer and watershed in which HVHF is occurring, and could rely on monitoring networks. Option B would require test results to be made available to the state and well owner within a short period of time, such as 10 days. The results would be posted on the state website. Option B would also require the operator to immediately notify the state and well owner of the presence of any contaminant of concern.

By broadening the scope of water sources to be tested, and by requiring testing at a set, regular interval, additional data on water quality—relative to the baseline—would be generated. Monitoring in this way would assist the various parties in determining if, and where, contamination of water sources has occurred. Regular testing would allow more timely remedial action, if necessary, to take place. Faster reporting of more contaminants and notification of the public could also limit exposure. This approach would assist the state, and operators, in protecting the public and the environment from potential risks associated with HVHF wells. It would do so, though, at a substantial cost to industry; operators would be required to test ground and surface water, over a larger area, as part of a larger monitoring system, and over a longer period of time. But without this suite of water quality testing and reporting measures, it is difficult to determine if contamination has occurred and what remedial action is needed.

4.2.4.3 Option C: Information policy employing a precautionary approach

Option C would impose more reporting obligations on the operator than currently exist at this time, but would limit public access to trade secret information. Under this suite of policies, the state and, in particular, the regulator, are the primary beneficiaries of the information. This would allow the state to adopt a more precautionary approach to managing HVHF activities within Michigan, including the management of human and/or ecological risks.

Information on chemical use

Option C would require operators to submit a list of all chemical constituents for use as part of a permit application and disclose any relevant health and safety studies. As in the proposed rules considered by New York, operators would be required to conduct an alternatives analysis to demonstrate that the proposed chemicals pose a smaller risk than other feasible alternatives. Any change in constituents after the permit is issued would require additional approval by the state. After HVHF, operators would verify that the constituents used in the fluid were the same as those in the permit application.

As in Option B, operators would have the ability to assert trade secret protection on behalf of product suppliers and service companies in relation to the specific identity of a chemical constituent. Operators would be required to submit the information claimed to be a trade secret to the state so that state experts could have full data on chemical use prior to making a decision on the permit application.

As part of the permit application, the operator would be required to include a plain-language explanation of foreseeable potential human and/or ecological risks associated with the use of chemical constituents and to list the chemical alternatives. Information not protected by trade secret protection would be made publicly available via the state's website, in a map-based form that is easily accessible. The public would be provided with an opportunity to comment on the permit application, and object accordingly.

This policy would ensure that the state and public have accurate information prior to HVHF, but once again, it is not clear that all companies would in fact disclose the information in a timely way. The policy would also restrict industry from altering chemical use on site, increase reporting

4.2.4.3: OPTION C: INFORMATION POLICY EMPLOYING A PRECAUTIONARY APPROACH

POLICY AREA	POLICY ELEMENTS	CURRENT POLICY	OPTION C (PRECAUTIONARY APPROACH)		
			PRECAUTIONARY POLICY	RELATIVE TO CURRENT POLICY	
				KEY STRENGTH	KEY WEAKNESS
CHEMICAL USE	SUBJECT OF DISCLOSURE	All constituents	All constituents; plain-language description of risks and alternatives; studies	Information is communicated in a way that is understood by the lay public; can facilitate awareness by all impacted parties regardless of their knowledge of HVHF	Increased reporting requirements for industry and financial costs of studies; information may not be accurate
	MEANS OF DISCLOSURE	Permit application; FracFocus	Permit application; state website	State can directly control risk communication on its own website	Information not part of a national website
	TIMING OF DISCLOSURE	Before HVHF and within 30 days after HVHF	Before HVHF	Focus is on accurate information prior to HVHF	Industry cannot alter chemical use; no reporting
	TRADE SECRET CLAIM REVIEW	Statement of claim; must use family name or other description	Full information provided to state	Complete chemical disclosure permits the state to better protect the public and environment via informed decision making	Could discourage innovation and investment in HVHF activity
WELL CONSTRUCTION	PRESSURE MONITORING	Monitored during HVHF and reported immediately to state if problem; HVHF ceases until plan of action implemented	Monitored during HVHF and reported immediately to state and nearby landowners if problem; status placed on website; operator must demonstrate integrity before continuing	Prompt information to owners and public about poor well integrity can reduce exposure	Increased action and reporting requirements for industry
	MECHANICAL INTEGRITY TEST	When monitoring during HVHF indicates problem	Prior to approval of HVHF; when monitoring indicates a problem	Risk of contamination is reduced by ensuring well integrity prior to HVHF	Financial cost to industry for mechanical integrity tests
WATER QUALITY	WATER SOURCE	Groundwater	Groundwater and surface water	Continuous groundwater *and* surface water data can be used to determine whether or not contamination occurred in critical water sources and remedial action is necessary, based on comparison against water quality standards that are intended to protect the public and environment from unacceptable risks	Financial cost to industry for continuous monitoring of groundwater *and* surface water
	AREA AROUND WELL	¼-mile radius around well	Based on characteristics of aquifer/watershed		
	NUMBER OF SOURCES TESTED	Up to 10	Based on importance of sources to be protected		
	FREQUENCY OF TESTING	Baseline test, >7 days but <6 months prior to drilling of new well or HVHF of existing well	Baseline test; long-term continuous monitoring of critical sources		
	TEST RESULTS	Within 45 days to state and owner; immediate report of BTEX to state	Prior to approval of well and within 10 days to state, owner, and public; immediate report of all contaminants	Faster reporting of all contaminants and notification of the public can limit exposure and reassure public	Increased reporting requirements for industry

requirements, and result in significant costs for studies. Information would be communicated in a way that is understood by the lay public, facilitating awareness by all impacted parties regardless of their knowledge of HVHF. Small operators may not, however, have the necessary in-house expertise for this, which would add an additional financial cost to them as part of the permit process. The state could directly control risk communication on its own website, but the information would not be part of a national website such as FracFocus. Finally, complete chemical disclosure would allow the state to better protect the public and environment via informed decision making, but it could discourage innovation and investment in HVHF activity in the state.

Information on well construction

Pursuant to Option C, operators would be required to conduct mechanical integrity tests of wells and to report the test data to the state prior to state approval of HVHF. If pressures during hydraulic fracturing indicate a lack of well integrity, Option C would require that this information be reported to the state immediately, and as in Option B, the operator would cease any HVHF activity. The operator would be obligated to notify the state, and submit a corrective action plan. Prior to recommencing HVHF, the operator would have the burden of demonstrating that the well's integrity is fully protective of the environment.

If Option C were adopted, prompt information to owners and public about poor well integrity could reduce exposure, and the risk of contamination would be reduced by ensuring well integrity prior to HVHF. But there would be increased action and reporting requirements for industry, and financial costs to industry for mechanical integrity tests.

Information on water quality

Option C would require the permit applicant to conduct baseline tests to identify the existing quality of groundwater and surface waters around the well, with a specific focus on sources that provide drinking water or are ecologically sensitive. The applicant would be required to submit baseline test results to the state as part of its permit application and to immediately notify the state and the well owner of any contamination. The state would consider the current uses of water sources and the existing water quality in making its permitting decision. If the permit is approved, the operator would then be required to conduct continuous long-term monitoring of critical water sources and report the results within a short period of time to the state and the well owner. The operator would have a duty to immediately notify the state and the well owner of any indication of contamination, and would be required to submit a corrective action plan.

Continuous groundwater and surface water data could be used to determine whether or not contamination occurred in critical water sources and remedial action is necessary, based on a comparison against water quality standards that are intended to protect the public and environment from unacceptable risks. In addition, faster reporting of all contaminants and notification of the public could limit exposure and reassure the public. But the policy would result in a financial cost to industry for continuous monitoring of groundwater and surface water and increase reporting requirements.

4.2.5 Summary

As this section has illustrated, the provision of information regarding HVHF is fundamental to governmental and individual decision making. That being said, even when policies are designed to specifically enhance transparency and reporting requirements for the public, the beneficiaries will be those individuals who are interested and/or aware of information sources such as websites, and have the means to access such sources. In the absence of significant efforts by the state to reach the broader public, state regulators and experts will continue to be the greatest beneficiaries of enhanced information polices for HVHF activities.

4.3 PRESCRIPTIVE POLICY

4.3.1 Introduction

The state has traditionally used prescriptive policies-or 'command and control' regulation-as a mechanism to influence and shape behavior. Compulsory in nature, prescriptive policies are often perceived as creating greater regulatory certainty, enhancing accountability and creating a level playfield for actors when compared to no regulation (or, rather, no specific regulation and/or co-regulatory or self-regulatory approaches). Yet such policies can lag behind rapid advances in technology and best practices employed by the industry. Unlike information policy, states have not been uniform in their attention to prescriptive requirements that restrict or control aspects of hydraulic fracturing.

4.3.2 Range of approaches

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.

4.3.2.1 Restrictions on chemical use

Two of the states surveyed specifically control chemical use beyond the disclosure requirements in permit applications or completion reports. Illinois prohibits the use of diesel.[119] New York is unique in having proposed state review and approval of chemicals before hydraulic fracturing operations may proceed. The operator would have been required to prove that "proposed chemical additives exhibit reduced aquatic toxicity and pose at least as low a potential risk to water resources and the environment as all known available alternatives," or that any alternatives would be economically unfeasible.[120] New York would also have limited the use of biocides to only those "registered for use in New York . . . for any operation at the well site."[121]

Michigan has no restrictions on chemicals used in HVHF wells.

4.3.2.2 Limitations on siting

In contrast to direct regulation of chemical use, all of the surveyed states have limitations on siting wells and associated facilities. Three states have limitations specific to HVHF wells and facilities.[122] The Governor of New York recently announced that no HVHF wells will be sited in the state, after the state Department of Health determined that there were "significant uncertainties about the kinds of adverse health outcomes that may be associated with HVHF, the likelihood of the occurrence of adverse health outcomes, and the effectiveness of some of the mitigation measures in reducing or preventing environmental impacts which could adversely affect public health."[123]

The most common limitation on siting is a requirement that wells and associated facilities be sited away from surface waters. Of the eight states surveyed, six require setbacks from surface waters for oil or gas wells,[124] while two require setbacks only for facilities that store flowback or produced water.[125] Two states require setbacks specifically for wetlands.[126] The distances range from fifty feet in Ohio[127] to three hundred feet in most other states[128] to 2,000 feet proposed by New York for surface public water supplies.[129] States also prohibit siting in locations that would block natural drainages[130] and 100-year floodplains.[131] Texas prohibits off-site commercial fluid recycling facilities that store flowback in sensitive areas, such as those near surface waters and wetlands.[132]

The second most common limitation is a setback from freshwater wells or springs that supply drinking water. Five of the surveyed states require setbacks from freshwater wells or springs, with distances ranging from fifty feet in Ohio to 2,000 feet in New York.[133] States often require public water supplies to be located further away than private water wells or springs. Illinois, for example, requires HVHF operators to adhere to a 500-foot setback from a water well or developed spring, but a 1,500-foot setback from the groundwater intake of a public water supply.[134]

Least common is a prohibition on the siting of wells and associated facilities within a certain protected area. New York's proposed policy would have expressly protected public lands by

TABLE 4.5: SUMMARY OF PRESCRIPTIVE POLICY OPTIONS FOR MICHIGAN						
POLICY AREA	POLICY ELEMENTS	CURRENT POLICY		OPTION A (PREVIOUS APPROACH)	OPTION B (ADAPTIVE APPROACH)	OPTION C (PRECAUTIONARY APPROACH)
RESTRICTIONS ON CHEMICAL USE		None		None	List of prohibited chemicals, amended over time	Approval of chemicals only if applicant demonstrates low toxicity
LIMITATIONS ON SITING	OBJECT OF SITING	Oil or gas well	Surface facility	No change	Oil or gas well and storage areas, modified over time based on risks of activities	Oil or gas well; storage and handling areas
	RESOURCE PROTECTED	Freshwater wells	Public water supply wells	No change	Particularly sensitive features, modified over time based on new findings/best practices	All potentially affected natural resources
	DISTANCE	300 feet	800-2,000 feet	No change	Varies by feature, modified over time based on new findings/best practices	Varies by feature with additional cushion; no siting in protected areas
CONTROLS ON GROUNDWATER RISKS	WELL CONSTRUCTION REQUIREMENTS	Casing and cementing requirements		No change	Current requirements, modified over time based on groundwater monitoring data/best practices	Additional requirements that create as many layers of safety as feasible
	AREA-OF-REVIEW ANALYSIS	Within 1,320 feet (for deep wells); relocation, demonstration of no movement, or other preventative actions		No change	Within area most affected by HVHF; corrective action; modified over time based on groundwater monitoring data/best practices	Within drilling unit or larger area; relocation of well unless no risk from conduits
CONTROLS ON SURFACE RISKS	HANDLING OF FLOWBACK AND CHEMICAL ADDITIVES	Flowback stored in tanks or approved containers; secondary containment for production wellheads and surface facilities, including flowback storage tanks; tanks monitored for leaks		No substantive change	Flowback stored in pits or tanks; practices modified over time based on leakage data/best practices	Closed loop system for chemical additives, flowback; additive handling restrictions

prohibiting surface disturbance from HVHF gas wells on state lands, including wildlife management areas, multiple use areas, natural resources management areas, fishing access sites, boat launch sites, hatcheries, game farms, and tidal wetlands.[135]

Michigan requires operators to site all oil or gas wells 300 feet from existing recorded freshwater wells and reasonably identifiable freshwater wells utilized for human consumption.[136] Storage tanks, including those that contain flowback, must be sited 800 feet from small public water supply wells and 2,000 feet from larger public water supply wells.[137]

4.3.2.3 Controls on groundwater risks

To reduce the risk of groundwater contamination, the states focus primarily on the adequacy of well construction. Many states have detailed requirements governing the concentric steel piping known as "casing strings" and the use of cement to fill voids around casing. The purpose of these requirements is to create multiple barriers between substances in the well and the surrounding environment.

Of the states surveyed, all have updated or proposed to update their well construction requirements since HVHF began.[138] The states have adopted several different casing and cementing requirements. Operators may be required to use new casing,[139] reconditioned casing only if tested,[140] or casing that has a minimum pressure rating greater than the maximum pressure anticipated in hydraulic fracturing.[141] Operators may also be required to ensure a certain excess volume of cement,[142] a specific length of cemented casing,[143] or a minimum compressive strength of cement.[144] Michigan's current rules contain some of these requirements. All casing must have a minimum strength of 1.2 times the greatest expected wellbore pressure to be encountered.[145] The state must approve of the cement mixture composition and volume, and the cement must reach a minimum compressive strength.[146]

Less commonly, states may require an "area-of-review" analysis to address potential conduits of contamination around the wellbore. Illinois specifically requires operators to plug all "unplugged well bores within 750 feet of any part of the horizontal well bore that penetrated within 400 vertical feet of the formation that will be stimulated as part of the high volume horizontal hydraulic fracturing operations."[147] New York's proposed policy would have required the operator to identify abandoned wells within the spacing unit and one mile from the wellbore.[148] In 2011, the current chief of the Oil, Gas, and Minerals division of the DEQ issued a letter directing permitting staff to conduct an area-of-review analysis for potential conduits within 1,320 feet of deep HVHF wells.[149] If a conduit is identified, the letter states that the operator must relocate the proposed well to another location, demonstrate that hydraulic fracturing will not cause contamination of a fresh water aquifer, or take actions necessary to prevent the potential fluid movement.[150]

4.3.2.4 Controls on surface risks

To reduce the risk of surface contamination from spills, states have focused much of their policy attention on storage of flowback and produced water. The most common prescriptive requirements are specific construction standards and limitations on the length of time the wastewater can be stored. Pit construction standards include the thickness and number of liners and the height of "freeboard" between the top of the pit and the fluid.[151] Six states limit the storage of flowback in pits,[152] with durations that vary widely from seventy-two hours[153] to ninety days[154] to one year.[155] Two states prohibit the use of pits, instead requiring operators to use storage tanks.[156] The tanks must be water tight[157] and corrosion resistant,[158] with storage limited to 45 to 60 days.[159] Michigan currently requires flowback to be stored in tanks or approved containers, and prohibits operators from handling flowback so as to create unnecessary environmental damage or unnecessary endangerment of public health.[160]

Less common prescriptive requirements are secondary containment measures and other restrictions on handling of chemicals and flowback. Two of the surveyed states specifically require secondary containment systems for tanks that store flowback or chemical additives on well sites; one also requires systems for chemical additive staging areas.[161] These containment systems include "dikes, liners, pads, impoundments, curbs, sumps or other structures or equipment capable of containing the substance."[162] In addition to these systems, New York would have required hydraulic fracturing additives to be removed from the site when the site is unattended, and vacuum trucks to be on standby at the well site during the pumping of hydraulic fracturing fluid and during flowback.[163] Michigan requires secondary containment for production wellheads and surface facilities, including tanks that store flowback.[164] The state does not require containment systems under chemical trucks and mixing areas; however, it strongly encourages the practice.[165]

4.3.3 Policy approaches

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 specified 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 initial 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.

Only two of the surveyed states have considered policies that directly govern chemicals used in HVHF. New York proposed a precautionary approach: the policy would have shifted the burden of uncertainty to well operators and required them to come forward with information about the toxicity of chemical additives. It is difficult to categorize Illinois, as its policy is likely a response to federal authority over fracturing fluids containing diesel under the Safe Drinking Water Act.

As to siting policy, all of the states have chosen a precautionary approach by requiring setbacks for wells and/or associated facilities so as to limit or prevent harm to certain resources. New York would also have taken the precautionary approach further by prohibiting siting on public lands. The state has now chosen to ban the siting of HVHF wells, thereby adopting the most stringent precautionary policy.

In contrast, all of the states have taken an adaptive approach to policies controlling groundwater risks. Each state has modified its well construction requirements to respond to HVHF, making it probable that the states would do so again based on new information about risk. One state also has a precautionary policy that requires operators to plug potential conduits near HVHF wells, preventing migration of contaminants into groundwater. In a variation of this policy, New York proposed that operators identify potential conduits within a large area, but did not specify any response.

Finally, most states have taken a largely adaptive approach to policies controlling surface risks. Six states allow flowback to be stored in pits; five have refined this policy by prescribing construction standards and five by limiting the storage time. Two states take a precautionary approach instead by requiring that flowback be stored in steel tanks. Extending this approach, New York proposed both closed-loop systems and removal of chemical additives from the site when unattended. Two of the states also take a remedial approach by mandating secondary containment for fluids associated with HVHF to minimize the harm of a spill on the well site.

As in the majority of states, Michigan has adopted a combination of approaches. Michigan takes a precautionary approach to well siting through setback requirements, though the policy is limited to groundwater drinking sources. The state's policies controlling groundwater risks are primarily adaptive: well construction requirements are made flexible by the discretion given to permitting staff to set conditions. Yet the state also employs a precautionary approach by requiring operators to address potential conduits. Lastly, Michigan's policies controlling surface risks are both precautionary (requiring flowback to be stored in tanks), and remedial (mandating secondary containment measures for storage tank areas, though not for chemical staging areas).

4.3.4 Analysis of policy options

Questions, and concerns, regarding scientific uncertainty and associated risks are likely to be central to the state's choice of policies on HVHF activities and chemical use moving forward. As section 4.3.3 illustrates, the policy options available to the state may reflect the previous status quo, be adaptive and responsive to changing information, or take a more precautionary approach than that which is currently the policy in Michigan. However, as evidenced by the experiences of other states, it is most likely that any prescriptive policies adopted by Michigan in relation to HVHF activities in the future will involve multiple approaches. Certain policy areas may, for example, be more precautionary in nature due to actual and/or perceived uncertainties and greater levels of concern regarding, for example, human and/or ecological risks. Others may be more adaptive in nature, with the ability to respond quickly to the evolving state of the science and/or public pressure. As with those policies dealing with information provision, in the following section, policy tools are set out in the context of a suite of policy tools; each suite focuses on, and addresses, a particular overarching goal that the state may have.

4.3.4.1 Option A: Prescriptive policy employing Michigan's previous approach

The previous prescriptive policies are substantively the same as the current ones; the only change has been to clarify that flowback is to be stored in tanks. Thus, a return to the previous approach would not alter the state's combination of approaches to uncertainty.

4.3.4.2 Option B: Prescriptive policy employing an adaptive approach

Option B is focused on reducing potential risk to humans and the surrounding ecology through explicit and comprehensive regulatory requirements. The suite of policy tools crafted under Option B provides the state with an adaptive approach to managing potential human and ecological risks in the short and long term. Policy makers may be inclined to adopt this suite of policy tools if additional information and experience will address potential risks.

TABLE 4.3.4.1: OPTION A: PRESCRIPTIVE POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH

POLICY AREA	POLICY ELEMENTS	CURRENT POLICY		OPTION A (PREVIOUS POLICY)		
				PREVIOUS POLICY	RELATIVE TO CURRENT POLICY	
					KEY STRENGTH	KEY WEAKNESS
RESTRICTIONS ON CHEMICAL USE	RESTRICTIONS	None		None	None	None
LIMITATIONS ON SITING	OBJECT OF SITING	Oil or gas well	Storage tanks at surface facility	No change		
	RESOURCE PROTECTED	Freshwater wells	Public water supply wells	No change		
	DISTANCE	300 feet	800-2,000 feet	No change		
CONTROLS ON GROUNDWATER RISKS	WELL CONSTRUCTION REQUIREMENTS	Casing and cementing requirements		No change	None	None
	AREA-OF-REVIEW ANALYSIS	Within 1,320 feet (for deep wells); relocation, demonstration of no movement, or other preventative actions		No change		
CONTROLS ON SURFACE RISKS	HANDLING OF FLOWBACK AND CHEMICAL ADDITIVES	Flowback stored in tanks or approved containers; secondary containment for production wellheads and surface facilities, including flowback storage tanks; tanks monitored for leaks		No substantive change	None	Reduced clarity

Restrictions on chemical use

At present, Michigan does not place any restrictions on operators in relation to the types of chemicals used in HVHF activities. Option B would seek to specifically control and limit the use of certain chemicals by well operators. The state would have the regulatory authority to prohibit the use of chemicals that exhibit particularly high risk due to their toxicological characteristics (e.g., chemicals that are acutely toxic to organisms in small quantities). The use of diesel would be prohibited outright. As more is known about the risks of specific chemical additives, the state could add or remove chemicals from the prohibited list.

A key strength of this approach is that, when compared to the current policy, the state would have an additional tool to help reduce risks posed by chemicals to the public and environment. This may be more effective than other measures (e.g., engineering or administrative controls), which are subject to error. The potential financial costs could, however, be significant to some operators if the alternatives are more expensive.

Limitations on siting

Option B would require operators to site HVHF well sites and tanks that store flowback away from all sensitive ecological resources, not just fresh water supplies as in Michigan's existing policy. The setback distance would be determined by identifying the risks to the particular resource, and limits could be amended over time in order to take into account new scientific findings, and/or changes to best practices. This greater flexibility in addressing particularized effects would be a real strength of the proposed policy, when compared to the current approach, but the policy over time may also limit siting possibilities.

Controls on groundwater risks

Option B would utilize existing well construction requirements. The requirements would be reviewed, and adapted, by the state every three years as a way to ensure that best practice continues to be followed. A key strength of this approach is that it would enable data to be used on an ongoing basis to mitigate (potential) public health and environmental risks that arise due to poor integrity. However, changes in well construction requirements based on this adaptive approach could place a substantial financial burden on industry.

Option B would also utilize an area-of-review analysis to identify potential conduits, but rather than use a set distance based on the depth of the well, the area of review would be individually determined for each well depending on the length of the horizontal leg and the characteristics of the surrounding area. This would increase the area of analysis to include the most affected areas. The operator would be required to address conduits that pose the greatest risk of fluid movement, such as plugging the nearest abandoned wells, and the state would adapt the policy based on the results of groundwater monitoring. These actions would result in greater costs to industry.

4.3.4.2: OPTION B: PRESCRIPTIVE POLICY EMPLOYING AN ADAPTIVE APPROACH

POLICY AREA	POLICY ELEMENTS	CURRENT POLICY		OPTION B (ADAPTIVE APPROACH)		
				ADAPTIVE POLICY	RELATIVE TO CURRENT POLICY	
					KEY STRENGTH	KEY WEAKNESS
RESTRICTIONS ON CHEMICAL USE	RESTRICTIONS	None		List of prohibited chemicals, amended over time	Reduce risks posed by chemicals to the public and environment; may be more effective than other measures (e.g., engineering or administrative controls), which are subject to error	Financial costs to industry for modifying operations to function without the use of certain chemicals
LIMITATIONS ON SITING	OBJECT OF SITING	Oil or gas well	Storage tanks at surface facility	Oil or gas well and storage areas, modified over time based on risks of activities	Added flexibility to modify siting requirements based on the feature, state of scientific opinion, and public views	Over time may limit siting possibilities
	RESOURCE PROTECTED	Freshwater wells	Public water supply wells	Particularly sensitive features, modified over time based on new findings/best practices		
	DISTANCE	300 feet	800-2,000 feet	Varies by feature, modified over time based on new findings/ best practices		
CONTROLS ON GROUNDWATER RISKS	WELL CONSTRUCTION REQUIREMENTS	Casing and cementing requirements		Current requirements, modified over time based on groundwater monitoring data/best practices	Data can be used to mitigate public health and environment risks that arise due to poor integrity	Financial cost to industry for changes in construction standards
	AREA-OF-REVIEW ANALYSIS	Within 1,320 feet (for deep wells); relocation, demonstration of no movement, or other preventative actions		Within area most affected by HVHF; corrective action; modified over time based on groundwater monitoring data/best practices	Could increase area of analysis; data can be used to mitigate public health and environment risks	Greater costs to industry
CONTROLS ON SURFACE RISKS	HANDLING OF FLOWBACK AND CHEMICAL ADDITIVES	Flowback stored in tanks or approved containers; secondary containment for production wellheads and surface facilities, including flowback storage tanks; tanks monitored for leaks		Flowback stored in pits or tanks; practices modified over time based on leakage data/ best practices	May be more efficient for industry to use pits and monitor for leakage; data can be used to mitigate public health and environment risks	May increase likelihood for contact of chemicals with the neighboring human and ecological communities; financial cost to industry for modifying operations

4.3.4.3: OPTION C: PRESCRIPTIVE POLICY EMPLOYING A PRECAUTIONARY APPROACH						
POLICY AREA	POLICY ELEMENTS	CURRENT POLICY		OPTION C (PRECAUTIONARY APPROACH)		
				PRECAUTIONARY POLICY	RELATIVE TO CURRENT POLICY	
					KEY STRENGTH	KEY WEAKNESS
RESTRICTIONS ON CHEMICAL USE	RESTRICTIONS	None		Approval of chemicals only if applicant demonstrates low toxicity	Ability to restrict the use of chemicals to reduce or eliminate public health and environmental risks	Financial costs to industry for modifying operations to function without the use of certain chemicals
LIMITATIONS ON SITING	OBJECT OF SITING	Oil or gas well	Storage tanks at surface facility	Oil or gas well; storage and handling areas	Ensures that risks of all facilities are considered	Would limit siting possibilities
	RESOURCE PROTECTED	Freshwater wells	Public water supply wells	All potentially affected natural resources	Additional distance buffer will further minimize the potential impact of HVHF activities on nearby water sources and sensitive areas.	Decreased access to natural gas reservoirs for industry and other interested parties
	DISTANCE	300 feet	800-2,000 feet	Varies by feature with additional cushion; no siting in protected areas		
CONTROLS ON GROUNDWATER RISKS	WELL CONSTRUCTION REQUIREMENTS	Casing and cementing requirements		Additional requirements that create as many layers of safety as feasible	Conservative approach to well construction and conduits generates additional confidence that nearby groundwater will be protected from potential contamination associated with poor well integrity.	Financial cost to industry for complying with conservative well construction conditions
	AREA-OF-REVIEW ANALYSIS	Within 1,320 feet (for deep wells); relocation, demonstration of no movement, or other preventative actions		Within drilling unit or larger area; relocation of well unless no risk from conduits		
CONTROLS ON SURFACE RISKS	HANDLING OF FLOWBACK AND CHEMICAL ADDITIVES	Flowback stored in tanks or approved containers; secondary containment for production wellheads and surface facilities, including flowback storage tanks; tanks monitored for leaks		Closed loop system for chemical additives, flowback; additive handling restrictions	Decreased likelihood for contact of chemicals with the neighboring human and ecological communities	Financial cost to industry for modifying operations

Controls on surface risks

Unlike Michigan's current policy, Option B would allow operators to place flowback in pits if they complied with best practices in pit construction, storage duration, and monitoring. It may be more efficient for industry to use pits and monitor for leakage, but it could also increase the likelihood of contact of chemicals with the neighboring human and ecological communities.

4.3.4.3 Option C: Prescriptive policy employing a precautionary approach

Option C adopts a precautionary approach to managing HVHF activities. Each component is designed to limit human and environmental exposure to chemicals used in HVHF activities. The key strength of this approach, relative to Michigan's current policy, stems from the state's ability to restrict operators from using certain chemicals in HVHF activities. This may reduce and/or eliminate potential public health and environmental risks associated with HVHF activities. Of the different options presented in this chapter, Option C would provide maximum protection to the public in relation to HVHF activities. But, it would do so at a substantial financial cost to industry, due to the substantial changes that would be needed to ensure compliance with this precautionary approach.

Restrictions on chemical use

Option C would adopt the precautionary approach proposed by New York in its regulations. The state would review and approve all chemicals prior to the commencement of HVHF activities; approval of each chemical would be dependent on the operator demonstrating in its application that the chemical poses "at least as low a potential risk to water resources and the environment as all known available alternatives." Option C would therefore represent a significant shift in policy from that which currently exists in Michigan, allowing the state to restrict the use of chemicals to reduce or eliminate public health and environmental risks. There would, however, be financial costs to industry for modifying operations to function without the use of certain chemicals.

Limitations on siting

The current Michigan approach requires an operator to site all oil or gas wells at least 300 feet from freshwater wells that have been recorded, or are reasonably identifiable. Option C would broaden this requirement so that facilities associated with oil and gas wells—including well sites, additive handling areas, and surface facilities—be set back a greater distance from both groundwater wells and surface features. Operators would also be prohibited from siting a well in locations that are particularly important to the public or the environment, such as water supply areas, state parks, or wilderness areas. While this proposed approach would ensure that the risks of all facilities are considered and the additional distance buffer would further minimize the potential impact of HVHF activities on nearby water sources and sensitive areas, a significant weakness of this approach is that it would limit siting possibilities, decreasing access to natural gas reservoirs for industry and mineral interest owners.

Controls on groundwater risks

Option C would require the state to continue to use, and enforce, detailed requirements for all facets of well construction, including requirements relating to casing and cementing. These requirements could be stricter than those set out in the current policy, and include, for example, standards used for disposal wells. Under Option C, should an area-of-review analysis identify potential conduits of contamination in the drilling unit or larger area, operators would be required to relocate the proposed well to another location unless they could demonstrate that there is no risk.

This conservative approach to well construction and conduits may generate additional confidence in members of the public, by reassuring them that groundwater nearby HVHF sites will be protected from potential contamination associated with poor well integrity. However, as with the other elements of this proposed approach, the potential financial costs to industry are likely to be substantial.

Controls on surface risks

Under Option C, operators would use a closed-loop system for HVHF, which would not only prohibit temporary storage of flowback in an on-site pit, but would require all fluids to be transferred through piping to water-tight tanks. One obvious benefit of this approach is the decreased likelihood for contact of chemicals with the neighboring human and ecological communities. The introduction of closed loop systems could thereby help reduce the concerns of some members of the public about the potential risks of HVHF activities within the state, but it would also result in significant financial costs to industry.

In addition, Option C would take a preventative approach by imposing additional restrictions on chemical handling; for example, the operator could be required to remove HVHF additives from the site when the site is not attended. These added physical measures are designed as a way to further prevent the leakage of HVHF chemicals into the surrounding environment in both the short and long term. And the measures would help to mitigate concerns that the public may have in regards to contamination of the surrounding environment, although again, at a significant cost to industry.

4.3.5 Summary

The prescriptive policy options discussed in this section focus on restricting and/or limiting the use of chemicals in HVHF activities, the siting of wells and associated facilities, and controlling potential risks to water. As section 4.3.4 highlights, the prescriptive policies available to the state are, for the most part, highly technical in nature. This means that compliance with any such policy is dependent not only on the actions of the well operator, but also on the will of the state to actively inspect, and enforce, the specific policy. Transparent monitoring and enforcement activities may have the additional benefit of promoting accountability between the relevant stakeholders. Such accountability mechanisms are a fundamental facet of any prescriptive policies adopted by the state for HVHF activities.

4.4 RESPONSE POLICY

4.4.1 Introduction

Spills, or accidental release, of chemicals used in HVHF activities (including chemical additives, hydraulic fracturing fluid, and flowback) and the implications of exposure to these chemicals by 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 spills, 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 releases occur.

4.4.2 Range of approaches

State spill response policies primarily focus on four areas:

1. planning for emergencies;
2. reporting and cleanup;
3. financial responsibility; and
4. liability to private parties.

4.4.2.1 Emergency planning

Three of the surveyed states require well operators to conduct emergency planning.[166] Colorado requires operators of wells in public surface water supply areas to implement an emergency spill response program that includes employee training, safety, and maintenance.[167] Pennsylvania mandates an emergency response plan for unconventional wells, which includes response measures and a summary of risks and hazards to the public.[168] New York proposed both an emergency response plan[169] and a specific surface spill prevention plan,[170] and would have required HVHF operators to notify the county emergency management office of well locations.[171] In Michigan, operators of hydrogen sulfide wells must create emergency response plans, but not other operators.[172]

4.4.2.2 Reporting and cleanup

Spills of fluids related to HVHF on well sites are subject to several federal and state laws. Depending on the substance spilled and the environmental effect, the federal Comprehensive Environmental Response, Compensation, and Liability Act (better known as the "Superfund" Act), the Emergency Planning and Community Right-to-Know Act, and the Clean Water Act could require reporting and/or cleanup. This section, however, will focus on two types of state laws: oil and gas well permitting laws, and generally applicable hazardous substance reporting and cleanup laws.

The majority of the surveyed states directly regulate spills of fluids related to HVHF as part of the states' oil and gas well program. Four states require well operators to notify the state of spills and clean them up. Two states focus on flowback spills,[173] while two others mandate reporting and cleanup of other HVHF fluids in addition to flowback.[174] In its proposed rules, New York required operators to notify the state of any "non-routine incidents," including surface chemical spills, and take remedial action.[175] The remaining three states generally prohibit pollution from oil and gas production activities, but do not specifically mandate reporting or cleanup actions.[176]

The policies vary by reporting threshold, deadline, and audience; and in the specificity of cleanup standards. Three states direct operators to clean up spills but require reporting of only those spills that meet a minimum threshold of one to five barrels.[177] Deadlines range from immediate notification to within twenty-four hours.[178] The primary audience is the state agency. Two states direct operators to notify surface owners of spills;[179] only one directs operators to notify local governments.[180] Most of the states use general cleanup standards. The exception is Colorado, which requires operators to meet specified concentration levels when there are threatened or actual significant adverse impacts to the environment.[181]

Beyond the oil and gas program, all of the surveyed states have adopted generally applicable laws that require owners or operators of facilities to report spills of identified hazardous substances and to remediate contaminated sites.[182] These laws apply to operators of HVHF wells that spill fluids containing such substances. Four states limit reporting to spills large enough to meet the federal "reportable quantity" threshold for the substance, while two states do not have a threshold. Two tie reporting to impacts to state waters. Pennsylvania, for example, requires reporting and remediation of spills that could pollute state waters,[183] and has issued guidance for oil and gas well operators on how to comply.[184]

Michigan's oil and gas laws require operators to report losses or spills of chemical additives and "brine," which includes flowback, to the state within eight hours of discovery.[185] Operators must also submit a written report within ten days.[186] Operators need not notify the state within eight hours if a spill of less than forty-two gallons of flowback occurs; the flowback does not contact surface waters, groundwater, or other environmentally sensitive resources; and the spill is completely contained and cleaned up within forty-eight hours of discovery.[187] Spills of less than forty-two gallons of flowback that occur while the operator is on site and are cleaned up within one hour are not subject to reporting.

While Michigan's oil and gas laws do not specify cleanup standards beyond prevention of surface and underground "waste,"[188] any well site that contains hazardous substances at concentrations in excess of those considered safe for residential use is a facility subject to the state's Environmental Remediation statute.[189] Under this law, the operator responsible for the spill must notify the DEQ and surface owner within thirty days, and the well site must be remediated according to state cleanup criteria.[190] There is no requirement that operators notify local governments of these spills.

4.4.2.3 Financial Responsibility

To ensure that operators clean up the site, states require firms to post a bond prior to drilling a well. These bonds usually take the form of low-risk securities (such as certificates of deposit or treasury securities), and they may only be recovered by the firm (with interest) after production is completed and the site is remediated. For small firms that cannot post the required minimum bond amount, states typically allow surety bonds, where an insurance company guarantees the firm's environmental performance.

There exists considerable variation across the surveyed states in bonding and insurance requirements. The lowest required per-well bond amount is $5,000 in Ohio.[191] At the other extreme is New York, which requires a bond amount up to $250,000 for wells deeper than 6,000 feet.[192] Pennsylvania sets the bond amount based on the type of well and bore length.[193] All of the surveyed states also have a blanket bond policy in which a single bond can cover many wells at once, thereby reducing the per-well bond amount. In Ohio, a single blanket bond for $15,000 can cover all of a firm's wells in the state,[194] while New York does not require financial insurance beyond $2,000,000.[195] None of these states indexes the required bond amounts to inflation or some other measure of remediation costs.

Michigan currently requires a bond of $10,000/well for wells less than 2,000 feet deep, $20,000/well for wells between 2,000 and 4,000 feet deep, $25,000/well for wells between 4,000 and 7,500 feet deep, and $30,000/well for wells deeper than 7,500 feet.[196] Michigan also permits blanket bonds. Up to 100 wells less than 2,000 feet deep may be covered by a $100,000 bond[197]; up to 100 wells between 2,000 and 4,000 feet deep may be covered by a $200,000 bond;[198] and an unlimited number of wells greater than 4,000 feet deep may be covered by a $250,000 bond.[199] These obligations may be fulfilled by surety bonds.[200] In a 2013 review of the DEQ's Office of Oil, Gas, and Minerals, the Michigan Auditor General found that the bond amounts allowed by statute are not sufficient to cover the cost of plugging a well. Of the total $693,638 necessary to plug 13 wells from 2005 to 2013, bonds covered only $229,568 and the DEQ paid the remaining $464,070.[201] A recent study that focused on the Marcellus Shale in Pennsylvania found that bonding requirements typically fall short of the funding necessary to cover expected reclamation costs.[202]

Even the largest bonding amounts required by state law are insufficient to cover damages caused by a catastrophic release, which can amount to millions of dollars. Some states therefore require firms to carry liability insurance in addition to posting a bond. This insurance helps to shield taxpayers from remediation costs. As with surety bonds, insurers can experience rate premiums for liability insurance products. Only Colorado, Illinois, and Ohio require liability insurance: Colorado requires a $1,000,000 policy,[203] Illinois requires $5,000,000,[204] and Ohio requires $1,000,000 for rural wells, $3,000,000 for urban vertical wells, and $5,000,000 for urban horizontal wells.[205] Michigan does not require such insurance. Scholars have noted that the above states' liability requirements encompass property damage and bodily injury, but not other environmental or resource damages (Illinois has since specified that liability insurance must cover "injuries, damages, or loss related to pollution or diminution"[206]).[207]

4.4.2.3 Liability to private parties

Three of the surveyed states have specific policies that provide administrative relief for contamination of private water sources. Illinois[208] and Pennsylvania[209] provide a mechanism for individuals who believe their water supply has been contaminated by hydraulic fracturing to request an investigation by the state. An operator found responsible for contamination must replace or restore the water supply.[210] Illinois has the strictest standard, requiring the operator to provide a water supply that meets or exceeds pre-drilling conditions.[211] In Ohio, oil and gas well owners who are found by the state to have contaminated a water supply must replace the supply or compensate the supply's owner for the damage.[212] The agency encourages private parties to submit complaints of groundwater contamination on its website.[213] There is no comparable investigatory process in Michigan.

In court, a private property owner generally has the burden to demonstrate that an oil or gas well operator is the source of contamination causing the owner harm. Illinois and Pennsylvania shift the burden by imposing a presumption of liability on the operator for groundwater contamination within a certain radius from the well site.[214] In its administrative investigation of complaints, Pennsylvania presumes an HVHF well operator is liable if the contaminated water supply is within 2,500 feet of the well and the contamination occurred within twelve months of the latest well activity.[215] Illinois applies a rebuttable presumption if the contamination occurred within 1,500 feet of the well and within thirty months of completing the well; in addition, there must be affirmative evidence of no pollution prior to the start of HVHF operations.[216] Both states allow well operators to rebut the presumption if the operator can demonstrate that the contamination already existed or is from another source.[217] There is no presumption of liability in Michigan.

4.4.3 Policy approaches

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 can happen and seek to minimize harm and hold actors responsible.

Only three states have emergency response planning policies. All of the state policies are fundamentally remedial in approach, as they are designed to minimize the harm of incidents through planning. One state has added adaptive measures by requiring plans for particularly sensitive areas, which could presumably be changed over time as the state and well operators learn more about responding to incidents. Another state has added precautionary measures by requiring all unconventional well operators to not only consider response measures but also the risks and hazards of

TABLE 4.6: SUMMARY OF PLANNING, RESPONSE, AND LIABILITY POLICY OPTIONS					
POLICY AREA	POLICY ELEMENTS	CURRENT POLICY	OPTION A (PREVIOUS APPROACH)	OPTION B (ADAPTIVE APPROACH)	OPTION C (PRECAUTIONARY APPROACH)
EMERGENCY PLANNING	EMERGENCY RESPONSE PLAN	Hydrogen sulfide wells; to state	No change	HVHF wells in sensitive areas; policy modified over time based on spill data; to state, surface owners, and nearby residents	All HVHF wells; includes preventative considerations; to state, surface owners, and public
REPORTING AND CLEANUP	NOTIFICATION	All spills of chemical additives and fracturing fluid; larger spills of flowback reported within 8 hours; exception for small spills of flowback that can be quickly contained; to state and surface owners	No change	All spills; larger spills reported immediately; threshold modified over time based on spill data; to state, surface owners, and nearby residents	Immediate reporting of all spills; to state, surface owners, and public
	REMEDIATION STANDARD	General cleanup criteria	No change	General cleanup criteria; criteria modified over time based on long-term monitoring data	Restoration of environment
FINANCIAL RESPONSIBILITY	BONDS AND INSURANCE	$30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance	No change	No blanket bonds; modify individual bond amount over time based on remediation costs	Individual well bonds of $250,000; liability insurance
LIABILITY TO PRIVATE PARTIES	TYPE OF CONTAMINATION	State common law	No change	All spills into groundwater	All spills
	PRESUMPTION	None	No change	For liability if do not monitor environment around well	Strict liability unless operator can demonstrate caused by other sources
	REMEDY	State common law	No change	Remediation; modified over time based on long-term monitoring	Restoration of environment

HVHF operations to the surrounding population.

The primary approach to reporting and cleanup policies is remedial. Five states mandate prompt reporting of incidents and remediation of the site to minimize harm from spills that have already occurred.

The primary approach to financial responsibility policies is also remedial. Individual well bonds and blanket bonds encourage operators to clean up spills more quickly, since the bonds will not be released until the site is fully restored. In addition, three states have adopted a precautionary approach: by requiring operators to obtain liability insurance, the states create incentives for operators to take more care.

In contrast, the primary approach to private liability policies is precautionary. Two states apply a presumption of liability for contamination of water supplies and mandate replacement or restoration of the affected supply; both policies encourage operators to take preventative actions to avoid liability. One state has adopted a remedial approach. Requiring operators to compensate individuals for damage to water supplies, while less likely to spur preventative actions, could encourage operators to minimize harm from a spill so as to reduce the compensation payment.

As in the majority of the states, Michigan's approach is remedial. In the event of a spill, the state requires quick reporting and cleanup. The state's financial responsibility policies encourage operators to take responsibility for a spill and remediate the site, but the state could do more to encourage prevention by also requiring liability insurance.

4.4.4 Policy options

As illustrated by the range of approaches that have been adopted by states in relation to spills and/or the accidental release of chemicals used in HVHF activities, the policy options available to the state include adaptive responses that would result in faster cleanup and proactive approaches that reduce the likelihood of such release. As this

4.4.4.1: OPTION A: RESPONSE POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH					
POLICY AREA	POLICY ELEMENTS	CURRENT POLICY	OPTION A (PREVIOUS APPROACH)		
			PREVIOUS POLICY	RELATIVE TO CURRENT POLICY	
				KEY STRENGTH	KEY WEAKNESS
EMERGENCY PLANNING	EMERGENCY RESPONSE PLAN	Hydrogen sulfide wells; to state	No change	None	None
REPORTING AND CLEANUP	NOTIFICATION	All spills of chemical additives and fracturing fluid; larger spills of flowback reported within 8 hours; exception for small spills of flowback that can be quickly contained; to state and surface owners	No change	None	None
	REMEDIATION STANDARD	General cleanup criteria	No change		
FINANCIAL RESPONSIBILITY	BONDS AND INSURANCE	$30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance	No change	None	None
LIABILITY TO PRIVATE PARTIES	TYPE OF CONTAMINATION	State common law	No change	None	None
	PRESUMPTION	None	No change		
	REMEDY	State common law	No change		

section seeks to illustrate, these policy options are not mutually exclusive. Accordingly, the suite of policy options articulated below range from continuation of the status quo, through to a suite of policy tools that would draw heavily on a precautionary approach to preventing any such releases.

4.4.4.1 Option A: Response policy employing Michigan's previous approach

Michigan's previous policy is the same as the current policy; therefore, the approaches to uncertainty are the same.

4.4.4.2 Option B: Response policy employing an adaptive approach

This suite of policy tools draws upon an adaptive approach, in that it requires the state to collect information from well operators, and apply this knowledge in a way that allows the state and operators to best manage the potential ecological impact of HVHF activities. In doing so, the state has the opportunity to address individual concerns about HVHF in a transparent way, while also displaying leadership on a range of ecological issues relating to planning, response, and liability policies.

Emergency Planning

Pursuant to Option B, operators of HVHF wells in sensitive areas–not just hydrogen sulfide wells, as required under the current policy–would be required to create emergency response plans. The policy would be similar to that of Colorado, in that operators would be required to have an emergency response plan for sensitive areas that would include employee training, safety and maintenance provisions. Operators would be required to lodge these plans with the state and provide them to surface owners and nearby residents within a short period of time after permit issuance.

The state would retain the power to change the areas subject to the requirement and the planning criteria over time, as more is known about effective responses to spills at HVHF sites. Because accurate information is critical to adaptive management, failure to comply with these requirements would result in a fine of $1,000 per day.

Option B's emphasis on protecting particularly valuable environmental features is a clear strength of the proposed policy. By requiring the operators to provide the plans to the state and the most affected individuals, the policy would also promote greater transparency and encourage individuals to take adaptive responses. The financial cost of emergency planning would be borne by industry, and with more wells likely to be captured by the broadening scope of the policy, an increased financial cost across the industry is likely.

Reporting and Cleanup

Option B would retain the requirement that operators report losses or spills of chemical additives and flowback to the state. Operators would also be required to immediately notify the state, surface owners, and nearby residents of any large spills. In the event of a release and/or spill, the well operator would be required to clean up and dispose of the contamination. Large spills would require not only remediation but long-term monitoring of the site. The operator would submit a comprehensive report of the event, including the nature of the event, the chemicals involved, and the cleanup activities, to the state within ten business days.

Option B should be viewed as a tool to encourage industry to manage large spills more effectively over time with greater transparency. Quicker action can be taken due to faster reporting of spills; this increases the chances for containing spills that pose serious public health and/or environmental risks. Affected individuals can also take adaptive actions in the event of a spill. While the increased obligations on industry are likely to be viewed favorably by individuals concerned about the potential human and environmental impact of spills, those within industry are likely to view these increased requirements as being burdensome and financially costly, especially to smaller firms.

4.4.4.2: OPTION B: RESPONSE POLICY EMPLOYING AN ADAPTIVE APPROACH					
POLICY AREA	POLICY ELEMENTS	CURRENT POLICY	OPTION B (ADAPTIVE APPROACH)		
			ADAPTIVE POLICY	RELATIVE TO CURRENT POLICY	
				KEY STRENGTH	KEY WEAKNESS
EMERGENCY PLANNING	EMERGENCY RESPONSE PLAN	Hydrogen sulfide wells	HVHF wells in sensitive areas; policy modified over time based on spill data; to state, surface owners, and nearby residents	Emphasis is placed on wells near at-risk environmental features	A greater number of operators would be required to comply, resulting in increased financial costs across industry.
REPORTING AND CLEANUP	NOTIFICATION	All spills of chemical additives and fracturing fluid; larger spills of flowback reported within 8 hours; exception for small spills of flowback that can be quickly contained; to state and surface owners	All spills; larger spills reported immediately; threshold modified over time based on spill data; to state, surface owners, and nearby residents	Quicker action can be taken due to faster reporting of spills, which increases the chances for containing spills that pose serious public health and/or environmental risks; greater transparency to affected individuals.	Increased financial cost to industry for conservative reporting requirements
	REMEDIATION STANDARD	General cleanup criteria	General cleanup criteria; criteria modified over time based on long-term monitoring data	Cleanup and monitoring of large spills	Compliance costs
FINANCIAL RESPONSIBILITY	BONDS AND INSURANCE	$30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance	No blanket bonds; modify individual bond amount over time based on remediation costs	Ensures that operator is held responsible for full costs	May adversely impact smaller firms, potentially weakening competition for leases
LIABILITY TO PRIVATE PARTIES	TYPE OF CONTAMINATION	State common law	All spills into groundwater	Mirrors public concern for chemicals that are used during HVHF activities	Does not address all contamination
	PRESUMPTION	None	For liability if do not monitor environment around well	Encourages industry to monitor the impact of their activities on the environment	Financial cost to industry to monitor the surrounding environment
	REMEDY	State common law	Remediation; modified over time based on long-term monitoring	Cleanup and monitoring of large spills	Compliance costs

Financial Responsibility
Option B would eliminate blanket bonds to ensure that operators properly clean up the site. The policy would hold the operator responsible for the full costs of remediation, but it may adversely impact smaller firms, potentially weakening competition for leases.

Liability to Private Parties
Operators would be presumptively liable for groundwater contamination as part of Option B. If the operator could not rebut the presumption through monitoring data during and after HVHF, then the operator would be required to clean up the contamination. In many respects, Option B mirrors the public's concern about the use of chemicals in HVHF activities. It encourages industry to more closely monitor the impact of its activities on the local environment. But the policy would not address all contamination, and monitoring would increase industry costs.

4.4.4.3 Option C: Response policy employing a precautionary approach

Option C is designed to incorporate a range of precautionary practices as a way to reduce spills and releases. Such an approach is likely to be viewed favorably by members of the public, as it places an onus on the operators to be proactive and to restore the environment to the condition it was prior to a spill/release event. A potential unintended consequence of Option C is that the increased financial burden to industry may discourage investment in the state, especially among smaller firms, and may weaken competition for leases within the state.

Emergency Planning
Under Option C, Michigan would require operators of *all* HVHF wells to create emergency response plans. The requirements would be similar to those of Option B; however, the plan would also include preventative measures such as enhanced safety checks during HVHF. Operators would be required to submit the plans to the state for approval prior

4.4.4.3: OPTION C: RESPONSE POLICY EMPLOYING A PRECAUTIONARY APPROACH					
POLICY AREA	POLICY ELEMENTS	CURRENT POLICY	OPTION C (PRECAUTIONARY APPROACH)		
			PRECAUTIONARY POLICY	RELATIVE TO CURRENT POLICY	
				KEY STRENGTH	KEY WEAKNESS
EMERGENCY PLANNING	EMERGENCY RESPONSE PLAN	Hydrogen sulfide wells	All HVHF wells; includes preventative considerations; to state, surface owners, and public	Emphasis is placed on all types of wells, irrespective of their distance to at-risk features (e.g., ground and surface water)	A greater number of operators would be required to comply, resulting in increased financial costs
REPORTING AND CLEANUP	NOTIFICATION	All spills of chemical additives and fracturing fluid; larger spills of flowback reported within 8 hours; exception for small spills of flowback that can be quickly contained; to state and surface owners	Immediate reporting of all spills; to state, surface owners, and public	Creates incentives for operators to take additional steps to avoid spills that could pose serious public health and/or environmental risks; greater transparency to public	Increased financial cost to industry for conservative reporting requirements
	REMEDIATION STANDARD	General cleanup criteria	Restoration of environment	Protects environmental values	Increased compliance costs, may not be feasible
FINANCIAL RESPONSIBILITY	BONDS AND INSURANCE	$30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance	Individual well bonds of $250,000; liability insurance	Encourages industry to be environmentally proactive during HVHF activities	May adversely impact smaller firms, potentially weakening competition for leases
LIABILITY TO PRIVATE PARTIES	TYPE OF CONTAMINATION	State common law	All spills	Applies to chemicals that are both used on the surface and return to the surface during HVHF activities	None
	PRESUMPTION	None	Strict liability unless operator can demonstrate caused by other sources	Encourages industry to be environmentally proactive during HVHF activities, places responsibility on actor best placed to prevent harm	Financial cost to industry to monitor the environment, and for defense activities (e.g., legal assistance) should claims be brought
	REMEDY	State common law	Restoration of environment	Protects environmental values	Increased compliance costs, may not be possible

to HVHF, so that the state could determine whether the procedures and equipment were fully protective. In addition, the plans would be posted on the state's website, and the public would be able to comment on the adequacy of the plans. Option C would protect a broad range of environmental values, but it would add costs across the industry and be a substantial shift from the current Michigan policy.

Reporting and Cleanup

Option C would require the immediate notification and reporting of any losses and/or spills by the operator; this would apply to any chemical used in HVHF activities, as well as chemicals in solution, diluted or concentrated form. In addition to cleaning up and disposing of the contamination, operators would be required to restore the environment to its state 'but for' the spill. By this we mean full restoration of the environment prior to the losses/spill. Spill reports and the progress of restoration would be displayed on a state website together with other information about the operator.

The proposed changes to the current policy would enhance transparency, create incentives for operators to take additional steps to avoid spills that could pose serious public health and/

or environmental risks, and protect a broad range of environmental values. The financial costs associated with conservative reporting requirements and extensive cleanup would be significant, however, and full restoration may not be feasible.

Financial Responsibility

Option C would revise the current bonding requirements by increasing the individual bond of a HVHF operator from $30,000 to $250,000 per well and requiring the operator to carry a liability insurance policy of $1,000,000. This policy would ensure that the operator is held responsible for the full costs of contamination, but it may adversely impact smaller firms, potentially weakening competition for leases.

Liability to Private Parties

As part of Option C, the HVHF operator would be strictly liable to individuals for contamination caused by spills of HVHF-related fluids unless the operator could affirmatively demonstrate that the contamination was caused by another party. This liability would extend to non-water environmental resources and may include, for example, agricultural production and personal property. The operator would be required to restore the environment in accordance with clear standards. Such a policy would protect a broader range of environmental and private property values, encourage industry to be environmentally proactive during HVHF activities, and place responsibility on the actor best placed to prevent harm. But there would be a financial cost to industry to monitor the environment, and for defense activities (e.g., legal assistance) should claims be brought.

4.4.5 Summary

To date, Michigan's policies on spills and/or the accidental release of chemicals used in HVHF may be viewed as being reactive in nature when compared to other potential policy approaches. As this section illustrates, this approach, which is characterized by a focus on remedial actions, is common across the states surveyed in this report. However, other policy options are available to the state. The state may incorporate, for example, approaches that would not only manage the release of such chemicals, but also reduce the likelihood of future releases. The adoption of a more adaptive or precautionary approach to response policy would involve a significant shift in policy. The costs of these approaches should be weighed against the potential benefits to the public, and the state more generally.

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78 Colo. Code Regs. § 404-1:317; 225 Ill. Comp. Stat. 732/1-70, 1-75 (cement evaluation or other approved evaluation on intermediate casing); High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); N.D. Admin. Code 43-02-03-27.1 (cement evaluation if hydraulic fracturing performed through intermediate casing string); 16 Tex. Admin. Code § 3.13 (cement evaluation if minimum separation well).

79 Ark. Code R. § 178.00.1-B-19; Colo. Code Regs. § 404-1:341; 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); N.D. Admin. Code 43-02-03-27.1; Ohio Admin. Code 1501:9-1-08; 16 Tex. Admin. Code § 3.13.

80 Wilson J, Schwank J. Hydraulic Fracturing in the State of Michigan: Technology Technical Report. Ann Arbor, (MI): Graham Sustainability Institute, University of Michigan; 2013 [accessed 2015 June 9].http://graham.umich.edu/media/files/HF-02-Technology.pdf.

81 25 Pa. Code § 78.88.

82 Colo. Oil and Gas Conserv. Comm'n, COGCC Policy for Bradenhead Monitoring During Hydraulic Fracturing Treatments in the Greater Wattenberg Area (2012).

83 N.D. Admin. Code 43-02-03-27.1 ("If during the stimulation, the pressure in the intermediate casing-surface casing annulus exceeds three hundred fifty pounds per square inch [2413 kilopascals] gauge, the owner or operator shall verbally notify the director as soon as practicable but no later than twenty-four hours following the incident.").

84 Ohio Rev. Code Ann. § 1509.12.

85 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

86 Mich. Admin. Code r. 324.1405.

87 Mich. Admin. Code r. 324.1405.

88 Mich. Admin. Code r. 324.1405.

89 Mich. Admin. Code r. 324.1405.

90 Colo. Code Regs. § 404-1:609; 225 Ill. Comp. Stat. 732/1-80; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); N.D. Cent. Code § 38-11.2-07; Ohio Rev. Code Ann. § 1509.06.

91 58 Pa. Cons. Stat. Ann. § 3218.

92 Colo. Code Regs. § 404-1:609 (well maintained domestic water wells preferred); High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012) (testing of residential water wells, domestic supply springs, and water wells and springs that are used as water supply for livestock or crops); N.D. Cent. Code § 38-11.2-07 (testing of water well or water supply); Ohio Rev. Code Ann. § 1509.06 (testing of water well).

93 225 Ill. Comp. Stat. 732/1-80 (all water sources).

94 N.D. Cent. Code § 38-11.2-07; Ohio Rev. Code Ann. § 1509.06.

95 Colo. Code Regs. § 404-1:609; 225 Ill. Comp. Stat. 732/1-80; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

96 225 Ill. Comp. Stat. 732/1-80.

97 *Compare* Ohio Rev. Code Ann. § 1509.06 *and* 225 Ill. Comp. Stat. 732/1-80 *with* N.D. Cent. Code § 38-11.2-07.

98 *See, e.g.,* Colo. Code Regs. §§ 404-1:100, 404-1:609 (requires testing of available water sources, which are defined as sources for which the owner has given consent for testing and public dissemination of the results).

99 Colo. Code Regs. § 404-1:609; 225 Ill. Comp. Stat. 732/1-80; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

100 N.D. Cent. Code § 38-11.2-07; Ohio Rev. Code Ann. § 1509.06.

101 Colo. Code Regs. § 404-1:609 (state and owner); 225 Ill. Comp. Stat. 732/1-80 (state or owner under non-disclosure agreement); High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012) (owner and state); Ohio Rev. Code Ann. § 1509.06 (state).

102 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012). Colorado's policy requires immediate reporting of results to the state when either certain methane concentrations or benzene, toluene, ethylbenzene and xylene (BTEX) compounds have been detected. Colo. Code Regs. § 404-1:609.

103 Mich. Admin. Code r. 324.1404.

104 Mich. Admin. Code r. 324.1404.

105 *See* Mich. Admin. Code r. 324.1002.

106 Mich. Admin. Code r. 324.1404.

107 Mich. Admin. Code r. 324.1404.

108 Mich. Admin. Code r. 324.1404.

109 Mich. Admin. Code r. 324.1404.

110 Mich. Admin. Code r. 324.1404.

111 Michael Kraft. Using Information Disclosure to Achieve Policy Goals: How Experience with the Toxics Release Inventory Can Inform Action on Natural Gas Fracturing. Ann Arbor (MI): CLOSUP Energy and Environmental Policy Initiative; 2014 [accessed 2015 June 9]. http://closup.umich.edu/files/ieep-2014-kraft-info-disclosure.pdf.

112 Secretary of Energy Advisory Board. Task Force Report on FracFocus 2.0. Washington (DC): U.S. Department of Energy; 2014 [accessed 2015 June 9]. 24 p. http://energy.gov/sites/prod/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.

113 Michigan Department of Environmental Quality, Supervisor of Wells Instruction 1-2011, at 3 (2011).

114 Michigan Department of Environmental Quality. Hydraulic Fracturing in Michigan. [accessed 2015 June 9]. http://www.michigan.gov/deq/0,4561,7-135-3311_4111_4231-262172--,00.html.

115 Occupational Safety and Health Standards, 29 C.F.R. § 1910.1200.

116 Michigan Department of Environmental Quality, Supervisor of Wells Instruction 1-2011, at 3 (2011).

117 For example, ethylene glycol (antifreeze) would be referred to as such, rather than as 1,2-Dihydroxyethane, Monoethylene glycol, or any one of its other variants. The CAS number for the chemical would also need to be provided.

118 Liroff R, Fugere D, von Reusner L, Heim S. Disclosing the Facts 2014: Transparency and Risk in Hydraulic Fracturing. Falls Church (VA): Investor Health Network; 2014 [accessed 2015 June 9]. 48 p. http://disclosingthefacts.org/report/.

119 225 Ill. Comp. Stat. 732/1-25.

120 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 3 (Dec. 12, 2012).

121 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

122 225 Ill. Comp. Stat. 732/1-25; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); 58 Pa. Cons. Stat. § 3215.

123 N.Y. State Department of Health. A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development [Albany (NY)]: N.Y. State Department of Health; 2014.

124 Colo. Code Regs. § 404-1:317B (surface water supply areas); 225 Ill. Comp. Stat. 732/1-25; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); N.D. Admin. Code 43-02-03-19 ("hazardously near" bodies of water); Ohio Rev. Code Ann. § 1509.021; 58 Pa. Cons. Stat. § 3215.

125 Ark. Code R. § 178.00.1-B-26 (tanks storing produced water); 16 Tex. Admin. Code § 4.272 (off-lease commercial recycling of fluid).

126 Ark. Code R. § 178.00.1-B-26; 58 Pa. Cons. Stat. § 3215.

127 Ohio Rev. Code Ann. § 1509.021.

128 Ark. Code R. § 178.00.1-B-26; Colo. Code Regs. § 404-1:317B; 225 Ill. Comp. Stat. 732/ 1-25.

129 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

130 N.D. Admin. Code 43-02-03-19.

131 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); 58 Pa. Cons. Stat. § 3215; 16 Tex. Admin. Code § 4.272 (off-lease commercial recycling of fluid).

132 16 Tex. Admin. Code § 4.272.

133 225 Ill. Comp. Stat. 732/1-25; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); Ohio Rev. Code Ann. § 1509.021; 58 Pa. Cons. Stat. § 3215; 16 Tex. Admin. Code § 4.272 (off-lease commercial recycling of fluid).

134 225 Ill. Comp. Stat. 732/1-25.

135 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 3 (Dec. 12, 2012).

136 Mich. Admin. Code r. 324.301.

137 Mich. Admin. Code r. 324.301.

138 Ark. Code R. § 178.00.1-B-15 (updated in 2011); Colo. Code Regs. § 404-1:317 (updated in 2008); 225 Ill. Comp. Stat. 732/1-70 (statute passed in 2013); High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012) (revised regulations proposed in 2012); N.D. Admin. Code 43-02-03-27.1 (added in 2012); Ohio Admin. Code 1501:9-1-08 (updated in 2012); 25 Pa. Code § 78.81 et seq. (updated in 2011); 16 Tex. Admin. Code § 3.13 (updated in 2013).

139 225 Ill. Comp. Stat. 732/1-70 (new intermediate casing); High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012) (all new casing); 25 Pa. Code § 78.84 (generally new casing).

140 Ohio Admin. Code 1501:9-1-08; 25 Pa. Code § 78.84.

141 N.D. Admin. Code 43-02-03-27.1; 16 Tex. Admin. Code § 3.13.

142 Ark. Code R. § 178.00.1-B-15; 225 Ill. Comp. Stat. 732/1-70; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

143 Colo. Code Regs. § 404-1:317; 225 Ill. Comp. Stat. 732/1-70; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); Ohio Admin. Code 1501:9-1-08; 16 Tex. Admin. Code § 3.13 (minimum separation wells).

144 Colo. Code Regs. § 404-1:317; 225 Ill. Comp. Stat. 732/1-70; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); Ohio Admin. Code 1501:9-1-08; 25 Pa. Code § 78.85; 16 Tex. Admin. Code § 3.13 (minimum separation wells).

145 Mich. Admin. Code r. 324.410.

146 Mich. Admin. Code r. 324.411.

147 225 Ill. Comp. Stat. 732/1-95.

148 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 3 (Dec. 12, 2012).

149 Harold R. Fitch, Chief, Office of Geological Survey, Supervisor of Wells Letter No. 2011-1 (2011).

150 Harold R. Fitch, Chief, Office of Geological Survey, Supervisor of Wells Letter No. 2011-1 (2011).

151 Ark. Code R. § 178.00.1-B-17; Colo. Code Regs. §§ 404-1:902, 404-1:904; N.D. Admin. Code 43-02-03-19.3; 25 Pa. Code § 78.56; 16 Tex. Admin. Code § 3.8 (non-commercial fluid recycling pits).

152 Ark. Code R. § 178.00.1-B-17; Colo. Code Regs. § 404-1:1003; N.D. Admin. Code 43-02-03-19.3; Ohio Admin. Code 1501:9-3-08; 25 Pa. Code § 78.56; 16 Tex. Admin. Code § 3.8 (non-commercial fluid recycling pits, if no leak detection system).

153 N.D. Admin. Code 43-02-03-19.3.

154 Ark. Code R. § 178.00.1-B-17.

155 16 Tex. Admin. Code § 3.8 (non-commercial fluid recycling pits, if no leak detection system).

156 225 Ill. Comp. Stat. 732/1-70 (pits allowed if unexpected conditions); High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012). Colorado prohibits pits within an "intermediate" buffer in surface water supply areas. Colo. Code Regs. § 404-1:317B.

157 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012). See also Ohio Admin. Code 1501:9-3-08 ("liquid tight").

158 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

159 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

160 Mich. Admin. Code r. 324.1405 (referencing Mich. Comp. Laws § 324.61501).

161 225 Ill. Comp. Stat. 732/1-75; 58 Pa. Cons. Stat. § 3218.2.

162 225 Ill. Comp. Stat. 732/1-75.

163 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

164 Mich. Admin. Code r. 324.1002.

165 Email communication, Harold R. Fitch, Chief, Office of Oil, Gas and Minerals, DEQ (July 2, 2015).

166 Colo. Code Regs. § 404-1:317B; High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012); 25 Pa. Code § 78.55.

167 Colo. Code Regs. § 404-1:317B.

168 25 Pa. Code § 78.55.

169 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

170 *See* High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012) (requiring a Spill Prevention Control and Countermeasure Plan for all high volume hydraulic fracturing wells).

171 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

172 Mich. Admin. Code r. 324.1110.

173 Ark. Code R. § 178.00.1-B-19 (requires reporting of releases of RCRA exempt materials and fluids used on-site in the Hydraulic Fracturing Treatment, immediate containment, and commencement of remediation efforts as soon as practical); Colo. Code Regs. § 404-1:906 (requires reporting of releases of E&P waste or produced fluids, immediate containment, and clean up as soon as practicable).

174 225 Ill. Comp. Stat. 732/1-75 (requires reporting of releases of chemical additives, hydraulic fracturing fluid, and flowback, immediate cleanup and remediation); N.D. Admin. Code 43-02-03-30 (requires reporting of releases of "fluid," no pooling or infiltration of the soil, and cleanup).

175 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012).

176 Ohio Rev. Code Ann. § 1509.22 (prohibiting actions that "cause[] or could reasonably be anticipated to cause damage or injury to public health or safety or the environment"); 25 Pa. Code § 78.54 (requiring control and disposal of fluids "in a manner that prevents pollution of the waters of this Commonwealth"); 16 Tex. Admin. Code § 3.8 (prohibiting "pollution of surface or subsurface water in the state").

177 Ark. Code R. § 178.00.1-B-34 (no minimum volume); Colo. Code Regs. § 404-1:906 (all spills that threaten waters of the state, one barrel spilled outside of berms or secondary containment or five barrels spilled regardless of berms or secondary containment); 225 Ill. Comp. Stat. 732/1-75 (one barrel); High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012) (no minimum volume); N.D. Admin. Code 43-02-03-30 (one barrel).

178 Ark. Code R. § 178.00.1-B-19 (within 24 hours); Colo. Code Regs. § 404-1:906 (as soon as practicable but no more than 24 hours after discovery); 225 Ill. Comp. Stat. 732/1-75 (no deadline); High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 4 (Dec. 12, 2012) (verbal report within 2 hours and written report within 24 hours of discovery); N.D. Admin. Code 43-02-03-30 (immediate verbal notification and online report within 24 hours of discovery).

179 Colo. Code Regs. § 404-1:906 (applies to spills that threaten state waters or occur outside of berms or secondary containment); N.D. Admin. Code 43-02-03-30 (applies to spills that occur or travel off of well site).

180 Colo. Code Regs. § 404-1:906 (applies to spills that threaten state waters or occur outside of berms or secondary containment).

181 Colo. Code Regs. §§ 404-1:906, 1:909, 1:910.

182 For a list of the state laws and minimum thresholds for reporting, see: Transportation Environmental Resource Center. Reporting Spills. [place unknown]: n.d. [accessed 2015 Jun 9]. http://www.tercenter.org/pages/reportingspills.cfm.

183 25 Pa. Code § 78.66.

184 Pennsylvania Department of Environmental Protection. Addressing Spills and Releases at Oil & Gas Well Sites or Access Roads. 2013 Sep 21 [accessed 2015 Jun 29]. Guidance document. 800-5000-001. http://www.elibrary.dep.state.pa.us/dsweb/View/Collection-11754.

185 Mich. Admin. Code r. 324.1008.

186 Mich. Admin. Code r. 324.1008.

187 Mich. Admin. Code r. 324.1008.

188 Mich. Comp. Laws §§ 324.61505, 324.61501. One rule provides that operators must clean up and dispose of losses of brine "in a manner consistent" with state and federal laws and regulations. Mich. Admin. Code r. 324.1006.

189 Mich. Comp. Laws § 324.20101.

190 Mich. Comp. Laws § 324.20114.

191 Ohio Admin. Code 1501:9-1-03.

192 High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 3 (Dec. 12, 2012).

193 58 Pa. Cons. Stat. § 3225.

194 Ohio Admin. Code 1501:9-1-03.

195 N.Y. Comp. Codes R. & Regs. tit. 6, § 551.6. New York's proposed policy would have amended the amount to instead read "an amount specified by the department." High Volume Hydraulic Fracturing Proposed Regulations, XXXIV N.Y. Reg. 3 (Dec. 12, 2012).

196 Mich. Admin. Code r. 324.212.

197 Mich. Admin. Code r. 324.212.

198 Mich. Admin. Code r. 324.212.

199 Mich. Admin. Code r. 324.212.

200 Mich. Admin. Code r. 324.211.

201 Michigan Office of the Auditor General. Performance Audit of the Office of Oil, Gas, and Minerals: Department of Environmental Quality. Lansing (MI): Michigan Office of the Auditor General; 2013 [accessed 2014 Nov 24]. Report No.: 761-0300-13. http://www.audgen.michigan.gov/finalpdfs/12_13/r761030013.pdf.

202 Mitchell, Austin L., "Analysis of health and environmental risks associated with Marcellus Shale development" (2013). *Dissertations*. Paper 267. Carnegie Mellon University.

203 Colo. Code Regs. § 404-1:708.

204 225 Ill. Comp. Stat. Ann. 732/1-35.

205 Ohio Rev. Code Ann. § 1509.07.

206 Ill. Admin. Code tit. 62, § 245 (2014).

207 Dana, David A. and Hannah Jacobs Wiseman, "A Market Approach to Regulating the Energy Revolution: Assurance Bonds, Insurance, and the Certain and Uncertain Risks of Hydraulic Fracturing." 99 Iowa L. Rev. 1523 (2014).

208 225 Ill. Comp. Stat. 732/1-83 (Defining private party as "[a]ny person who has reason to believe they have incurred pollution or diminution of a water source as a result of a high volume horizontal hydraulic fracturing treatment of a well").

209 58 Pa. Cons. Stat. Ann. § 3218 (Restricting private parties to a "landowner or water purveyor suffering pollution or diminution of a water supply as a result of the…operation of an oil or gas well.").

210 225 Ill. Comp. Stat. 732/1-83; 58 Pa. Cons. Stat. Ann. § 3218.

211 225 Ill. Comp. Stat. 732/1-83 (requiring the operator to replace the affected supply with an alternative source of water adequate in quantity and quality for the purposes served by the water source).

212 Ohio Rev. Code Ann. § 1509.22.

213 Ohio Department of Natural Resources. Investigations, Reports, Violations, & Reforms. Groundwater Contamination or Disruption Complaint. Columbus (OH): Ohio Department of Natural Resources; c2015 [accessed 2015 June 9]. http://oilandgas.ohiodnr.gov/resources/investigations-reports-violations-reforms.

214 225 Ill. Comp. Stat. 732/1-85; Ohio Rev. Code Ann. § 1509.22; 58 Pa. Cons. Stat. Ann. § 3218.

215 58 Pa. Cons. Stat. § 3218.

216 225 Ill. Comp. Stat. 732/1-85.

217 *See* 58 Pa. Cons. Stat. § 3218 (rebutting presumption if operator can prove that pollution existed before, refused access to predrilling survey, contamination is not within feet or time limits, or pollution from another cause); 225 Ill. Comp. Stat. 732/1-85 (rebutting presumption if contamination is either proved to be from another source or does not satisfy time and distance requirements).

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POLICY FRAMING

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LEAD AUTHORS

Chapter 5

5.1 INTRODUCTION

This chapter provides a general frame for reviewing the policy options presented in Chapter 2 (Public Participation), Chapter 3 (Water Resources) and Chapter 4 (Chemical Use). As noted previously, in situations where there may be 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. This chapter provides additional information for understanding these approaches along with examples from the previous chapters. Adaptive policies are discussed first and followed by precautionary policies.

5.2 ADAPTIVE POLICIES

Based on a multi-year project examining adaptive policymaking across a range of sectors—natural resources management, healthcare, transportation, engineering, information technology, and international development—the International Institute for Sustainable Development (ISSD) and the Energy and Resources Institute (TERI) offer a useful conceptual framework for applying adaptive policies. This framework was also informed by case study analyses of agriculture and water resources policy in the face of climate change.[1] In the report *Designing Policies in a World of Uncertainty, Change, and Surprise*, ISSD and TERI contributors note that "experience demonstrates that policies designed implicitly or explicitly to operate within a certain range of conditions are often faced with challenges outside of that range."[2] In response to this, policymakers need ways to design policies that can adapt to a range of conditions.[3,4]

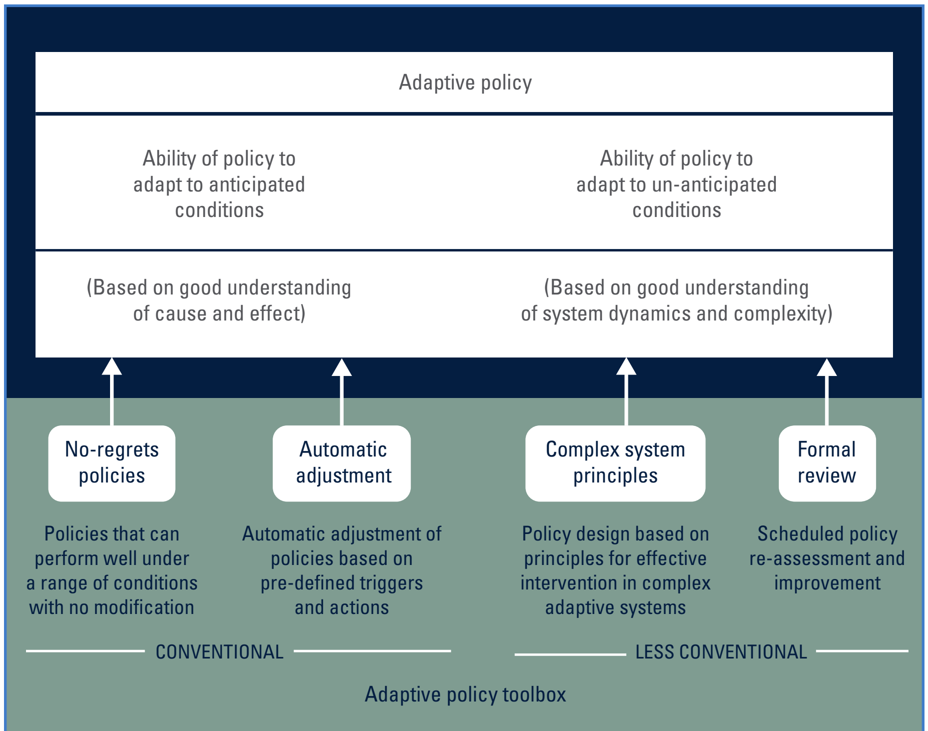

FIGURE 5.1: Adaptive policy conceptual framework[5]

Figure 5.1 illustrates the conceptual framework for the adaptive policy approach developed by ISSD and TERI. Policies can be categorized as those which can be applied to anticipated conditions and those which can be applied to unanticipated conditions. Policies which respond to anticipated conditions can be divided into those policies which work under a range of conditions without modification and those which involve adjustments based on pre-defined thresholds. Policies which respond to unanticipated conditions can be divided into those which involve complex systems and those which involve reassessing policies on a scheduled basis.

Following this conceptual framework, several policy options from the preceding chapters will be used to demonstrate the four adaptive policy categories: no regrets, automatic adjustment, complex systems principles, and formal review. This should not be perceived as an absolute categorization. Rather, it is meant to provide helpful examples for identifying policy options that might best fit different conditions or scenarios. Chapter section references are included for each example to guide the reader to more information on each policy option including additional details and the strengths and weaknesses.

5.2.1 Adaptive policy: no regrets

Bankes notes that no regrets policies are policies that are likely to work well no matter what anticipated conditions might prevail.[6] With respect to HVHF in Michigan, this includes policy options which deserve consideration regardless 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. Every policy response, including no response, can come with an associated cost—financial or administrative. Examples of no regrets policies include:

- Increasing stakeholder representation on Oil and Gas Advisory Committee (2.2.3.8)
- Increasing public notice of permit applications (2.4.3.2)
- Requiring public notice on new high-capacity water withdrawal wells (3.2.8.2.4)
- Disclosing a list of constituents the applicant anticipates will be used in the HVHF fluid, including the specific identity and CAS number (4.2.2.1)

There is benefit to each of these options (broader input, expanded notification and greater transparency) regardless of future conditions or HVHF activity in Michigan.

5.2.2. Adaptive policy: automatic adjustment

Bhadwal et al. claim that automatic policy adjustments are adaptive policy mechanisms which help policies respond well in a variety of plausible and clearly identified future circumstances.[7] These are options which are already developed but are not activated until a particular threshold is reached or activity takes place. Bhadwal et al. explain that the pre-establishment of the options can accelerate the process of responding to conditions that are more or less anticipated.[8] Examples of relevant existing and potential HVHF policies that demonstrate this category include:

- Organizing water resources assessment and education committees whenever a subwatershed enters a Zone C designation (or Zone B in cold-transitional systems) in order to increase the technical understanding of available water resources in a subwatershed area and provide recommendations for assessing competing water uses. (3.2.8.2)
- Monitoring well pressure during HVHF and reporting immediately to the state if pressures indicate a problem; ceasing HVHF until plan of action is implemented (4.2.2.2)

Both examples demonstrate clear thresholds (WWAT results and well pressure results) which can prompt additional action.

5.2.3. Adaptive policy: complex systems principles

A third category of adaptive policy identified through the work of ISSD and TERI are those policies which involve complex systems principles[9] or conditions which require examining multiple factors. Based on health care policy analysis, Glouberman et al. recognized that in complex systems, which change over time and respond dynamically to outside forces, it is necessary to constantly refine policies.[10,11] Of the options presented in this report there are only a few within the Water Resources chapter can be considered examples of this category. These include:

- Providing options for wastewater recycling (3.3.6.3.2)
- Using alternative water sources for HVHF (3.3.6.3.3)
- Recycling wastewater and providing alternative, non-potable water sources for HVHF operations would diminish the amount of water removed from the local environment. However, both options would require examining multiple factors given the potential to increase surface contamination risks, water quality impacts, and additional truck traffic for transporting the water.

5.2.4. Adaptive policy: 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[12] and that it is necessary to adjust and refine interventions through an ongoing process of variation and selection.[13] However, Tomar and Swanson argue that it is fundamentally 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. In contrast, formal review is a mechanism for identifying and dealing with unanticipated circumstances, emerging issues, and issues for which signposts or triggers for action may not be apparent without such reviews.[14] The Water Resources and Chemical Use chapters present adaptive policy options which can be categorized as formal review options. Examples include:

- Implementing a mechanism for updating the models underlying WWAT (3.2.3.3)
- Developing a list of prohibited chemicals which could be amended over time (4.3.4.2)
- Modifying general cleanup criteria over time based on long-term monitoring data (4.4.4.2)

All three examples involve potentially emerging issues which could influence decision making. New scientific models and data could become available for improving the WWAT, and new understandings of chemical hazards could influence decision making about specific chemicals to prohibit from use in HVHF or in guiding cleanup criteria. Regular, formal review is an important strategy for managing such topics as specific signposts or triggers for action may not be apparent without such reviews.

5.3 PRECAUTIONARY POLICIES

A second overall approach is precautionary policy which is based on the precautionary principle. Many definitions of the precautionary principle exist but two ideas lie at the core of the principle:[15]

1. an expression of a need by decision makers to anticipate harm before it occurs. Within this element lies an implicit reversal of the onus of proof: under the precautionary principle it is the responsibility of an activity proponent to establish that the proposed activity will not (or is very unlikely to) result in significant harm.
2. the concept of proportionality of the risk and the cost and feasibility of a proposed action.

One of the primary foundations of the precautionary principle, and globally accepted definitions, results from the work of the Rio Conference, or "Earth Summit" in 1992. Principle #15 of the Rio Declaration notes: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[16] One well know example of the precautionary policy is the Montreal Protocol for addressing concerns about the depletion of stratospheric ozone.[17] In this case, while scientific work was still underway there was sufficient consensus that action was needed and clear options and alternatives were available. While there has been increasing reference to policy based on the precautionary principle, there are also questions about its application as there can be risks with regulating and not regulating certain activities.[18] The recent decisions to ban HVHF in New York[19] and Quebec[20,21] based in part on potential health and environmental impacts can be viewed as a precautionary approach.

Precautionary policy options exist across all three chapters, Public Participation, Water Resources, and Chemical Use, including:

- Banning HVHF (2.2.3.6)
- Setting a total volumetric water withdrawal limit for HVHF operations (3.2.2.2.4)
- Approving chemicals only if applicant demonstrates low toxicity (4.3.4.3)

Each option in this category presents a range of challenges and costs, but the objective is to avoid or limit risk through preventing HVHF or limiting key inputs such as water and chemicals.

5.4 SUMMARY

This chapter has provided a frame for the policy options presented in the preceding chapters. Two primary frames were employed—an adaptive policy frame and a precautionary policy frame. Within adaptive policy, four different categories were used to organize the policy option: no regrets, automatic adjustment, complex systems principles, and formal review. Each category has unique conditions under which the policy option might work best. For example, no regrets could be applied in any future or scenario whereas automatic adjustments only engage once specific, anticipated criteria are met. Complex systems principles fit policies which must consider multiple factors, and formal review policies outline mechanisms and timetables for updating processes. For precautionary policies, there are different opinions for when they are best applied. For some, they should be applied early to prevent any harm. For others there must be some consideration of proportionality of the risk and the cost and feasibility of a proposed policy response.

ENDNOTES

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LIMITATIONS + KNOWLEDGE GAPS

Chapter 6

6.1 LIMITATIONS

While this integrated assessment 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 provide a quantitative assessment of the risks (human health or environmental) 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. Completing such assessments is currently a key point of discussion related to HVHF despite the challenges of uncertainty and limited available data—particularly baseline data. An overview of this discussion is provided in Appendix B. Completing a quantitative risk assessment would also require significantly more time and funding.

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 assess fully the economic impact of various policy actions, including no change of current policy.

6.2 KNOWLEDGE GAPS

In addition to the status and trends information provided in the technical reports, additional areas of investigation and knowledge gaps were identified. Those are listed below following the thematic areas of the technical reports. Several other emerging research questions identified in a recent publication of the *Annual Review of Environment and Resources*[1] are also referenced.

Technology

- Analyzing comparatively water-based and water-free fracturing methods.
- Assessing the effectiveness and impacts of refracturing or other restimulation efforts.[2]
- Investigating whether horizontal drilling and HVHF lead to higher stresses that require engineering safeguards to be reevaluated, particularly the mechanical properties of steel and cement.[3]
- Comparing recent well integrity statistics to past statistics.[4]
- Evaluating the legacy effects of older wells (older than 25-50 years) for greenhouse gas emissions and potential groundwater contamination.[5]

Geology/hydrogeology

- Evaluating the impact of HVHF chemicals on the release and transport of toxic metals, hydrocarbons, and naturally occurring radionuclides.
- Establishing standard measurement techniques (e.g. microseismic) for evaluating the extent and direction of major fracture networks during HVHF.
- Conducting modeling studies to assess subsurface flow, fluid residence times, and leakage risk up existing wells.
- Reevaluating current regulatory definition of "produced water" including analyzing flowback water chemistry and comparing it with that of the produced brine from older wells nearby.
- Evaluating the adsorption of hydraulic fracturing chemicals.

Environment/ecology

- Establishing a decision matrix that guides decision making on establishing HVHF operations in "sensitive/susceptible" ecosystems.
- Establishing baseline ecosystem monitoring in susceptible areas that continues through post-operation periods to establish whether or not detrimental impacts occur.
- Assessing the cumulative impacts of multiple HVHF operations within a watershed for downstream surface waters and groundwater.
- Establishing to what degree other likely stressors in watershed, unrelated to HVHF operations, impact aquatic communities.
- Identifying areas for improved quality control and/or best practices in HVHF operations, especially near riparian zones, surface waters, and shallow aquifers.
- Establishing a publically available database for HVHF studies and data, with close attention paid to the findings published in the "peer-reviewed" scientific literature in the coming months to years, to improve decision making.
- Evaluating how potential HVHF impacts compare to the environmental impacts of energy-related activities, such as coal mining, that it may be replacing.

Public health

- Collecting empirical data in Michigan concerning a number of public health indicators, such as air and water quality, exposure assessments in workers, and health of fish and wildlife.
- Establishing baseline measurements in order to make judgments against acceptable thresholds and compare to other HVHF regions.
- Assessing potential for risk broadly by overlaying some available datasets, such as well locations and the locations of homes, agricultural fields, hospitals, and schools.

Law/policy

- Examining private landowner leases signed in Michigan and the ways in which they create a private standard addressing contamination and HVHF.
- Surveying local units of government and residents to determine the issues of greatest concern.[6]

Economics

- Examining the occupational risks of exposure to the chemicals currently used in HVHF in order to develop guidelines for minimizing worker occupational illness and injury.

- Estimating the level of direct industry employment that is imported from out-of-state.
- Estimating the necessary bonding requirements on industry to mitigate liabilities to the state; this will require a risk assessment to determine whether insurance levels sufficiently cover potential remedial costs.
- Tracking employment changes in high natural gas utilization industries and comparing the movement of jobs with the price of natural gas.
- Examining the question of HVHF and property values in Michigan.

Public perceptions

- Evaluating whether appropriate tax structures are in place to support rapid population growth in small communities.
- Assessing mineral rights owners' awareness of standard leasing procedures and helping connect them to resources like the Michigan State University Cooperative Extension, which provides information about best practices.
- Conducting an in-depth study of local perceptions in communities where natural gas extraction through HVHF is likely to continue and expand.

Finally, other useful resources for information on HVHF and shale gas development include:

- The Physicians, Scientists, and Engineers (PSE) study citation database.[7] The citation database provides bibliographic information, abstracts, and links to many of the vetted scientific papers housed in the PSE Health Energy Library. This comprehensive database directly pertains to shale gas and tight oil development. The literature is organized into twelve different categories including air quality, water quality, climate, public health, and regulations.[8]
- The Center for Sustainable Shale Development (CSSD). This is a non-profit organization whose mission is to support continuous improvement and innovative practices through performance standards and third-party certification. Focused on shale development in the Appalachian Basin, the Center provides a forum for a diverse group of stakeholders to share expertise with the common objective of developing solutions and serving as a center of excellence for shale gas development.[9]
- The Shale Gas Project of Resources for the Future (RFF). Includes reports on managing risks and the economics of shale gas development.[10]
- Resources from the American Petroleum Institute (API) on hydraulic fracturing. These include guidelines for community engagement and other best practice resources.[11]
- The Center for Local, State and Urban Policy (CLOSUP) at the University of Michigan's Ford School of Public Policy. CLOSUP's Energy & Environmental Policy Initiative Fracking Project provides reports on public opinion surveys and shale gas governance issues.[12]
- The Air, Water, Gas project at the University of Colorado-Boulder. Funded by the National Science Foundation and involving 27 researchers from 9 institutions, this project seeks to provide a logical, science- based framework for evaluating the environmental, economic, and social trade-offs between development of natural gas resources and protection of water and air resources and to convey the results of these evaluations to the public in a way that improves the development of policies and regulations governing natural gas and oil development.[13]

ENDNOTES

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GLOSSARY OF TERMS

Appendix A

Note: Uncited definitions come from *Modern Shale Gas Development in the United States: A Primer.*[1] Definitions from other sources are indicated with separate endnote references.

ADVERSE RESOURCE IMPACT. An impact that impairs a lake or stream's ability to support its characteristic fish population[2]

AIR QUALITY. A measure of the amount of pollutants emitted into the atmosphere and the potential of an area to dilute those pollutants

AQUIFER. A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs

BASIN. A closed geologic structure in which the rock beds dip toward a central location: the youngest rocks are at the center of a basin and are partly or completely ringed by progressively older rocks.

BIOGENIC GAS. Natural gas produced by living organisms or biological processes

BRINE. Nonpotable water resulting from, obtained by, or produced from the exploration, drilling, or production of oil and/or gas[3]

CASING. Steel piping positioned in a wellbore and cemented in place to prevent the soil or rock from caving in that also isolates fluids, such as water, gas, and oil, from the surrounding geologic formations

CHEMICAL ABSTRACTS SERVICE (CAS) NUMBER. The unique identification number assigned to a chemical by the division of the American Chemical Society that is the globally recognized authority for information on chemical substances[4]

COAL BED METHANE/NATURAL GAS (CBM/CBNG). CBNG is a clean-burning natural gas found deep inside and around coal seams that has an affinity to coal and is held in place by pressure from groundwater. CBNG is produced by drilling a wellbore into a coal seam and pumping out large volumes of groundwater to reduce the hydrostatic pressure, which allows the gas to dissociate from the coal and flow to the surface.

COMPLETION. The activities and methods that prepare a well for production and follow drilling, including installation of equipment for production from a gas well

CONVENTIONAL 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.[5]

CORRIDOR. A strip of land through which one or more existing or potential utilities may be co-located

DISPOSAL WELL. A well which injects produced water into an underground formation for disposal

DIRECTIONAL DRILLING. The technique of drilling at an angle from a surface location to reach a target formation not located directly underneath the well pad

DRILL RIG. The mast, draw works, and attendant surface equipment of a drilling or workover unit

EMISSION. Air pollution discharge into the atmosphere, usually specified by mass per unit time

ENDANGERED SPECIES. Those species of plants or animals classified by the Secretary of the Interior or the Secretary of Commerce as endangered pursuant to Section 4 of the Endangered Species Act of 1973, as amended; see also *Threatened and Endangered Species.*

EXPLORATION. The process of identifying a potential subsurface geologic target formation and the active drilling of a borehole designed to assess the natural gas or oil

FLOW LINE. A small diameter pipeline that generally connects a well to the initial processing facility

FLOWBACK FLUID. Defined by the State of Michigan as hydraulic fracturing fluid and brine recovered from a well after completion of a hydraulic fracturing operation and before the conclusion of test production[6]

FORMATION (GEOLOGIC). A rock body that is distinguishable from other rock bodies and is useful for mapping or description. Formations may be combined into groups or subdivided into members.

FRACTURING FLUIDS. A mixture of water and additives used to hydraulically induce cracks in the target formation

GALLONS PER DAY. Although water withdrawal laws are written in terms of gallons per day, this report has converted these rates into gallons per minutes, except where noted.

GROUNDWATER. Subsurface water that is in the zone of saturation and serves as the source of water for wells, seepage, and springs; the top surface of the groundwater is the "water table."

HABITAT. The area in which a particular species lives; in wildlife management, the major elements of a habitat are food, water, cover, breeding space, and living space.

HIGH VOLUME HYDRAULIC FRACTURING. High volume hydraulic fracturing well completion is defined by State of Michigan regulations as "well completion operations that intend to use a total volume of more than 100,000 gallons of primary carrier fluid."[7,8]

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

HYDRAULIC FRACTURING. The process of injecting fracturing fluids into the target formation at a force exceeding the parting pressure of the rock, which induces a network of fractures through which oil or natural gas can flow to the wellbore

HYDROSTATIC PRESSURE. The pressure exerted by a fluid at rest due to its inherent physical properties and the amount of pressure being exerted on it from outside forces

INJECTION WELL. A well used to inject fluids into an underground formation either for enhanced recovery or disposal

LEASE. A legal document that conveys to an operator the right to drill for oil and gas; also, the tract of land, on which a lease has been obtained, where producing wells and production equipment are located. In Michigan, state mineral rights leases do not convey a right to drill. They only convey the exclusive right to pursue development of the oil and gas resource, after obtaining all necessary permissions, if the lessee chooses to do so.[9]

MICHIGAN COMPILED LAWS. The codification of the statutes of the State of Michigan

NATURALLY OCCURING RADIO-ACTIVE MATERIAL (NORM). Low-level, radioactive material that naturally exists in native materials

ORIGINAL GAS IN PLACE. The entire volume of gas contained in a reservoir, regardless of the ability to produce it

PARTICULATE MATTER (PM). A small particle of solid or liquid matter (e.g., soot, dust, and mist); PM10 refers to particulate matter with a diameter of less than 10 millionths of a meter (micrometer) and PM2.5 being less than 2.5 micrometers in diameter.

PERMEABILITY. A rock's capacity to transmit a fluid, dependent upon the size and shape of pores and interconnecting pore throats; a rock may have significant porosity (many microscopic pores) but have low permeability if the pores are not interconnected. Permeability may also exist or be enhanced through fractures that connect the pores.

PRIMACY. A right that can be granted to a state government by the federal government that allows state agencies to implement programs with federal oversight; usually, the states develop their own set of regulations; however, these must be at least as protective as the federal standards they replace, and may be even more protective in order to address local conditions. Once these state programs are approved by the relevant federal agency (usually the EPA), the state then has primacy jurisdiction.

PRODUCED WATER. Water produced from oil and gas wells

PROPPING AGENTS/PROPPANT. Silica sand or other particles pumped into a formation during a hydraulic fracturing operation to keep fractures open and maintain permeability

PROVED RESERVES. The portion of recoverable resources that is demonstrated, by actual production or conclusive formation tests, to be technically, economically, and legally producible under existing economic and operating conditions

RECLAMATION. Rehabilitation of a disturbed area to make it acceptable for designated uses; this normally involves regrading, replacement of topsoil, re-vegetation, and other work necessary to restore it.

SETBACK. The distance that must be maintained between a well or other specified equipment and any protected structure or feature

SHALE GAS. Natural gas produced from low permeability shale formations

SITE SPECIFIC REVIEW. An assessment of potential impacts due to water withdrawals at a site conducted by the Michigan Department of Environmental Quality (DEQ)

SLICKWATER. A water-based fluid mixed with friction-reducing agents, commonly potassium chloride

SOLID WASTE. Any solid, semisolid, liquid, or contained gaseous material that is intended for disposal

SPLIT ESTATE. Exists when the surface rights and mineral rights of a property are owned by different persons or entities; also referred to as "severed estate"

STIMULATION. Any of several processes used to enhance near wellbore permeability and reservoir permeability

STIPULATION. A condition or requirement attached to a lease or contract, usually dealing with protection of the environment, or recovery of a mineral

SULFUR DIOXIDE (SO_2). A colorless gas formed when sulfur oxidizes, often as a result of burning trace amounts of sulfur in fossil fuels

TECHNICALLY RECOVERABLE RESOURCES. The total amount of resource, discovered and undiscovered, that is thought to be recoverable with available technology, regardless of economics

THERMOGENIC GAS. Natural gas that is formed by the combined forces of high pressure and temperature (from deep burial within the earth's crust), resulting in chemical reactions of the organic matter in the source rock matrix

THREATENED AND ENDANGERED SPECIES. Plant or animal species that have been designated as being in danger of extinction; see also *Endangered Species*.

TIGHT GAS. Natural gas trapped in a hardrock, sandstone, or limestone formation that is relatively impermeable

TOTAL DISSOLVED SOLIDS (TDS). The dry weight of dissolved material, organic and inorganic, contained in water, usually expressed in parts per million

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. 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.[10]

UNDERGROUND INJECTION CONTROL PROGRAM (UIC). A program administered by the Environmental Protection Agency, primacy state, or Indian tribe under the Safe Drinking Water Act to ensure that subsurface emplacement of fluids does not endanger underground sources of drinking water

UNDERGROUND SOURCE OF DRINKING WATER (USDW). Defined by Safe Drinking Water Act regulations as an aquifer or a portion of an aquifer (not an exempted aquifer) 1) which supplies any public water system; or 2) which contains a sufficient quantity of groundwater to supply a public water system and a) currently supplies drinking water for human consumption, or b) contains fewer than 10,000 mg/l total dissolved solids[11]

WATER QUALITY. The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use

WATER RESOURCES ASSESSMENT AND EDUCATION COMMITTEE. A component of the Water Withdrawal Assessment Program that provides information about available water resources in a watershed for the purposes of assisting in making local decisions about water use within a Water Users Committee[12]

WATER USERS COMMITTEE. A component of the Water Withdrawal Assessment Program intended to help resolve water disputes among large-volume water withdrawal registrants[13]

WATER WITHDRAWAL ASSESSMENT PROGRAM. The regulatory system under which most large-volume water withdrawals are governed in the state of Michigan[14]

WATER WITHDRAWAL ASSESSMENT TOOL. The online assessment tool component of the Water Withdrawal Assessment Program used to provide an initial assessment of whether a proposed water withdrawal from groundwater or a stream is likely to cause an adverse resource impact[15]

WATERSHED. All lands which are enclosed by a continuous hydrologic drainage divide and lay upslope from a specified point on a stream

WELL COMPLETION. See *Completion*.

WORKOVER. To perform one or more remedial operations on a producing or injection well to increase production; deepening, plugging back, pulling, and resetting the liner are examples of workover operations.

ENDNOTES

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BROADER CONTEXT

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Appendix B

B.1 INTRODUCTION

During the public comment period following the release of the technical reports, numerous comments were received regarding topics extending beyond the geographic scope of Michigan and not limited to high volume hydraulic fracturing (HVHF), but encompassing expanded natural gas development in general. Similar topics were also identified in the technical reports themselves. While not central to the focus of the Integrated Assessment (IA), the Integration Team and Report Team determined it would be useful to present a concise summary of key aspects of the these topics so that readers of the IA report could understand the broader context and national discourse of issues related to expanded gas production and use. The objective of this chapter is not to advocate a particular perspective but to present the results of key reports and analyses on: 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 economic impacts of expanding U.S. natural gas exports, and methodological approaches to understanding and managing human health risks. Additional topics relevant at the state and local level are presented in Appendix C.

B.2 CLIMATE CHANGE: WHAT ARE THE EFFECTS OF NATURAL GAS PRODUCTION AND FUGITIVE METHANE EMISSIONS?

The potential impact of shale gas development on climate is a subject of significant concern and debate.[1–3] The combustion of natural gas emits nearly 50% less carbon dioxide (CO_2) per unit of energy generated than coal.[i] However, the overall effect of a shift toward natural gas on climate change is not as clear when the full life cycle of natural gas development (exploration through end use) is considered. This is, in part, because fugitive methane emissions during the production, delivery, and use of natural gas reduce the net climate benefits of using natural gas in electricity generation and transportation. Methane is the primary component of natural gas[ii] and a potent, short-lived greenhouse gas (GHG) with a global warming potential (GWP)[iii] 28-34 times greater than CO_2 over a 100-year timeframe, and 84-86 times greater over a 20-year time horizon.[4] Given that methane is a potent GHG, as well as a ground-level ozone precursor, and that natural gas systems are the second largest contributor to U.S. anthropogenic methane emissions,[5] the role of the production and use of shale gas in contributing to methane emissions is worthy of consideration.

B.2.1 Relative life cycle GHG emissions

Total GHG emissions from the production and use of unconventional gas compared to conventional gas and other fuel sources such as coal have been the subject of considerable recent research. Studies to date have come to conflicting conclusions, due largely to different data, assumptions, and methodologies[6,7]; however, some general trends are notable. First, most studies indicate that GHG emissions from the shale gas life cycle through energy generation are smaller than those from the coal life cycle. Estimates from nine studies, employing various assumptions and data, suggest that GHG emissions from natural gas (including shale gas specifically) are likely between 20% to 53% less than GHG emissions produced from coal.[8–15] The exception is a study by Howarth et al. that estimates that GHG emissions from shale gas could be anywhere from 20% to 200% greater than coal in the 20-year timeframe and comparable in the 100-year timeframe.[16] Among other differences, the Howarth et al. study utilized significantly higher methane leakage rates (including an assumption that excess methane is vented and not flared), a heat generation basis, and a shorter GWP timeframe, assumptions that have been challenged.[17] Many of the other studies utilized U.S. Environmental Protection Agency (EPA) methane emissions estimates for at least some of their data, but as discussed later, evidence suggests these estimates may be too low overall[18–21] or with respect to certain sources along the supply chain.[22,23]

Researchers have also explored the relative GHG emissions from unconventional and conventional gas production and arrived at different conclusions, again reflecting different underlying assumptions, data, and scopes. To clarify, the potential difference in question is due to differences in the drilling and recovery process, primarily methane leakage, and not a difference in the gas itself downstream. On the high end, Howarth et al. estimated that the GHG footprint of shale gas is as much as 19% greater than that of conventional gas on a 100-year time horizon.[24] Other studies have estimated that unconventional GHG emissions are between 2% and 11% greater than conventional gas emissions through the electricity

[i] Pounds of CO_2 per million Btu of energy: natural gas 117.0; coal (anthracite) 228.6; coal (bituminous) 205.7; coal (lignite) 215.4; coal (subbituminous) 214.3 (U.S. EIA, n.d., available http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).

[ii] Natural gas is a hydrocarbon gas mixture consisting primarily of methane (70-90%), but it can also include ethane, propane, butane, and pentane, as well as carbon dioxide, nitrogen, and hydrogen sulfide. Dry natural gas is almost completely methane, while wet natural gas contains less than 85% methane and a higher percentage of liquid natural gases such as ethane and butane. Processing removes liquefied hydrocarbons and non-hydrocarbon impurities (U.S. Energy Development Corporation, n.d., http://www.usenergydevcorp.com/media_downloads/Natural%20Gas%20Dry%20Vs%20Wet_050913.pdf).

[iii] GWP refers to the total energy a compound absorbs over a period of time, typically 100-years, compared to CO_2 (i.e., a GWP of 10 means that it is 10 times more potent than CO_2 at the given timeframe). While methane's perturbation lifetime is only 12 years, its GWP takes into account indirect impacts from changes to ozone and stratospheric water vapor (IPCC 2013).

generation stage.[25–29] Burnham et al. estimated that total shale gas GHG emissions are 6% less than conventional gas emissions, but an overlap in value ranges leads to uncertainty about whether shale gas emissions are actually lower.[30]

There are a number of factors underlying the differences among studies' estimates, but the lack of consistency in assumptions and data is likely a principle contributor to the differing conclusions. Key differences and uncertainties, as identified in the literature, are summarized in Box B.1. If these assumptions or estimates differ, then estimates of GHG emissions may also be differ.

Studies attempting to reconcile these underlying differences suggest that unconventional and conventional gas GHG emissions are comparable. One review study using Monte Carlo uncertainty analysis to compare normalized "best estimates" from six studies comparing shale and conventional gas concluded upstream GHG emissions were similar.[49] Additionally, harmonized lifecycle GHG emissions from eight studies indicated that median estimates of GHG emissions from shale gas-generated electricity are similar to those for conventional natural gas, with both approximately half that of coal.[50] It is worth noting, however, that even if the GHG intensities of conventional and unconventional gas are similar, as much research suggests they are, advances in hydraulic fracturing technology have increased significantly accessible gas reserves. This is potentially significant for climate change because with more gas being produced and moving through distribution systems, if there are high fugitive methane emissions along the supply chain, the increased throughput would lead to greater methane emissions.

Box B.1: Differences and uncertainties in GHG emissions estimates

Global warming potential

The IPCC's 100-year GWP time is standard for GHG accounting. Some, such as Howarth et al.,[31] have also used alternative estimates and shorter timescales arguing that a 20-year timeframe is more appropriate given the climate system's responsiveness to changes in potent, short-lived emissions.[32] According to the IPCC, "there is no scientific argument for selecting 100 years compared with other choices," and the selection is a policy choice about how short- and long-term costs and benefits are weighted.[33]

Life cycle assessment (LCA) boundaries and scope

LCAs must have equivalent systems boundaries to be directly comparable. Some assessments only consider stages upstream of electricity generation, others include generation (with some excluding downstream transmission and distribution), and still others consider emissions from upstream and combustion without specifying end-use and efficiency. Additionally, studies that focus on a limited geographic scope may reflect unique conditions not applicable elsewhere. Studies have also had different scopes, focusing on shale gas exclusively or unconventional gas more generally.

Data sources, parameters, and assumptions

Rather than conducting direct measurements, many studies rely on EPA and industry methane emissions data, which may be incomplete as a result of limited sampling, subject to bias, or outdated data.

Moreover, there are uncertainties at points throughout the gas supply chain. For brevity's sake, examples from upstream sectors are provided here, but there are also uncertainties in midstream and downstream sectors. During completion, the emission of natural gas from flowback water is a significant source, but the amount of methane released is uncertain, storage requirements and practices vary, and studies have utilized different flowback emission factors.[34–37] A 2014 top-down study observed high emissions during drilling, a pre-production stage previously thought not to contribute significant emissions.[38] During the production stage, workovers, maintenance, and liquids unloading (the periodic removal from a well of liquids and other debris that impede gas flow, which was recently documented as relevant to shale gas production[39]) are primary potential sources of emissions, and studies have utilized different assumptions regarding the frequency at which these occur.[40] Liquids unloading has been identified as a factor to which emissions estimates are most sensitive,[41] and studies utilizing direct measurements found that liquids unloading[42] along with pneumatic devices[43] contribute a significant proportion of emissions.

Emissions are typically reported per unit of natural gas produced. For that reason, the total lifetime production of a well is important in determining total methane emissions. Estimated ultimate recovery (EUR) has been identified as one of the most influential parameters on GHG estimates.[44–46] Uncertainty in EURs reflects the lack of long-term historical production data[47] and variation between wells and basins.[48]

Evolving technology

Due to advancement in technology, practices and emissions controls, different data and assumptions may not reflect current practices and conditions.

B.2.2 EPA emissions inventories and leakage rates

Of the uncertainties associated with total GHG emissions, the lack of reliable estimates of total methane emissions, in particular, has received significant recent attention. The EPA publishes official estimates of methane emissions from natural gas systems annually in its *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.[51] The EPA does update its methodology and data as new information becomes available, as it did in 2011 when it revised the way fugitive methane emissions from natural gas systems were estimated. Fugitive methane emissions are the emissions due to accidental methane leaks and routine venting. Over the last decade, official estimates of methane emissions from natural gas production operations have ranged from <0.2% to 1.5% of gross national gas production.[52–54]

While one study utilizing direct measurements at gas production sites estimated nationwide methane emissions comparable to EPA's estimates,[55] top-down atmospheric studies consistently suggest that the EPA significantly underestimates methane emissions.[56,57] In comparison to the EPA's estimated total leakage rate for natural gas systems from wells to end-users of 1.4%,[58] regional atmospheric studies find, for instance, methane emissions corresponding to a leakage rate between 3% to 17% of total natural gas production.[59,60] A national modeling study[61] and recent synthesis[62] find smaller excess methane emissions, but still suggest that national methane emissions are 1.5 times greater than EPA estimates (although that higher estimate still yields lower GHG emissions than coal for electricity generation).[63] In reconciling these discrepancies, studies[64,65] have suggested that high regional estimates, and a small number of "superemitter" sources, are likely not representative of the norm across the U.S.

In theory, both bottom-up approaches (process-based modeling, where emissions from each process involved in production is estimated separately) and top-down approaches (atmospheric observations of methane concentration levels over a spatially distributed area) to collecting emissions data should yield comparable emissions factors, but that has not been the case. The bottom-up approach can be quite thorough, but when it is extrapolated to larger scales, uncertainty arises from large variations in emissions over time and region, limited sample sizes,[66] and potential sampling bias from self-selected cooperating facilities.[67] The top-down approach is most limited in its ability to attribute emissions to multiple potential sources, but also can suffer from too few observations and weaknesses in modeling.[68]

Additional challenges to calculating an accurate leakage rate include potentially large regional and site differences stemming from geology, whether production is dominated by oil or gas and characteristics of the gas (wet or dry), variation in equipment and field performance, and state regulation. In some situations, the metric used for leakage can itself be problematic; for instance, in an oil basin that produces very little methane, the total methane emissions divided by a very low amount of gas production could result in seemingly very high percentage loss rates because the denominator is not a good baseline.[69] All approaches are further challenged by the rapid evolution of gas technologies, production practices, and emissions controls and may not reflect current conditions.[70]

Peer-reviewed journal articles resulting from an ongoing series of studies led by the Environmental Defense Fund in partnership with researchers and industry provide additional data on sources of methane emissions. These studies identify and provide more information about significant contributors throughout the supply chain including: pneumatic devices[71] and liquids unloading[72] during production; venting from liquids storage tanks at gathering and processing facilities[73]; compressors and equipment leaks in the transmission and storage sector[74]; and older underground distribution pipelines.[75] Many of these studies, as well as others, found skewed distributions where a small number of sites,[76] gathering facilities,[77] or distribution leaks[78] contributed disproportionately to the emissions in that sector.

Despite the lack of consensus around and continued research on emissions, there has been little, if any, debate in the existing literature that methane emissions at all stages of production can be reduced. By using a range of existing technology and best practices, methane emissions from all forms of natural gas at all stages of production through distribution can be mitigated,[79] and in many cases, at relatively low cost.[80] Some progress has already been made. Between 1990 and 2013 the EPA reported an overall 8.7% decrease in methane emissions from the natural gas sector,[81] including a recent 73% decrease from 2011 to 2013.[82] The EPA credits the decline to replacement of unprotected steel and cast iron pipelines, increased use of plunger lifts (although new data suggests that frequency of unloadings may be more significant[83]), voluntary reduction efforts, and regulatory reductions from the 2012 New Source Performance Standards (NSPS).[84] The NSPS requires green completions (observed to capture virtually all emissions from well completion flowback[85]) or flaring at all new wells starting in 2013, and green completions at all new wells starting in 2015, which is expected to result in even further reductions.[86] Lower leakage rates in distribution have been observed due to upgrades and replacement of metering and regulation facility equipment.[87]

Moreover, there is general agreement that the CO_2 emissions from end-use combustion contribute more than 75% of lifecycle natural gas GHG emissions. [88,89] Consequently, improvements in the efficiency of heat, electricity, and transportation uses of gas are also important emissions reduction opportunities to consider.[90]

B.2.3 Future emissions

The effect of unconventional gas development on future GHG emissions depends also on broader systems changes. There are multiple productive uses for an increased gas supply beyond power generation, such as transportation, industry, and export, and a variety of factors will affect how gas is used across different sectors. The full impact of an energy shift must consider these system-levels issues, requiring the linking of LCA to economic, policy, and technology models.[91] Newell and Raimi analyze environmental and economic modeling projections and estimate that lower natural gas prices from increased supply would increase overall energy consumption by 3% but reduce greenhouse gas emissions ~0.5% (subject to upstream emission estimates) by encouraging fuel-switching from coal to natural gas for electricity generation. Absent policy interventions, they conclude increased shale gas development will not substantially change the course of global GHG concentrations.[92] At a more simplistic but still significant level, the climate change benefits that increased use of gas may provide are dependent upon gas actually displacing coal (that is, the coal remaining in the ground) rather than merely adding to total fossil fuel use.

In sum, the diversity of data and conclusions from the small but growing body of literature on shale gas highlights the need for additional research on GHG emissions throughout the gas life cycle. The debates over timeframes and estimate/observation methodologies emphasize the importance of establishing consistent study protocols and standards. Additionally, consideration and re-evaluation of methane emissions from oil or coal production are also necessary in order to make accurate comparisons between fossil fuels. While much more research is needed on the contribution that unconventional gas production, including hydraulic fracturing, will make to GHG emissions, and how these emissions compare to those from coal and conventional natural gas, it is clear that there are opportunities to reduce GHG emissions now.

B.3 RENEWABLE ENERGY: WILL NATURAL GAS BE A BRIDGE TO A CLEANER ENERGY FUTURE?

Another key issue for those concerned with global climate change, as well as current and future energy systems and the domestic economy, is the relationship between natural gas and renewable energy technologies. Increased domestic interest and investment in shale gas production have resulted in some analysts questioning whether this growth could negatively impact the development, and use, of low- or zero-carbon technologies.

Some stakeholders, including the current U.S. Energy Secretary Dr. Ernest Moniz,[93] see shale gas, and more broadly natural gas, as a 'bridge fuel'—bridging the gap, and facilitating the transition, between the current fossil-fuel dependent economy and a renewable-energy based future. In this view, a shift in the overall energy portfolio away from coal and toward gas is an important initial step. As explained previously, current research suggests that natural gas likely has less of a climate impact than coal (provided that it is used for electricity generation and that methane leakages during production and extraction are kept to a minimum). The greater abundance and affordability of natural gas, along with state, regional, and federal regulations[94] and advances in generation technology,[95] already have been a major factor in the shift away from coal toward natural gas in the power sector, which has contributed to declines in greenhouse gas emissions.[96] However, the growth of shale gas as an energy source has consequences beyond coal. Significantly, it has the potential to affect investment in research, development, and deployment of low- or zero-carbon technologies.[97]

B.3.1 Natural gas as a complement

Proponents of natural gas, including J. Podesta of the Center for American Progress, argue that natural gas complements renewable energy technologies.[98] In their view, the intermittent output nature of some low-carbon energy sources, such as wind or solar, means that fossil fuels will be an essential component of the energy mix going forward. Unlike coal or other fossil fuels, natural gas is perhaps the only fossil fuel energy source that is well suited to fill in these gaps in renewable energy availability.[99–102]

B.3.2 Natural gas as a competitor

If the goal is to reach near-zero greenhouse gas emissions as quickly as possible, or even to cut emissions substantially, then low-/zero-carbon technologies must rapidly become competitive within the marketplace, as the current business-as-usual trajectory leads to an increase in emissions by 2050.[103,104] This has led many to be concerned that focusing on natural gas as a bridge fuel could delay important research, development, and deployment of low-carbon technologies, which "may set us back more than the climate benefits achieved from a marginal reduction in U.S. coal consumption."[105] Barring a technological breakthrough, or other unforeseen developments that would make low carbon technologies cost-competitive, there is a growing sense in the scientific literature that market forces alone are not likely to lead to natural gas becoming an effective bridge fuel or renewable technologies becoming a significant part of the national energy mix.[106] Without a federal regulatory structure in place to promote accelerated development and deployment of low-carbon energy technologies, an affordable and abundant gas supply is projected to increase gas use and displace both nuclear and renewable sources of energy,[107] thus outcompeting the very technologies to which bridge-fuel advocates want to transition.

B.3.3 Policy context

One of the primary factors in determining whether natural gas will serve as a bridge-fuel is the domestic regulatory landscape, specifically, interventions designed to control carbon emissions or drive growth in low-carbon technologies. Even though the future is unknown, it is possible to look at future scenarios that could plausibly unfold, given current trends and forecasts. In an analysis of 23 such scenarios provided by a range of academic researchers, along with government and industry analysts, Shearer et al. concluded that in fact, without "strong limits on GHG emissions or policies that explicitly encourage renewable electricity, abundant natural gas may actually slow the process of decarbonization."[108] This finding echoes those of Paltsev et al. and Brown et al., who in separate scenario analyses likewise found that without any sort of "climate policy," the proportion of electricity generation from natural gas would increase, while nuclear and renewable sources would either be displaced or contribute only slightly more than at present.[109,110]

The three primary climate policy interventions discussed by Shearer et al. include a price-based approach (such as a carbon tax or price-per-unit emission), a quantity-based approach (such as a tradable emissions permit system or non-tradable emissions quotas), and a federal renewable mandate. The analysis projected that both a price-based and a quantity-based approach would have two main effects in the near- to intermediate-term: lowering overall energy consumption and favoring natural gas over other fossil fuels for electricity generation.[111,112] However, it remains unclear with these interventions how long it might take before low-carbon technologies are favored, or if other incremental improvements (such as efficiency upgrades) might further delay the adoption of low-carbon technologies. Indeed, the analysis consistently found that with an abundant supply of gas, both coal and renewable energy would be used less, and both price- and quantity-based interventions would only dampen this trend but not change it.[113] In contrast, the third type of climate policy, a federal renewable mandate, was the only policy option that ensured a similar utilization of natural gas and renewables in Shearer's analysis, since the mandated renewable electricity use would decrease market competition between natural gas and renewables.[114]

There are additional policies that have the potential to affect the relationship between natural gas and renewables. For instance, the Shearer et al. analysis did not include subsidies, production tax credits, or state level renewable mandates, even though these are common existing policies. Another significant policy change is the EPA's Clean Power Plan (CPP). These new rules being developed under the Clean Air Act to reduce GHG emissions from fossil fuel fired power plants are expected to be finalized in the summer of 2015. In an analysis of the likely effects of the CPP, the Energy Information Administration found that the plan is expected to result in increasing renewable generation over the next few decades.[115] This finding holds for a number of scenarios of different levels of policy stringency and overall economic growth, but the effect is diminished under a scenario that assumes conditions leading to lower natural gas prices. In contrast to projections of renewables reaching close to or exceeding 30% of total generation by 2040, estimates assuming lower gas prices project that renewables would not surpass 20% of total generation over the same time period. This reduced growth in renewables is attributed to regions relying less on renewable development and more on natural gas dependent compliance strategies.

B.3.4 Key uncertainties

Whether increased natural gas production will ease or hinder a transition to a low-carbon domestic energy system is not clear. The overall energy portfolio in the U.S. is affected by a number of factors that remain uncertain, including future energy and climate policies, the availability and costs of low-carbon energy and carbon-storage technology, and broad macroeconomic factors impacting natural gas markets and prices. Each, independently or in partnership with each other, could heavily influence the viability of natural gas as a bridge fuel in the short- to medium-term.

B.4 MANUFACTURING: WILL NATURAL GAS DEVELOPMENT REVITALIZE DOMESTIC MANUFACTURING?

The economic implications of shale gas production have also received significant attention. Among other considerations, many industry experts and analysts have been projecting a so-called manufacturing renaissance in the U.S.[116–125] Analysts from IHS, PricewaterhouseCoopers (PwC), and other organizations predict significant increases in employment, household income, tax revenue, and gross domestic product (GDP) value added, in addition to increased demand in consumption and government spending.[126–129] These projections are attributed to a boom in domestic manufacturing arising from the availability of abundant and affordable natural gas.[130–136] Although these potential benefits have received fairly widespread attention, there is concern among some that estimates are overstated due to methodological issues, unrealistic assumptions, and the omission of potentially significant considerations,[137–140] as well as observations that some predicted trends have simply failed to materialize.[141] An overview of more optimistic overall and sector-specific predictions is provided first, followed by a discussion of some of the criticisms that have been raised.

B.4.1 Industry trends

A number of industry groups and analysts have predicted that expanded shale gas production will make significant contributions to the broader economy over the next decade. For instance, IHS used an input-output model to estimate the full value chain for unconventional gas and oil.[iv] They concluded that it supported 2.1 million jobs nationally, created nearly $75 billion in tax revenue, and contributed $283 billion to the U.S. GDP in 2012 alone. IHS and PwC also projected that by 2020, unconventional fuels could contribute between 1 and 3.9 million additional jobs, $532.8 billion in GDP value added, and an increase of over $3,500 in average household disposable income.[142,143]

Analysts project this growth to occur along multiple portions of the value chain. In addition to upstream growth associated with exploration, drilling, new construction, and transportation infrastructure,[144,145] several downstream

[iv] Although this report concerns shale gas specifically, the IHS report cited here does not separate unconventional gas from oil, as it would be difficult to differentiate the economic impacts of oil and gas production. Oil production often produces gas that can be marketed separately, and dry gas production can yield natural gas liquids as well.

manufacturing industries are expected to benefit. Specifically, industries reliant upon natural gas for use as a feedstock or for energy are expected to see significant cost-savings.[146–149] A few industries are described below.

Natural gas liquids, which can be extracted directly or formed as a by-product during processing of dry natural gas, are valued as raw materials by the petrochemical industry.[150] These liquids, which include hydrocarbons such as ethane, propane, butane, and pentane, can be processed and refined into derivative compounds, and further into a variety of intermediate and end products.[151]

Globally, many chemical manufacturers use naphtha, refined from crude oil, as a primary feedstock in chemical manufacturing.[152] Compared with the more expensive naphtha, and the rising production costs in the Middle East, the United States is emerging as a cost-advantaged producer of ethylene, which is the main product created from ethane and one of the primary building blocks in the chemical value chain.[153] Moreover, because prices for many high-volume natural gas or ethylene-intensive chemicals such as ammonia or high density polyethylene are set on world markets, U.S. chemical producers currently enjoy a large gap between input and output prices relative to chemical producers elsewhere in the world.[154] As ethylene is one of the primary building blocks in the chemical value chain, this trend has the potential to positively impact the domestic manufacturing industry as a whole.[155]

To take advantage of this, 148 chemical industry-related projects (including new factories, expansions, and process updates to increase capacity), valued at over $100 billion, had been announced as of February 2014.[156] Most of these new plants are planned for the Gulf Coast region, where infrastructure already exists.[157] This level of new capital investment is nearly triple IHS' 2013 prediction of an estimated $31 billion of investment by 2016.[158]

Metal manufacturing has potential to benefit from the shale gas boom through both decreased energy costs and increased demand,[159] although the magnitude of these benefits remains unclear. Many U.S. facilities traditionally have used coal as a fuel in processing iron ore, but some are beginning to switch to natural gas to take advantage of its lower cost.[160,161] Demand is experiencing an uptick as well, as the shale gas production process requires steel products.[162,163] While some are optimistic that this is the start of a longer-term trend that could lead to the creation of one million new domestic manufacturing jobs,[164] others assert that the benefits may not be as substantial. They note that the demand increase is likely to be in the short-run[165] and that the cost savings from switching to natural gas may represent less than 2% of the per-ton cost of steel production ($8-10/ton in savings compared to an overall production cost of approximately $600/ton).[166]

As noted in the University of Michigan Energy Institute's report on domestic shale gas,[167] as long as the price difference between natural gas and diesel is large enough, parts of the transportation sector could stand to benefit. In fact, a natural gas trade association projected a 20% growth rate in natural gas powered truck sales for 2014, based in part on the lower fuel costs relative to diesel.[168] However, the Energy Institute's report also notes that the use of natural gas as a transportation fuel faces a number of obstacles,[169–172] such as a limited nationwide fueling infrastructure, fuel storage issues, relatively high up-front costs, safety concerns,[173–179] and price challenges from motor gasoline. Whether and the extent to which this industry benefits depends heavily on how the price of domestic natural gas relates to motor gasoline and diesel. If natural gas prices increase as a result of greater demand (either from exports—see section B.5 Exports for more—or from expanded domestic accessibility[180]), or if motor gasoline prices decrease substantially (as was beginning to happen as of the end of 2014[181]), then the competitiveness of natural gas as a transportation fuel could be significantly affected.

While most of the discussion around natural gas usage in the transportation sector has focused on the trucking industry, and to a lesser extent, passenger vehicles, PwC notes that railroads are already hauling equipment and chemicals needed during the extraction process and shale gas and oil after extraction. Additionally, in the airline industry, the combination of high jet fuel prices and crude oil price volatility has motivated Shell (RDSC) and Qatar Petroleum to look for cheaper fuel alternatives, such as those derived from natural gas.[182]

B.4.2 Other perspectives

Despite the detailed commentary and data published by business and industry groups, to date there have been only a handful of peer-reviewed studies or evaluations examining a potential manufacturing renaissance from expanded shale gas production. These publications, and others, paint a less optimistic and more nuanced picture of the effects of expanded natural gas production.

A recent study commissioned by the Brookings Institute studying gas-intensive and non-gas-intensive manufacturing suggests that employment in gas-intensive industries was 3.4% to 9.1% higher in 2012 owing to low natural gas prices.[183] Using the total employment for those gas-intensive industries in 2013 (710,000), the authors note that their estimates suggest job gains from expanded shale gas production in the range of 24,000 to 65,000. The paper stresses that the total manufacturing employment impact depends on difficult-to-measure factors such as whether new jobs in gas-intensive industries were moved from other sectors and the extent to which new positions are pending completion of slow-moving capital investment projects. To put their numbers in perspective, total employment in 2013 was 136 million.[184]

Many industry studies take a broader perspective, including direct effects in the oil and gas development sector itself, indirect effects in industries that provide materials and services to the gas and oil sector, and induced effects from directly and indirectly generated income being spent more broadly in the economy. Input-output models use "multipliers" and other assumptions to estimate how expenditures will have ripple effects in these related sectors and more broadly.

While input-output analysis is a well-established method, like all models, it has limitations. Its predictions depend on the underlying assumptions and data, which have raised several concerns among some researchers. They have questioned the accuracy of estimates of future drilling activity (i.e., the expenditures upon which the estimate is based),[185–187] multipliers used to capture the effects on other industries,[188,189] and assumptions about whether inputs are sourced and expenditures made within the same region as development (affecting where the effects are realized),[190,191] all of which can significantly affect projections. The Economics Technical Report raises these concerns, as well as others such as whether jobs numbers are standardized to accurately represent changes in workers needed over the lifetime of a well and what percent of labor hired is from the region of interest when considering benefits at smaller geographic scales.[192] These concerns are significant given that the number of direct jobs created by natural gas development is small, and the majority of the projected job gains made for the industry are based on indirect and induced effects.[193]

Shale gas extraction may have a number of indirect negative consequences not included in some analyses. The input-output model used in many industry assessments does not necessarily capture losses in other sectors, and, therefore, presents gross, not net, economic impacts.[194] For example, shale gas extraction could displace coal mining in some regions, and the associated increase in natural gas related jobs could come at the expense of fewer jobs in coal production and coal-dependent industries.[195] Tourism and farming are other industries that might be negatively impacted by industrial activity.[196–198]

A potential negative effect relevant to manufacturing in particular is an economic phenomenon known as "Dutch Disease" which concerns the observed relationship between increasing exploitation of natural resources and a corresponding decline in the manufacturing sector. The underlying theory in the context of natural gas extraction in the U.S. is that increased local wages and land costs resulting from gas production may cause a *decline* in local firms that manufacture tradable goods. A recently published study examining oil and gas booms found that industries that are not linked to oil and gas and that are likely to trade outside local markets contracted during resource booms; however, most industries were positively affected, because they either supply to the oil and gas sector or benefit from increases in local demand.[199]

Another concern is whether industry studies utilize an appropriate baseline for comparison. A standard best practice in economics when analyzing the effect of an intervention or change (in an input-output model or otherwise) is to compare it to the counterfactual—what would happen without the intervention. Comparing projections to conditions when a policy or change started, rather than a counterfactual, does not control for underlying trends or other factors that could contribute to the projected outcomes.[200,201] Inadequate use of counterfactuals could lead to significantly different conclusions and projections.

To illustrate how these differences can affect estimates, consider Pennsylvania, home of the Marcellus Shale region. Researchers at the Ohio State University estimate that from 2004 to 2010, shale-drilling activities in Pennsylvania created approximately 20,000 jobs.[202] This corresponds closely to other estimates from 2009,[203] but is far less than the 140,000 jobs associated with natural gas estimated for the same year by an industry-funded study[204] that used higher multipliers and assumptions about planned expenditures and how much money stayed in state. While this example is admittedly on a different scale and is more narrowly focused than the national employment projections, it underscores the importance of the underlying data. It also highlights a trend that certain researchers note: that shale gas production may be associated with significant income effects, but only modest employment effects.[205] Still others suggest that the income effects too may be less than input-output models suggest.[206]

Methodological considerations aside, there are other factors that could reduce the benefits to manufacturing of expanded gas production. An analysis published in mid-2014 by Goldman Sachs found that reinvestment rates in energy-intensive manufacturing lags similar reinvestment in the Middle East and Asia by a ratio of 15-to-1.[207] It also found that the infrastructure to ensure the benefits of abundant energy supplies can be fully reaped is lacking.[208] By their calculations, if these trends continue, North America would, over the next decade, forego more than 2 million new jobs and 1.0% of additional GDP growth.[209] While these numbers incorporate considerations beyond only manufacturing, this sector is a major component.

Lastly, it is worth making a few, perhaps obvious, points. First, there are many other potential effects on the economy beyond manufacturing, but those are beyond the specific focus of this section. Additionally, this discussion is based largely on the expectation that gas prices stay low, but gas prices inevitably change. When prices are low, consumers of gas (e.g., manufacturers and the general public) benefit, but production becomes less profitable, and production drops. The loss of capacity may then push natural gas prices up again. This affects who, be it natural gas producers, manufactures, or public more broadly, benefits.

In all, shale gas has the potential to bring significant benefits to the U.S. economy. The manufacturing, and gas- and energy-intensive industries more broadly, appear likely to benefit from expanded shale gas production. Yet, while business and industry analysts are optimistic in their projections, others have adopted a more cautious perspective of the economic potential of expanded shale gas production, citing the need for a closer examination of various key factors before drawing strong conclusions.

B.5 EXPORTS: WHAT ARE THE IMPLICATIONS OF NATURAL GAS EXPORTS?

In large part as a result of technological advances in drilling, the country now faces an abundance of natural gas, which has driven prices down to levels that give the U.S. a cost-advantaged status globally. With market conditions thus shifting from favoring U.S. natural gas imports[210] towards favoring exports, debate has emerged around producers' interest in expanding exports.[211]

The U.S. Department of Energy's Office of Fossil Energy and the Federal Energy Regulatory Commission (FERC) are the primary authorizing agencies for any gas exporting processes.[212] Federal law currently prohibits any imports or exports of natural gas without authorization from FERC, which also has authority over import/export terminals.[213] As of March 3, 2015 FERC had granted final approval for five liquefied natural gas LNG export projects and conditional approval for another four projects, with additional applications under review.[214] As part of the permitting process, exports are required to be "in the public interest," but concerns continue in Congress about whether, and how, to allow expanded exports.[215]

To date, there have been a number of analyses conducted by various public and private institutions regarding the potential impacts from expanded exports. It is difficult, however, to directly compare these studies, since they look at different issues, use various modeling methodologies, and are based on widely different assumptions.[216]

There is, however, consensus that a significant increase in exports would raise the domestic price of gas, although the magnitude of the increase is unclear.[217] Producers generally contend that due to an ample supply to meet domestic demand, increasing exports would not greatly raise current prices.[218] Such statements have done little to alleviate consumer fears of being negatively impacted by price increases.[219] Of eight separate studies evaluated by ICF International (ICF), all eight projected that expanded exports would lead to an increase in domestic natural gas prices, ranging from as little as $0.03/million BTU (MMBtu) to as much as $4/MMBtu (or $0.03 - $0.33/MMBtu per 1 billion cubic feet per day (bcfd) when normalized across the scenarios).[220] A study commissioned by the Brookings Institute released in 2015 estimates that exports of 9.2 bcfd would lead to a price increase of $0.48/MMBtu, while exports of 24.6 bcfd would lead to a price increase of $1.33/MMBtu.[221] Some studies point out that the global gas market would limit how much domestic natural gas prices can rise, since importers would simply not purchase U.S. exports if U.S. wellhead prices rise above the cost of competing supplies.[222,223]

The main effects of an increase in price would be to promote the expansion of natural gas production, reduce its cost advantage compared to other forms of energy generation, and reduce the benefits to consumers and gas- and energy-intensive sectors. Findings from selected reports are presented below to illustrate these points, but the projected consequences of expanded exports on natural gas exporters are effectively the reverse of the effects of low gas prices described in the previous sections. While estimates of the magnitude of these effects vary, they would be proportional to the total quantity of gas exported.

In terms of the overall U.S. energy portfolio, a Purdue study projected that by 2035, natural gas exports would cause a decrease in the proportion of natural gas, and increase in the proportions of coal, oil, and to a lesser degree nuclear and renewables, in U.S energy consumption.[224] Because natural gas is used for electricity generation, an increase in the price of gas is expected to increase the price of electricity; estimates vary from, for instance, 1.2% or less in a Deloitte study[225] up to as much as 7.2% in an analysis from Purdue.[226]

Studies by NERA Economic Consulting and Purdue found that energy-intensive sectors and natural gas-dependent goods and services producers would be negatively impacted by increased prices of gas and electricity.[227,228] The Purdue and Deloitte studies, however, came to different conclusions about whether the price impact from exports would[229] or would not[230] render U.S. industry less competitive globally, respectively. What is uncontested is that natural gas suppliers would benefit from exports.[231,232]

Much like the earlier manufacturing discussion, there are differing views on the effect of higher gas prices on employment and GDP. NERA and Deloitte studies found exports would be unlikely to affect overall employment in the U.S.,[233,234] an ICF study found an increase of up to 450,000 jobs through 2035,[235] and a 2012 Brookings study suggested such gains were overstated due to their temporary nature and losses in other industries.[236] While the NERA and ICF studies predict increases in GDP, the Purdue report found a decline and observed that $10 billion net increase in GDP predicted by NERA is quite small in a $15 trillion economy, equating it to just six hours of U.S. economic activity.[237,238]

Although these studies focus on economic consequences, the 2012 Brookings study also mentions other effects. For instance, expanded exports might give the U.S. geopolitical leverage in international trade negotiations, perhaps ensuring U.S. access to important markets, such as Chinese rare earth metals. It observes that the increase in domestic natural gas prices would disproportionately impact low-income consumers[239] and that the expansion of shale gas production could amplify the environmental, social, and health impacts associated with development.[240] The Purdue study also looked at GHG emissions and predicted that 'emissions transaction costs' from liquefying, transporting, and de-liquefying the gas could still result in a net GHG increase even if there is a shift toward natural gas in generation.[241]

Should exports of natural gas continue and expand, the price is expected to increase, resulting in costs to some and benefits to others. Overall, with the notable exception of the Purdue study,[242] the analyses mentioned here project net economic benefits for the U.S., with the natural gas industry being a clear winner.[243–245]

B.6 HUMAN HEALTH RISKS: HOW DO WE KNOW IF SHALE GAS DEVELOPMENT IS "SAFE"?

Amongst the general public within the U.S., there is a strong desire to know whether or not shale gas development, including hydraulic fracturing, is 'safe,' as well as to understand what human health risks may be specifically associated with the practices. Such questions are reasonable; however, they are inherently complicated, and cannot be answered definitively at this time. This section focuses on different approaches that can help answer these questions.

Some commentators within industry and various regulatory agencies point to the more than 60 years of hydraulic fracturing activity in the U.S. to argue that the practice does not adversely impact human health.[246] However, researchers and practitioners within the fields of medicine and public health do not necessarily see a lack of data as evidence of an absence of acute or chronic human health risks.[247] Just like any other fossil fuel, the development of shale gas poses inherent potential environmental public health risks. It is the extent of the risks from shale gas development and their effect on health outcomes that are relevant to the "safety" question, and they remain unknown.[248,249] Better understanding of them can help manage and reduce the risks, as well as to understand shale gas in the context of other energy sources and potential tradeoffs.

Despite ongoing efforts, the body of peer-reviewed environmental health research on shale gas development and hydraulic fracturing is limited.[250,251] For example, the Institute of Medicine noted, "public health is lacking critical information about environmental health impacts of these [shale gas extraction] technologies and is limited in its ability to address concerns."[252] Notably, there have been no comprehensive studies of the public health effects of shale gas development, and significant uncertainties, data gaps, and research limitations persist.[253–256] Key uncertainties include the types and magnitudes of human exposures to hazards, identities and concentrations of chemicals used, synergistic effects of multiple stressors, and long-term cumulative effects. The lack of baseline and monitoring data, the length of time it takes for certain health outcomes to manifest, and the multi-causal nature of some potential outcomes pose further challenges to assessing associations between hazards and health outcomes.[257–261]

These substantial uncertainties and data gaps have prompted numerous researchers and organizations[262–268] to call urgently for additional human health research. Data generated in such studies are critical to our understanding of the human health impacts associated with hydraulic fracturing and shale gas development more broadly.

For more specific discussion of the public health issues concerning hydraulic fracturing in Michigan refer to the Public Health Technical Report.[269] Refer also to Appendix C for further discussion of air quality and landowner/community issues (including noise, light, etc.), which are potential public health concerns surrounding hydraulic fracturing.

B.6.1 Types of health assessments

There are several methods beyond the scope of this Integrated Assessment that could be used to develop a comprehensive assessment of the human health-related effects of hydraulic fracturing and unconventional gas development. Each of these methods requires a substantial commitment of resources to arrive at useful and actionable conclusions. For instance, the evaluation of the human health effects of just one chemical in a traditional risk assessment requires extensive laboratory studies, research into population exposure data, computer modeling, and other time and labor intensive activities. With hydraulic fracturing, there are many variables and confounders; there is not merely one standard approach to the process, which can make use of numerous chemicals and methods in a range of settings (see the Public Health Technical Report[270] and Chapter 4 Chemical Use, this report). As such, determining the potential types of assessments required and evaluating the potential health impacts is a complex and resource-intensive process.

As described in the Public Health technical report, traditional risk assessment combines hazard identification, exposure assessment, and dose-response assessment to characterize risk and eventually inform management decisions.[271] While it can be thorough and effective at illuminating quantitative information concerning the risks associated with a certain substance, it is limited in that it does not incorporate perceived risks, nor does it compare risks between multiple policies, or include an analysis of the economic/social implications of a policy under consideration.[272]

In contrast to traditional risk assessment, cumulative risk assessment considers the combined adverse effects of multiple stressors from various sources and through different routes of exposure. Cumulative risk assessment considers both chemical and nonchemical stressors, the latter of which includes physical (e.g., noise, light) and psychosocial (e.g., housing, access to medical care, neighborhood safety) factors.[273] By factoring in real-life circumstances, cumulative risk assessments aim to be more realistic, relevant, and responsive to stakeholder concerns. This can make them more challenging to complete—particularly factoring in nonchemical stressors—and methods are still being developed and improved.[274]

Health impacts assessment (HIA) is another approach that has been used to understand health risks. HIAs use a variety of data sources—including input from stakeholders—and analytic methods to determine the potential effects of a particular practice or policy on the health of a given population.[275] HIAs are not intended to evaluate whether a project or plan should or should not be implemented, but rather to inform decision makers as to how to make a proposed action plan more likely to promote health and avoid negative health outcomes.[276] HIAs are used routinely by international development organizations, governments ranging from the UK and Canada, to countries in Africa and Asia, and even industry, and they are growing in usage in the U.S..[277,278] There are, however, limitations associated with the approach. There have been remarkably few attempts to review the accuracy of predictions made about health within HIAs, not to mention or the impacts that HIAs have had on the policy making process.[279]

There are also methods to compare risks across different hazards. Comparative risk analysis is a science-policy approach used to measure, compare, and rank environmental risks and potential options for managing those risks. Comparative risk assessment can help to identify the worst problems—in terms of relative magnitude of risk—and to evaluate the benefits and costs of different risk reduction options.[280]

B.6.2 Current and future assessments

Despite the lack of comprehensive assessments, there have been efforts to assess human health risks focused on smaller scales, such as specific exposure routes or a limited geographic area. For instance, Adgate et al.[281] note that published health risk assessments have focused on risks from air exposure.[282,283] A draft HIA was prepared by the Colorado School of Public Health for the Battlement Mesa community in Colorado.[284] More recently, the School of Public Health at the University of Maryland prepared a "rapid" HIA of potential public health impacts of natural gas development and production in the Marcellus Shale in Western Maryland,[285] and the Maryland Departments of the Environment and Natural Resources released an assessment of risks from unconventional gas well development in the same region.[286]

Other major studies are also underway. Examples mentioned in the New York State Department of Public Health's 2014 public health review[287] include the Marcellus Shale Initiative's work to estimate the effect of shale gas development on asthma, cardiovascular disease, and pregnancy outcomes[288]; EPA's draft study of hydraulic fracturing and its potential impact on drinking water resources was released in early 2015[289]; and National Science Foundation funded cooperative agreement with the University of Colorado Boulder to investigate conflicts between natural gas development and water and air resource protection.[290]

While these studies have been, or are likely to be, helpful in illuminating aspects of the issue, there is still a lack of comprehensive studies on the public health effects of shale gas development and hydraulic fracturing. Interest in such a study is growing, as calls for a comprehensive health impacts assessment are increasing, from organizations ranging from the Institutes of Medicine[255] to the Health Effects Institute.[291] Until such a comprehensive study is completed, however, the scientific and public health communities cannot conclusively answer whether or not shale gas development through hydraulic fracturing is 'safe' for public health.

B.7 CONCLUSION

In response to public comments received during the IA and broader context topics identified in the technical reports, this chapter has provided an overview of the literature on several key issues related to expanded shale gas production. While not exhaustive, the issues discussed in this chapter are central to the national debate and discourse regarding the challenges and opportunities of expanded shale gas production. Many of these issues are unresolved by scientific studies due to the use of different methodological approaches, datasets, scenario assumptions, and other factors. In other areas, there are clearer indications of outcomes, such as opportunities to reduce GHG emissions through existing technology and best practices, the influence of federal renewable mandates for transitioning to low- or zero-carbon technologies, economic benefits for gas-intensive industries from lower gas prices, and price effects of expanding natural gas exports. These discussions should not be read as definitive conclusions but a snapshot of current understandings of these topics. Despite a recent increase in research on the topic, the body of peer-reviewed research is new; one comprehensive review of the available scientific peer-reviewed literature estimated that only 73% of the literature has been published since January 1, 2013.[292] As has been noted above, much still needs to be examined regarding expanded shale gas development, and there is significant work currently taking place that hopefully will better inform decision making moving forward.

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ADDITIONAL ISSUES

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Appendix C

C.1 INTRODUCTION

Drawing from the range of public comments received during this project, this appendix provides a scan of topics relevant to natural gas development in Michigan but not necessarily specific to high volume hydraulic fracturing (HVHF). These include a range of potential environmental impacts, air quality concerns, landowner and local community impacts, as well as agency capacity and financing issues. These topics were identified based on key concerns about and potential impacts from hydraulic fracturing identified in the public comments, as well as the integrated assessment technical reports, media releases, and scientific literature.

In contrast to the discussion in Appendix B, which addresses issues at the national scale or in terms of general methodological approaches, the topics presented in this appendix are relevant directly at the state and local levels. At the same time, unlike the topics addressed in the analysis of policy options in Chapters 2–4 of the full report, the topics here are not specific to HVHF. That is, they are, in general, neither unique to well sites where HVHF occurs nor limited to the hydraulic fracturing part of the shale gas development lifecycle. To varying degrees, they are common to all drilling sites. However, despite not being exclusive to HVHF, these issues do occur within the context of HVHF-drilled wells and are relevant to shale gas development more generally, and therefore are included here.

For each of these issues, this appendix gives an overview of the potential impacts and concerns, a brief description of regulations or practices in Michigan related to the topic, and a list of different approaches intended to address aspects of these concerns or examples from other states. A variety of resources were consulted in order to develop the lists of example approaches, including existing and proposed state oil and gas regulations from other states, policy analyses and interpretations from legal scholars and non-profit organizations, articles published in academic journals, and recommendations from industry groups. An in-depth analysis of options, as was done with the chapters on public engagement, water resources, and chemical use, is not provided. It is important to stress that the listed approaches are not comprehensive—they are intended only to highlight various possibilities—and their inclusion does not indicate a recommendation. The very nature of some of the example approaches, including existing regulations and recommended practices, indicates that actions are being taken in some places and by some operators to reduce these potential impacts; however, it is beyond the scope of this section to address the extent to which those are implemented. Industry groups such as the American Petroleum Institute have also developed resources and guidelines for hydraulic fracturing.[1]

C.2 ENVIRONMENTAL IMPACTS

The full shale gas development life cycle has the potential to adversely impact ecosystems in a number of ways. In addition to the potential for environmental impacts from chemical usage, water withdrawals and contamination, and waste management described elsewhere in this report, shale gas development can have other adverse ecological impacts, such as habitat fragmentation and the introduction of invasive species. See the Environment/Ecology Technical Report for additional details.[2] Although little of the current literature surveyed mentions habitat disruptions as a prominent part of the discussion around environmental impacts of hydraulic fracturing, there can indeed be impacts to local flora and fauna.[3] As part of the site preparation stage–when land is cleared and infrastructure constructed–there is a consensus among a wide variety of experts surveyed by Resources for the Future as part of the Managing the Risks of Shale Gas project (which included academic, industry, government, and NGO experts), as well as support in the academic literature, that habitat fragmentation is a possibility and concern.[4,5] Other environmental impacts are possible as equipment and water are brought in from distant locations. Invasive species, which can disrupt normal ecosystem functioning, are of particular concern.[6] Finally, increased levels of light and noise from operations can cause disturbances—especially around reproduction, rest, and feeding—for flora and fauna, potentially leading to disruptions within ecosystems.[7]

Currently in Michigan, state regulations require the Department of Natural Resources (DNR) and Department of Environmental Quality (DEQ) to evaluate potentially sensitive areas for impacts to wildlife, water, and other areas of concern before issuing gas development permits.[8] Additionally, the state's permitting process (which includes both the DNR for well-site permits for state-owned surface land and the DEQ for drilling permits[9]) sets out a number of specific site requirements, such as, although not limited to: setback distances, the use of silt curtains, covering pervious ground in plastic, and using native species to reclaim the site after operations have completed.[10] Table C.1 offers a range of policy approaches addressing some environmental impacts. For each topic, a description of current practice in Michigan is included first.

C.3 AIR QUALITY

Most stages of the shale gas exploration and production process, along with the supporting logistics and infrastructure have the potential to impact air quality. Pollutants that have been connected with shale gas operations in Michigan and in other states include nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOCs), methane, diesel, hydrogen sulfide, and crystalline silica.[27] Indeed, these pollutants are known to have a range of adverse effects on human health, as well as negative impacts to ecosystems.[28] While workers at well sites likely have the greatest potential for

TABLE C.1: ENVIRONMENTAL IMPACTS – EXAMPLE APPROACHES	
EXAMPLE APPROACHES FOR DIFFERENT IMPACTS	**SOURCE**
HABITAT LOSS AND FRAGMENTATION	
Michigan: The state sets requirements for hydraulic fracturing operations to reduce their potential impacts, including constructing the well-pad at least 1,320 feet from the nearest stream (for state leases) and the use of an "optimal" location for private properties.[11]	
Require a minimum 300 foot aquatic habitat setback, with the distance measured from the edge of any land disturbance (not from the location of a particular wellbore) to the edge of a particular habitat	Best Management Practices / Recommendations[12]
Minimize well pad size, cluster multiple well pads, and drill multiple wells from each pad to minimize the overall extent of disturbance and reduce fragmentation and associated edge effects	Best Management Practices / Recommendations[13,14]
Co-locate linear infrastructure as practicable with current roads, pipelines, and power lines to avoid new disturbances; when possible, existing roads should be used.	Best Management Practices / Recommendations[15]
Surveying and data collection to choose the least environmentally sensitive site from which the target formation may be effectively accessed and to reduce land use conflicts and/or absolute magnitude of ecological impact	Best Management Practices / Recommendations[16]
State agencies must consult with the relevant state oil and gas commission, the surface owner, and the operator on a location assessment when the proposed location will be within areas of known occurrence or habitat of a federally threatened or endangered species; also if the operator requests an increase in well density to more than 1 well per 40 acres.	Colorado regulations[17]
A written E&S (environment and safety) plan is required if disturbing 5,000 ft^2 or more in total or if activity has the potential to discharge to high quality water.	Pennsylvania regulation[18]
Establish 'sensitive habitat areas' – gas projects proposed within such zones must first receive approval from the appropriate state agency (such as Parks & Wildlife, Department of Natural Resources, etc.)	Colorado regulations[19]
In high value/high risk watersheds, impose a cap (for instance, 2%) on cumulative surface development (including all well pads, access roads, public roads, etc.)	Best Management Practices / Recommendations[20]
FLORA AND FAUNA	
Michigan: The state prohibits the intentional depositing of non-native invasive species, and it requires well-site owners to reclaim the site using native vegetation after site operations have ended.	
Applicants for drilling permits must submit a plan with every well application for preventing the introduction of invasive species and controlling any invasive that is introduced. Plans should include: • Flora/fauna inventory surveys • Procedures for avoiding transfers of species • Interim reclamation following construction/drilling • Annual monitoring/treatment of new invasive species as long as well is active • Post-activity restoration to pre-treatment community structure and composition	Best Management Practices / Recommendations[21]
Establish habitat- and land area-specific requirements for operators, such as: • Treating water pits that could breed mosquitos to prevent the spread of West Nile Virus to wildlife • Installing and using bear-proof dumpsters in black bear habitat • Disinfecting water suction hoses and water transportation tanks in designated Cutthroat Trout habitat	Colorado regulations[22]
Master Leasing Plans (MLPs), issued by the Bureau of Land Management and focused primarily on the American west, identify large blocks of unleased federal lands with high mineral potential and high recreational/wildlife value. They place some lands off-limits to leasing while requiring that others be developed in phases with tighter pollution controls or lower densities of roads and well pads.	Current Bureau of Land Management rule (Master Leasing Plans)[23]
SOIL	
Michigan: The state requires those applying for DEQ drilling permits to also file a soil erosion and sedimentation control plan, which describes when erosion control structures are needed, and requires applicants identify any such structures that they will use.	
For activities that involve "earth disturbance" (including gas drilling), require developers to implement and maintain a series of best management practices for minimizing accelerated erosion and sedimentation	Pennsylvania regulation[24]
Michigan: Michigan has several requirements related to soil protection for shale gas operations, such as avoiding hillsides, using silt curtains, and covering pervious grounds in plastic to contain any spillage.	
Lay reusable mats over well pad site and planned access routes (rather than laying gravel) to reduce risk of erosion damage, reduce risk of soil and surface water contamination, and speed the reclamation process once well is put on production	Best Management Practices / Recommendations[25]
OTHER	
Reuse of drilling fluids and muds ("closed-loop drilling") reduces solid waste and could reduce truck traffic, thereby reducing air emissions, noise, and road damage	Best Management Practices / Recommendations[26]
Comprehensive Development Plans (CDPs)—refer to C.4 Landowner and community impacts	

exposure to the widest variety of air pollutants, impaired air quality at the local and regional levels is possible.[29] Broadly speaking, there are two main sources of air emissions: on-site activities and transportation. On-site activities that can produce emissions include the use of motors and engines, shale gas leaks, and compounds mixed in with the fracturing fluid, among others. On the transportation side, the creation and use of access roads can lead to increased levels of dust and dirt being sent airborne, and the use of fossil fuel powered trucks to transport materials to and from drill sites also has the potential to generate air emissions.

The federal government and the State of Michigan both have regulations that govern various types of airborne emissions from on-site and off-site sources. For instance, on the federal level, the EPA has published rules under the Clean Air Act, which are meant to control VOC and methane emissions.[30] To comply with these new rules, operators are currently allowed to either flare on-site VOCs and methane or capture them using green completions, but beginning January 1, 2015, all operators must use green completions.[31] Green completions refer to the process of capturing gasses and hydrocarbon liquids that would otherwise be vented or flared into the atmosphere. These captured gasses can then be used commercially or otherwise, thereby reducing atmospheric emissions and providing additional economic opportunities.[32] While Michigan does not mandate any technology or process for VOC emissions control, some operators in the state nonetheless already employ techniques similar to green completions, in order to prevent lost gas and lost revenue.

The State of Michigan has several regulations that are applicable to shale gas development and associated impacts to air quality. Operators are required to burn, process, or dispose of gas from operations if it is not going to be utilized.[33] Generally, operators choose to burn the gas through flaring,[34] though the EPA's new rule will likely change this. Flowback liquids are also prohibited from being stored in open pits,[35] preventing emissions through evaporation. Michigan's oil and gas rules also prohibit creation of a "nuisance odor,"[36] defined as "... an emission of any gas, vapor, fume, or mist, or combination thereof, from a well or its associated surface facilities, in whatever quantities, that causes, either alone or in reaction with other air contaminants, injurious effects to human health or safety; unreasonable injurious effects to animal life, plant life of significant value, or property; or unreasonable interference with the comfortable enjoyment of life or property."[37] The rules also require an operator to report a condition that may cause a nuisance odor.[38] Additionally, Michigan regulations prohibit gas operations to begin or to continue at a location where "it is likely that a substance may escape in a quantity sufficient to pollute the air..."[39] There are also multiple Michigan regulations that specifically target hydrogen sulfide (H_2S).[40]

Gas operations in Michigan may also be subject to air quality permitting requirements. An Air Quality Permit to Install is required for oil and gas facilities if total potential emissions of criteria pollutants or VOCs exceed specified thresholds.[41] There are exemptions for certain pieces of oil and gas equipment if they meet prescribed criteria[42]; however, the overall thresholds generally apply.[43] An Air Quality Renewable Operating Permit is required for any facility that has the potential to emit 100 tons per year of lead, sulfur dioxide, nitrogen oxides, carbon monoxide, PM-10, PM-2.5, ozone, or volatile organic compounds; or that exceeds prescribed levels of greenhouse gas emissions or one or more hazardous air pollutants.[44]

Table C.2 offers a selected list of strategies for addressing air quality concerns. These strategies include proposed and current legislation and performance standards.

C.4 LANDOWNER AND COMMUNITY IMPACTS

In addition to concerns about impacts to air and water, other primary areas that could potentially impact communities and landowners include noise, light, aesthetics, and traffic, which (with the exception of aesthetics), could all also have human and ecological health implications.[58] As shale gas exploration and development activities increase, there is generally an accompanying influx of machinery and people. The machinery used at and around well sites is frequently powered by diesel motors, which, in addition to generating air emissions, also generate noise. The operating hours of well sites can vary in areas without local or other ordinances governing noise levels, with some potentially operating outside of daylight hours. When operations take place after dark or otherwise in low-light conditions, artificial lighting is usually used.[59,60] Depending on the type of lighting used, generators could contribute to elevated noise levels, and light could travel beyond the boundaries of the well site.

Sites are not always located directly on or near existing roads, so operators will sometimes create access or service roads in order to allow equipment, personnel, and trucks to get to and from the sites. These roads have been connected with increased levels of well site traffic,[61] in addition to potentially adverse environmental consequences.[62] The increase in traffic connected with shale gas development can impact areas differently. In some communities with ample resources, such an increase may have negligible consequences, while in other communities (especially those in which residents already experience barriers—geographical, financial, or physical—to community services[63]) such an increase could have significant negative impacts on traffic control, road maintenance, parking, and other traffic related issues. In Michigan, this may be of greater relevance, considering the state's ranking as 50th out of 50 states for spending on road maintenance and quality.[64] In Texas, for instance, which is home to the Eagle Ford shale play, roads in the region have been pushed to their limits, resulting in up to a 40% increase in traffic fatalities in 2012 alone. However, in November 2014, a legislatively-referred constitutional amendment passed, and some revenue from the state's oil and gas taxes will go the state's Department of Transportation to help alleviate some of the financial constraints on road repair.[65]

Aesthetic concerns have also surfaced surrounding the visibility of well sites and their associated operations.[66,67] There have been reports and claims of equipment and machinery, pipelines, and access roads all interfering with residents' viewsheds.[68] As well site density increases in certain productive regions, greater quantities of these visual disruptions may be expected to appear, unless steps are taken to reduce their visual impact.

At the landscape scale, with shale gas development occurring on separate tracts of private land, there is risk of development occurring in an uncoordinated way that results in excessive impacts. These might include additional, unnecessary truck routes; the needless conversion of land to support oil and gas infrastructure; the resulting loss of wildlife habitat or agricultural land; altered landscape views; wear and tear on roads; and other sensory disturbances. To encourage more efficient development, several states have called for Comprehensive Development Plans (CDPs).[69,70] CDPs encourage a more holistic approach to unconventional shale gas development by considering the cumulative impacts to the landscape.

These issues are not the only community and landowner concerns. There are also concerns about the effects of oil and gas development on property values. Research on the property values in Pennsylvania and New York suggests both increases and decreases depending on specific property characteristics (groundwater- or piped-water), well-production history, and overall concentration of activity occurring at the same time.[71] Refer to the Public Health[72] and Public Perceptions[73] technical reports for further discussion of these and additional community impacts.

Before considering the laws and regulations in Michigan governing shale gas development and its associated community impacts, it is important to note that the State of Michigan's 2006 Zoning Enabling Act states that "a county or township shall not regulate or control the drilling, completion, or operation of oil and gas wells

TABLE C.2: AIR QUALITY IMPACTS – EXAMPLE APPROACHES	
EXAMPLE APPROACHES	SOURCE
ON-SITE EMISSIONS—MONITORING, TECHNOLOGY, AND REPORTING	
Michigan: Routine ongoing air sampling for oil and gas facilities not required; however, DEQ staff conducts on-site monitoring on a case-specific basis whether a specific air quality permit is or is not required. Michigan currently restricts flares in residential areas[45] and prohibits flaring of gas from Salina-Niagara wells,[46] but otherwise does not require specific technological interventions to manage air emissions. Permit holders are required to record and report all "reportable" losses, spills, and releases of natural gas and products/chemicals used in association with oil and gas exploration, production, disposal, or development.	
Require gas developers to reduce or eliminate "air emissions" during drilling and production, as well as to monitor and report air quality for pollutants regulated under the federal Clean Air Act or Arkansas law if: • Drill pad is within 1,000 feet of a habitable dwelling • Arkansas Department of Environmental Quality determines there is a reasonable risk of air pollution from multiple wells being located in the same area	Proposed Arkansas House Bill 1395[47]
Department of Environmental Quality required to provide air monitoring to residents who complain about air quality within 10 days	Proposed Arkansas House Bill 1395[48]
Operators required to test and monitor for fugitive emissions (specifically methane and VOCs)—which generally come from leaking valves or connectors—quarterly, and are required to develop and implement a leak detection and repair program	Ohio EPA rules[49]
Convert drilling rig engines at the well pad that are powered by diesel to another fuel source, such as dual-fuel, electricity, or natural gas	Center for Sustainable Shale Development performance standards[50]
Activities or materials (such as produced water tanks, etc.) that produce above 5 tons/year of VOCs and that are within 1,320 feet of a building must use an emissions control device and obtain a special permit from the Department of Public Health and Environment.	Colorado regulations[51]
All gas must be captured and put to a beneficial use (e.g., directed into a pipeline or used for onsite energy generation) unless it can be demonstrated that it would be technically or economically infeasible to do so.	Illinois law (Illinois Hydraulic Fracturing Regulatory Act)[52]
Any gas analysis that indicates the presence of hydrogen sulfide (H_2S) gas must be reported to the oil and gas commission and to the "local governmental designee."	Colorado regulations[53]
OFF-SITE EMISSIONS—PERFORMANCE STANDARDS, MANDATES, AND TECHNOLOGY	
Michigan: Michigan does not currently have performance standards, mandates, or technological standards beyond federal requirements for off-site air emissions associated with shale gas development.	
Trucks used to transport fresh water or well flowback water must meet EPA's Final Emission Standards for 2007 and Later Model Year Highway Heavy-Duty Vehicles and Engines for particulate matter emissions.	Center for Sustainable Shale Development performance standards[54]
All on-road vehicles and equipment must limit unnecessary idling to 5 minutes or otherwise follow local laws if they are more stringent.	Center for Sustainable Shale Development performance standards[55]
Operators must employ practices to control fugitive dust (e.g., speed restrictions, regular road maintenance, restriction of construction activity during high-wind days, etc.).	Colorado regulations[56]
Trucks must be required to use ultra low sulfur diesel for fuel.	Center for Sustainable Shale Development performance standards[57]

or other wells drilled for oil or gas exploration purposes and shall not have jurisdiction with reference to the issuance of permits for the location, drilling, completion, operation or abandonment of such wells." [74] The regulatory authority to issue such permits falls to the DEQ Office of Oil, Gas and Minerals (OOGM).[75]

However, this is not to suggest that local governments have no authority in regulating shale gas development. In fact, some communities have been aggressive in their use of zoning districts and special use standards to limit oil and gas processing, since the processing, refining, and transportation of oil and gas (at least in between the drilling site and a Michigan Public Service Commission regulated pipeline) is something over which local governments have authority.[76] Indeed, some interpret current statutes and Michigan law as enabling local governments to regulate certain community impacts, including hours of operation, noise levels, dust control measures, traffic, transportation, and other risks or impacts from shale gas development, under the police powers to regulate health, safety, and welfare.[77] It is important to note however, that this interpretation has not yet been tested in the courts and may or may not hold up.

In February 2015 the Michigan Supervisor of Wells issued instruction 1-2015 to address concerns about oil and gas development in highly populated areas. The instruction, which is not specific to

TABLE C.3: LANDOWNER AND COMMUNITY IMPACTS – EXAMPLE APPROACHES	
EXAMPLE APPROACHES	SOURCE
NOISE	
Michigan: The state lays the responsibility upon the site supervisor for preventing regular/recurring nuisance noise (and odor) in the exploration or development, production, or handling of gas.[84] Additionally, many local governments in Michigan have established maximum noise level thresholds (in decibels) for various municipal zones. The state does not formally require monitoring for ambient noise levels; however, if a site supervisor receives one or more complaints of noise, the supervisor may require the permit holder to collect decibel readings to determine the noise level. If a determination is made of a nuisance noise emanating from the well-site, the site supervisor may, at their discretion, require noise control measures. If this happens, then the permit holder must submit an abatement plan and schedule for implementation. Additionally, the state lays out several constructions standards for noise abatement, including requiring that compressor motors rated for more than 150 horsepower be completely enclosed, that the interior of the enclosure be lined with sound-absorbent material, and that the compressor drive motor be equipped with a hospital-type muffler.[85]	
Establish specific max decibel levels for residential/agricultural/rural, commercial, light industrial, and industrial zones (for instance, in Colorado, the limits range from 50 to 80 db between 7 p.m. and 7 a.m. depending on the zone)	Regulation or law in: Colorado[86,87]; Arkansas[88]; Farmington, New Mexico[89]; Arlington, Texas[90]
Restrict hours and times of operation to avoid or minimize conflicts	Maryland best management practices / recommendations[91]
Require a measurement of ambient noise levels prior to operation	Maryland best management practices / recommendations[92]
Require all motors/engines to be equipped with appropriate mufflers	Maryland best management practices / recommendations[93]
Construct artificial sound barriers where natural noise attenuation would be inadequate (also see Aesthetics strategy below)	Maryland best management practices / recommendations[94]
Require electric motors instead of diesel-powered equipment for any operations within 3,000ft of an occupied building	Maryland best management practices / recommendations[95]
LIGHT	
Michigan: The state has not established any formal requirements related to well site lighting; however, the OOGM will commonly impose permit conditions on lighting and screening, on a case-by-case basis.[96]	
Night lighting should be used only when necessary, directed downward, be shielded, and make use of low pressure sodium light sources when possible.	Maryland best management practices / recommendations[97] Colorado regulations[98]
TRAFFIC	
Michigan: The state does not have formal requirements related to trucking activities connected with shale gas operations.	
Site preparation, well servicing, truck deliveries of equipment and materials, and other related work conducted on the well site must take place between 7a.m. and 6 p.m.	Arlington, Texas regulation[99]
If the well is to be established within a "Designated Setback Location" (if it's within an established buffer zone, exception zone, or urban mitigation area), then it must include a traffic plan (coordinated with the local jurisdiction, if required) prior to commencement of move in and rig up.	Colorado regulations[100]
Operators must submit transportation plans, which could include proposed truck routes, trucks' estimated weights, evidence of compliance with weight limits on streets, a bond and excess maintenance agreement to ensure road repairs, evidence that intersections on proposed routes have sufficient turning radii, baseline assessments of road conditions, etc.	Regulation or law in: Collier Township, Pennsylvania[101] and New York[102]
Reduce the number of required truck trips by: • Making use of centralized pumps and impoundments with pipes, used to hydraulically fracture multiple surrounding sites ("centralized fracturing") • Installing temporary pipes to transport large volumes of water for short-term needs (such as HF)	Best management practices / recommendations[103]

TABLE C.3: LANDOWNER AND COMMUNITY IMPACTS – EXAMPLE APPROACHES	
EXAMPLE APPROACHES	SOURCE
AESTHETICS	
Michigan: Michigan currently has setback requirements for wells and facilities from occupied structures (300 feet in general[104] and 450 feet in townships over 70,000[105]), which are in part intended to address aesthetic issues.[106] Otherwise, there are no other formal requirements related to aesthetics or visual impacts connected with shale gas development or production activities.	
Production facilities that are observable from a public highway must be painted with uniform, non-contrasting, non-reflective color tones, matched and slightly darker than the surrounding landscape.	Colorado regulations[107]
Natural gas producers and operators are using large fences made of steel frames and neutral-colored fabrics to provide a buffer between equipment and ecologically sensitive or residential areas. The walls can help companies comply with the state's noise limits and are being considered for wildlife habitat where operations might otherwise interfere.	Practice in Colorado[108]
Natural gas producers can include "nuisance easements" as part of their lease agreements with landowners—offering them compensation in exchange for permitting specific nuisances, such as visual impacts, noise, light, or odors.	Practice in Pennsylvania[109]
ODOR	
Michigan: The state has established detailed regulations surrounding nuisance odors connected with wells that produce hydrogen sulfide, including requiring the permit holder to conduct numerical modeling to determine H2S concentrations in the air and empowering the site supervisor to require emission control measures for hydrogen sulfide. More generally, the site supervisor is also required to prevent regular or recurring nuisance odor in the exploration for or development, production, or handling of gas.[110]	
If a person who resides or works on a nearby property complains of an odor, the company must meet with the Township to establish an effective "odor control plan," and the operator must pay for investigative costs associated with assessing the odors.	Collier Township, Pennsylvania regulation[111]
Companies must take all precautions to minimize odors perceptible on property within 500 feet of the well-site while drilling and fracking.	Collier Township, Pennsylvania regulation[112]
OTHER	
Recently released guidelines help local governments better understand the socioeconomic impacts caused by energy development and support requests to industry and state government for assistance to implement appropriate mitigation. Guidelines cover population growth and worker residency patterns; employment, personal income, and local business effects; cost of living and housing; service, infrastructure, capacity, and revenue; and quality of life and other local concerns.	Headwaters Economics[113]
Encourage well operators to submit a CDP considering cumulative landscape impacts when they will either be drilling multiple wells within an area or when they know other operators will be drilling in the same area; future well permits that are covered by the CDP are offered priority processing.	Colorado voluntary rule[114]
Make a Comprehensive Gas Drilling Plan (CGDP) a prerequisite to receiving a well permit. Operators would be allowed to drill one exploratory well within a 2.5 mile radius, and a CGDP would be required for any additional exploratory or production. Plan would be subject to a mandatory public review and approval process.	Maryland best management practices / recommendations[115]

TABLE C.4: MICHIGAN OOGM STAFFING AND BUDGET, 2010–2014		
FISCAL YEAR *Ending Sept. 30 of the following year*	FULL-TIME EQUIVALENT	ANNUAL BUDGET
2010	60.0	$11,173,600
2011	60.0	$11,176,500
2012	61.0	$11,670,400
2013	61.0	$11,916,700
2014	61.0	$12,031,900

hydraulic fracturing or HVHF, applies where all of the following conditions exist: 1) the well site is within a county with a population of 750,000 or more, 2) the location is zoned exclusively residential, and 3) there are 40 or more structures used for public or private occupancy in any 90 degree quadrant within 1,320 feet of the well location. The instruction specifies a number of requirements regarding notification, noise, lighting, visual screening, safety, time restrictions, and groundwater monitoring, among other factors.[78] Despite the changes, concerns remain among some citizen groups that the instruction does not go far enough.[79]

Michigan also has several state laws in place to protect residents against nuisances, in particular noise and odor. In addition to extensive regulations detailing the proper treatment of hydrogen sulfide containing wells,[80] the state's oil and gas regulations prohibit the creation of a 'nuisance odor' during any phase of the shale gas lifecycle.[81] Michigan also requires that pumps or pump jacks located in residential areas either be powered by electricity or otherwise have powerful mufflers to reduce their noise.[82] The regulation specifically requires that the residential area must have been zoned so before January 8, 1993, and the pumps/pump jacks must have been installed after the effective date of the oil and gas rules.

Michigan more generally prohibits the creation of a 'nuisance noise' from the production, handling, or use of shale gas or brine, or any product associated with them.[83] While these regulations do not require action be taken if any complaints are received, it does grant authority for the site supervisor to require the permittee (i.e., the operator) to collect noise-level readings. The law also creates specific definitions for what constitutes a 'noise-sensitive area,' and what constitutes a 'nuisance noise.' Table C.3 lists a range of approaches for addressing landowner and community impacts.

C.5 AGENCY CAPACITY AND FINANCING

In most states, regulatory and oversight authority of hydraulic fracturing operations resides within state agencies, such as the DEQ and DNR in Michigan. At various points in time, agencies such as these, as well as others nationwide, have faced challenges related to their capacity to properly carry out their responsibilities.

In late 2013, the Office of the Auditor General for the State of Michigan conducted a performance audit for OOGM–the office within the state's DEQ that is largely responsible for shale gas wells and hydraulic fracturing operations. Their audit concluded that while OOGM was at least moderately effective at executing their responsibilities, there was room for improvement in a few key areas. First, the audit showed that OOGM did not complete field inspections of all well sites at the frequencies specified in OOGM policy and procedure. The number of wells that were inspected at the target frequency ranged from 31.5% (for producing wells) to 93.9% (for plugged wells).[116]

Next, the audit found OOGM to be moderately effective at promoting compliance with relevant regulations. The audit specifically examined two types of special agreements into which the OOGM enters: stipulation and consent agreements (SCAs) and transfer settlement agreements (TSAs). If a violation is reported or uncovered at a well site, SCAs give the permit holder of the well an opportunity to resolve the alleged violation by a specified deadline. TSAs allow the permit holder to transfer a violated permit to another party, while giving the new party a chance to fix the problem. The audit found that OOGM did not always enter into these agreements in a timely manner, nor did they always enforce all the terms–such as assessing fines and penalties. As a result, environmental concerns were allowed to exist for extended periods of time, and the OOGM neglected a potential revenue source (for instance, only nine wells in violation could have been assessed over $350,000).[117]

The audit also reported that the OOGM may not have pursued or resolved violations in a timely manner. Specifically, it found that OOGM did not always notify a well's responsible party of violations and that OOGM did not always conduct or document that it conducted follow-up inspections to confirm that violations had been resolved. In a related finding, the audit noted that the OOGM did not consistently document inspection and violation information in the Michigan Implementation of Risk Based Data Management System (MIR)—an automated system used to track violations and report results—or maintain hard copies of supporting documentation.[118]

The audit also revealed that current state law does not provide for bond amounts sufficient to cover OOGM's costs of plugging a well. In some instances, OOGM is responsible for stepping in and plugging a well, generally if it has been abandoned or as part of an enforcement action. To cover the costs connected with plugging nonproductive wells, permit holders pay a surety bond. However, current bond amounts do not sufficiently cover the costs, and OOGM itself may have to pay, potentially putting a strain on its financial resources.[119] Finally, the audit found a lack of inter-agency coordination. In particular, while the Michigan Department of Treasury is responsible for collecting a severance tax from shale gas producers or transporters, they do not know the total number of active wells, if production was being reported for all active wells, or the production totals reported to OOGM. Without this information, the Treasury could not properly ensure that severance taxes and privilege fees were accurately calculated. While the audit noted variances of less than 2% when they reconciled the production and sales totals provided to both agencies, they also noted that the two agencies did not coordinate any effort to reconcile gas amounts on a monthly, quarterly, or annual basis.[120] For all of these findings, the DEQ issued a preliminary response indicating that it agreed with the recommendations and providing additional information. For instance, OOGM noted that it was in the process of implementing electronic document management system and making other database upgrades that would help address some of the findings.[121]

Michigan has also been subject to external audits. In 2002 (before HVHF operations had commenced in Michigan), a multi-stakeholder organization known as STRONGER (State Review of Oil and Natural Gas Environmental Regulations, Inc.), which formed from the Interstate Oil and Gas Compact Commission (IOGCC), conducted a review of Michigan's oil and gas exploration and production wastes against a series of guidelines from 2000.[122] This review found that the DEQ had a well-managed oil and gas environmental regulatory program, which met, and in some instances exceeded the 2000 guidelines.[123] Some of the highlights of this review include the presence of a robust contingency plan, strong public participation, well-trained personnel, and thorough regulations concerning pits, tanks, and abandoned sites.[124]

Since Michigan's review, STRONGER has updated and expanded its guidelines. Guidelines specific to hydraulic fracturing were released in 2010 and revised in 2013, and guidelines for air quality programs related to oil and gas exploration were approved in 2014.[125] The newly published 2015 edition of the guidelines includes a new section on reused and recycled fluids and updates to a number of sections, including the hydraulic fracturing and NORM sections.[126] Of the 22 state programs that have undergone a review, 13 have had at least one follow-up review, including 7 that included hydraulic fracturing guidelines.[127]

A critical part of empowering state agencies to effectively manage shale gas operations and activities is ensuring that the needed funds are available for all of the agency's activities. Table C.4 shows the level of OOGM staffing and budget for the past several years.[128–132] Staffing and budget have remained essentially static, and Michigan thus far has seen limited HVHF activity.

In Michigan, the state receives revenue from gas extracted on its property in three main ways: royalties, fees, and taxes.[133] With a couple exceptions, royalties are calculated as a proportion of the gross revenue from the sale of gas (one-sixth of the gross revenue). The state also receives payments from producers for the right to explore and establish a well pad on state property. These are generally arrived at by auction and direct negotiation, and so do not have a set rate.[134] Additionally, the state receives payments for the underground storage of gas for later use. In Michigan, gas extracted from private land is subject to two income taxes: the severance tax and the privilege tax. The severance tax is fairly stable over time, since it is adjusted by statute (in 2012, it was 5%). The privilege tax is used primarily to pay for the regulation activities of the DEQ, and is adjusted annually (in 2010 it was 0.0029%).[135]

The funds collected through these taxes, royalties, and other fees go to different end uses. A large proportion goes to finance state land development, in the form of the Michigan Natural

Resources Trust Fund. This fund is intended to finance improvements on state-owned land to protect scenic areas and for recreational use. When the ceiling for this fund ($500 million) is reached, the remainder is allocated to the Michigan State Parks Endowment Fund, the Michigan Game and Fish Protection Fund, and the state general fund.[136] For additional information on the economics of hydraulic fracturing in Michigan, see the Economics Technical Report from an earlier phase of this project.[137]

Outside of Michigan, states vary in how they tax and otherwise generate enough revenue from shale gas development to ensure that communities are compensated for the infrastructure and other impacts that such development may have. According to the National Council of State Legislatures, as of 2012, 35 states had fees or taxes on oil and gas production. These severance taxes generally are calculated as a fraction of the market value of the gas, the volume produced, or some combination.[138] Taxes on the volume of gas produced are relatively simple to implement, but do not generally reflect price fluctuations in the same manner as value taxes. Value taxes–taxes on the market value of the produced gas–can be difficult to implement due to the close monitoring of the market that is required, and are generally applied at the point of production, before accounting for transportation and distribution costs.[139] To overcome the challenge of constant monitoring, states such as Colorado and Illinois instead tax the gross income from the produced gas.[140]

While severance taxes may currently be the most common form of taxation on shale gas development, certain states have opted to take different approaches. Pennsylvania, for instance, is the largest natural gas producer that does not impose a severance tax. Instead, it charges an impact fee on every producing gas well in the state, regardless of the volume produced.[141] For comparison, studies suggest that a 5% tax on production value would yield nearly $800 million for the state by 2015, while the impact fee will yield approximately $237 to $261 million.[142]

Several states have likewise been subject to audits from STRONGER and other agencies which have addressed hydraulic fracturing. Examples of how other states are facing the issues of agency capacity and financing are provided in Table C.5.

TABLE C.5: AGENCY CAPACITY AND FINANCING—EXAMPLES FROM OTHER STATES

REVIEW FINDING OR RECOMMENDATION	SOURCE
PENNSYLVANIA	
Review team commended PA Department of Environmental Protection (DEP) for increasing its staff levels to address additional permitting, inspection, and enforcement activities related to increased unconventional gas well development. Over 4 years, as unconventional gas well development increased in PA, the OOGM increased its staff from 64 to 202 employees. Permit fee increases enabled the DEP to expand staffing.	Pennsylvania – 2013 STRONGER report[143]
"DEP was unprepared to meet the challenges of monitoring shale gas development effectively." "DEP was unprepared to meet these [environmental and other] challenges because the rapid expansion of shale gas development has strained DEP, and the agency has failed to keep up with the workload demands placed upon it." "Although DEP has…raised permit fees and penalties so that it has the money to meet its mission, these efforts fell short in ensuring DEP was adequately prepared to monitor shale gas development's boom."	Pennsylvania – 2014 Commonwealth of Pennsylvania Auditor General report[144]
OHIO	
Reorganization and staffing changes – In July of 2000, the Division of Mines and Reclamation was merged with the Division of Oil and Gas into the Division of Mineral Resources Management (DMRM). Work assignments were shared among staff. More recently, DMRM decided to realign staff into the single program areas. The oil and gas program developed a realignment plan, with stakeholder input, that included an analysis of funding, staffing levels and priority workloads. This plan was used as a guideline in the development of SB 165. Comprehensive review and change of oil and gas law – DMRM conducted a thorough assessment of its oil and gas program since 2000, and as a result, they developed a plan, with stakeholder input, that included revisions to its regulatory program, addressing hydraulic fracturing, funding, staffing levels, and workload priorities, among other things. This plan was used as a guideline in the development of SB 165.	Ohio – 2011 STRONGER report[145]

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REVIEW PANEL SUMMARY REPORT + RESPONSE

Appendix D

D.1 REVIEW PANEL SUMMARY REPORT

DATE: **March 30, 2015**

TO: **Integration Team for the Hydraulic Fracturing in Michigan Integrated Assessment**
Maggie Allan, U-M Graham Sustainability Institute
Mark Barteau, U-M Energy Institute
John Callewaert, U-M Graham Sustainability Institute
Andy Hoffman, U-M Erb Institute for Global Sustainable Enterprise
Drew Horning, U-M Graham Sustainability Institute
Andrew Maynard, U-M Risk Science Center
Don Scavia, U-M Graham Sustainability Institute
Tracy Swinburn, U-M Risk Science Center

FROM: **Review Panel for the Hydraulic Fracturing in Michigan Integrated Assessment**
John Adgate, University of Colorado-Denver
David Burnett, Texas A&M University
Susan Christopherson, Cornell University
Michael Kraft, University of Wisconsin-Green Bay
Reagan Waskom, Colorado State University
Hannah Wiseman, Florida State University College of Law

SUBJECT: **Review Panel Summary**

This memorandum constitutes the summary report of the review panel for the Hydraulic Fracturing in Michigan Integrated Assessment Draft Report (draft IA report). It includes background information on the review panel process and its role in the integrated assessment (IA), and it provides a summary of the key strengths, areas for improvement, and additional items identified by the panel.

REVIEW PANEL BACKGROUND

To ensure a rigorous analysis of the topic, the Integration Team (see the IA plan[1] for details about the IA organizational structure and process) identified six subject area experts representing multiple disciplines to serve on a review panel, whose membership is listed above. As technical experts on the subject, the reviewers evaluated the credibility, rigor, and integrity of the assessment.

In January 2015 the panelists received the draft IA report and an individual review form. After preparing individual reviews of the draft IA report, panelists met in person at the University of Michigan and via teleconference on March 3, 2015 to discuss their reviews. The panel then developed this single written summary review of the draft IA.

Reviewers were reimbursed for travel expenses by the Graham Institute and received a $1,000 honorarium for their time. As with the overall IA project, the review panel efforts were funded exclusively with funds from U-M's Graham Institute, Energy Institute and Risk Science Center. Funding sources were limited to the U-M General Fund and gift funds, all of which are governed solely by the University of Michigan. All reviewers completed conflict of interest forms adapted from National Academy of Sciences materials stating they had no conflicts (financial or otherwise) related to their contributions to the IA.

Considering the review panel input and other comments, the Report Team will prepare the final IA report. Responses will be prepared to address major issues raised by the review panel and other comments received, and to explain how comments were utilized for the final IA report. All decisions regarding content of project analyses and reports will be determined by the IA Report and Integration Teams.

REVIEW PANEL SUMMARY

The review panel did not aim for consensus. Rather, the review summary was developed to reflect input from all of the panelists, including both jointly-held and divergent views. The following provides a high-level summary of the key strengths and areas for improvement identified by the group. Specific comments and edits from the individual reviews were provided directly to the report authors for consideration.

Key Strengths

Integrated approach

The panel agreed that a major contribution of the report is that it provides a wide-ranging, multi-criteria assessment of many issues associated with hydraulic fracturing in Michigan, and a framework for thinking about complex and controversial issues. From a sustainability perspective it is critical to think about whole systems, and therefore the panel praised the report for considering a number of factors, not merely technical and economic, but also environmental and social. Further, the panel observed that it is important to consider all aspects of the shale gas development process, including potential expansions in the scale of development enabled by high-volume fracturing. Although hydraulic fracturing has occurred for more than half a century, high-volume fracturing is a more recent development and creates new concerns beyond the wellhead, including, for example, liquid waste management.

[1] The IA plan is available at: http://graham.umich.edu/media/files/hydraulic-fracturing-ia-plan.pdf

The panel therefore praised the attention to aspects of the development process that extend beyond hydraulic fracturing.

The panel also noted that rather than presenting a narrow or one-sided argument, the report takes a step back in order to identify and assess a range of potential alternatives and their implications, and it abstains from taking positions and making recommendations about what the State of Michigan should do. Given that scientific uncertainties are always associated with these issues, the panel agreed that the report makes productive use of existing data to identify potential productive paths forward, including maintaining existing policies. The panel expressed a need for additional scientific research and data collection at the national and state level to reduce uncertainties, but noted that these uncertainties should not prevent states from considering or taking additional actions. The panel saw this systematic approach as a strength of the assessment, and noted that it provides a potential model for how other states can assess these issues.

Extensive background research

The panelists felt there was substantial effort and analysis in the report. They noted that the overall project provides a thorough assessment of Michigan's resources and conditions, and they emphasized the importance and value of the technical reports as the underpinning of the draft IA report. Given the extensive background data and pertinent information about hydraulic fracturing in Michigan that the technical reports contain, the panel suggested that additional referencing of the text and analysis from the technical reports within the IA report would strengthen the report and make the methods used clearer, thereby contributing to the analysis of policy options and helping to address topics not covered fully in the IA report itself.

Consideration of different state policies and approaches to uncertainty

The panel agreed that the report does an excellent job of surveying a useful cross-section of different state policies and considering novel approaches that could be taken in specific issue areas related to hydraulic fracturing. The panel acknowledged the limits of this approach, noting that it is not a results-based evaluation of different regulatory outcomes. However, some panelists noted that to the extent that identification of the full array of options is an important pre-requisite for comparing regulatory approaches, they hoped the report will support more informed regulatory evaluation, even beyond Michigan.

The panel noted that the report considers various regulatory options ranging from no-change in current policy to very demanding alternatives, and includes both command-and-control and market-based mechanisms (although the latter could be further emphasized). They agreed that the report's consideration of a range of options, combined with a framework for thinking about different regulatory approaches to uncertainty (e.g., adaptive and precautionary), is useful, and has not, to their knowledge, previously been fully considered in the shale gas context. The panelists noted that readers would benefit if the approach framework and terminology were introduced and more clearly explained earlier in the report.

It was pointed out that other states that have already experienced rapid gas shale development could provide examples of both successful and less successful policy actions.

Engagement process

The panel expressed support for the report process, including both the solicitation and consideration of public comment and the work with a multi-sector advisory committee that includes representatives from government, industry, and environmental organizations.

Public participation options

The panel recognized state agencies' deep expertise in oil and gas development developed through decades of regulatory oversight, but at the same time agreed that options in the report to improve public participation processes are strong and important to consider. Today's public is increasingly polarized over many issues and suspicious of government and new industrial practices, and has greater expectations of information provision and participation in decision making. In light of this, state agencies' reliance on a track record for regulating oil and gas activities in the past, or on traditional limited public hearings, is unlikely to suffice. Instead, states should be open to new, more sophisticated and inclusive approaches to public involvement. Maintaining public trust will require making information available in a format that is clear and understandable, including information about accidents or spills. Information provision alone is not sufficient, however, and states will need to demonstrate in more detail that they have the capacity and intention to deal with a wide range of concerns, including environmental, health, and socioeconomic impacts that go far beyond the wellhead.

Inclusion of the broader context and additional issues

The panel agreed that the issues discussed in Chapter 6 (e.g., climate change, effects on manufacturing, health impacts) and Appendix B (e.g., community issues, environmental impacts) of the draft report are important topics that merit inclusion in the final report. The sections provide valuable context for thinking about society's energy choices and acknowledge the wide range of issues that have arisen as hydraulic fracturing has expanded in recent years. The panel did not, however, agree as to where those topics should be presented and how they should be treated in the report (discussed in further detail below).

Areas for Improvement

The panel also had specific suggestions for improving the IA report to make it more accessible to the public and useful for decision makers. The following comments are offered in that regard.

Strengthen the executive summary

The panel stressed the critical importance of having a more effective executive summary that functions as a standalone interpretable document and makes the report findings clear and accessible. Suggestions included: emphasizing the comparison of policy alternatives, which was seen as a valuable contribution of the report; more clearly establishing what the report authors see as the hierarchy of concerns; and succinctly capturing the salient points from summaries at the end of each chapter. The panel agreed that the technical language in the body of the report is necessary for a complete and credible analysis, but noted that the executive summary should be written for a broad audience.

Include findings/conclusions

Panelists recommended consistently including summary findings/conclusions in each chapter. They noted this could improve the report's impact by helping readers identify the key points in each chapter, where the potential uncertainties lie, and ways to think about the issues within the larger context. This can be done while still remaining consistent with the report's overall objective to stop short of making recommendations. One option the panel suggested was to use a similar approach as used by the National Academies of Science that separates findings from conclusions.

Provide information about scale of future development

The panel recommended that the final report provide more information about the anticipated scale of future development because the extent and concentration of development are important factors for determining the potential impacts and what options to address those impacts might be. The panel acknowledged the challenge associated with this, given that the extent of development is affected by technological innovation, market conditions and economic feasibility, as well as the distribution of the resource.

Improve the policy analysis tables

The panelists noted that the policy option tables are helpful in the analysis of potential substantive regulatory approaches and valuable for readers wanting a quick understanding of tradeoffs, but expressed concerns with their current form. The panel discussed the need for improvements to the presentation and analytical structure, as well as the importance of completeness and objectivity, including adequate citation, explanation in the text, and recognition of uncertainties. One panelist suggested integrating the summaries into fewer and more informative tables.

Clarify the report scope

Panelists agreed that the scope of the report requires further explanation. While the report is extensive, it is not comprehensive, and there are issues that are not addressed or given equal scrutiny. At a minimum, the report should clarify whether the scope is strictly limited to hydraulic fracturing or more inclusive of other gas and development impacts, and reiterate the process determining which topics are included as focus areas, included but treated differently, or omitted. Additionally, the panel agreed it would be helpful to provide a clearer framing of the debate about what hydraulic fracturing means, what stages of oil and gas development it includes, and whether wells would be drilled but for hydraulic fracturing. Some panelists stated that they believed a focus only on the HVHF step in the development process does not communicate to the public the potential broad impact of gas development which includes, for example, development of related infrastructure such as pipelines and compressor stations.

A portion of the panel's discussion of the report's scope focused specifically on Chapter 6 (Broader Context) and Appendix B (Additional Issues). The panel agreed that while the material from both sections merits inclusion in the report, the current organization and differential treatment of the topics is problematic. There was, however, divergence of opinion on how to resolve this. One panelist suggested that both sections would be appropriate as appendices. Others suggested that the Appendix B material should be incorporated into the body of the report because it covers issues that, while not exclusive to HVHF per se, are certainly experienced in that context. Another panelist noted that, either way, the health assessment information in Chapter 6 would be more appropriately placed with the discussion of community impacts presented in the Appendix.

Panelists thought that draft IA did not adequately address air quality and public health. While included in Chapter 6 (Broader Context) and Appendix B (Additional Issues), those sections may not cover these topics in sufficient detail. There was an acknowledgement that the lack of substantive research on public health presents a significant challenge. One panelist noted that the main public health issues are air quality, traffic, and community impacts. Health risks around air quality include emissions from the development and production processes (episodic emissions from well unloading, etc.), VOCs that may contribute to ground level ozone formation, and health risks from air toxics - particularly when the activity is concentrated in a relatively small area. It was pointed out that air quality issues are being examined by both policy makers and researchers in the Western U.S. where such concerns are of paramount importance.

Additional Comments

Water quantity management and recycling and reuse

Panelists noted that the water withdrawal assessment tool (WWAT) might be a more sophisticated approach to water withdrawal management than what other states are using for hydraulic fracturing. At the same time, however, they expressed concerns with the WWAT, which uses a model that was not designed with this type of withdrawal in mind, has not been updated, and will need monitoring and continued validation to ascertain whether it is protective at the right level (neither overly lax or stringent).

The panelists expressed support for the inclusion of options related to wastewater recycling and reuse. They noted that the technology is improving rapidly, the associated costs and complexity are not that high, and it is important for states to be prepared for it. It was noted that responsible recycling and re-use of brines recovered after fracturing operations can mitigate impacts of water usage in well operations and reduce extensive truck traffic to and from well sites and remote disposal sites. One panelist expressed concerns, however, about the potential for environmental contamination that can occur when flowback water is stored on the surface and transported for reuse.

The panel had divergent opinions on the value of including an option requiring the use of Class I wells for wastewater disposal. Some viewed it as an acceptable highly protective (yet expensive) pathway to consider, which could drive recycling/reuse, but others stated it would be a prohibitive regulation, and that it is not clear whether it would have a better environmental outcome.

Chemical use

The panel was positive about the treatment of chemical disclosure, which acknowledges that disclosure is important, but recognizes that in the case of highly technical information disclosure alone does not guarantee that the public will understand the potential risks. Panelists also appreciated the inclusion of options limiting wells or chemicals used, as those options have received comparatively less attention than disclosure in the general discourse. One panelist, however, felt that there was not adequate attention given to siting/setbacks. The panel discussed concerns about the lack of uniform data on chemical use among the states and the limitations of non-uniform data collection and reporting. The panel expressed different opinions about FracFocus, the chemical disclosure database administered by the Groundwater Protection Council. These included the suggestion that state agencies consider using FracFocus as a basis for chemical disclosure regulatory compliance as well as concerns with the usability of the website.

Additional items

Panelists also recommended that the report:

- incorporate greater recognition of mineral rights and the potential conflicts between surface and mineral rights,
- make clearer the need for robust and transparent data on a range of issues (e.g., air quality, water quality, human health), and
- acknowledge associated infrastructure (e.g., pipelines, pump and compressor stations, etc.) have potential short and long-term impacts.

Conclusion

The panel hopes that the Integration Team and Report Team will find this review useful in developing the final IA report and, more generally, in supporting informed decision making around hydraulic fracturing in the state of Michigan.

D.2 RESPONSE TO THE REVIEW PANEL SUMMARY

This document is the response of the Hydraulic Fracturing in Michigan Integrated Assessment (IA) report team to the summary report of the review panel dated March 30, 2015. The report team thanks the review panel for their thorough review and salient observations. The IA aims to support informed decision making by providing an assessment of potential options for high-volume hydraulic fracturing (HVHF) in Michigan grounded in solid background research and strengthened by stakeholder engagement. The report team noted the review panel's support for the overall approach and considered their comments, along with those from the public and the advisory committee, for the final IA report. The following addresses the major issues the panel raised and provides information about how the comments were used for the final IA report.

Executive summary

The revised executive summary more clearly emphasizes the analysis of policy options for HVHF in Michigan in the areas of public participation (Chapter 2), water resources (Chapter 3), and chemical use (Chapter 4), which constitutes the key contribution of the full IA report. Additional background information from the technical reports was added to assist in making the executive summary an effective standalone document.

Findings/conclusions

Summaries are now included at the end of each of the three main chapters (Chapters 2–4) in order to emphasize the key points raised within the options analyses. Consistent with the overall purpose of the IA, these summaries do not provide recommendations.

Scale of future development

The scale of future development is an important factor in determining the potential effects of HVHF in Michigan; however, at this time there is not sufficient publicly available information or HVHF activity in Michigan to make accurate projections. The report provides an overview of activity to date in Michigan and notes it is likely to remain relatively low at current prices (Chapter 1), and it discusses different approaches to policy-making when faced with uncertainty (Chapter 5).

Policy analysis tables

The purpose of the policy analysis tables is to highlight key strengths and weaknesses of the options, not to present comprehensive or quantitative analyses. The overall structure of the tables was retained in order to guide readers quickly to strengths, weaknesses, and different types of considerations. Additional information was added to the analysis tables and chapter text.

Report scope and organization

The IA report primarily focuses on Michigan and HVHF, defined by State of Michigan regulations as well completion operations that intend to use a total volume of more than 100,000 gallons of primary carrier fluid. The report's main topical areas of public participation, water resources, and chemical use are directly relevant to HVHF wells, and they were identified based on review of key issues presented in the technical reports, 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 limits of this scope, however, are not absolute. The report incorporates the experience of other locations that are relevant to Michigan's geology, regulations, and practices, and considers implications for other practices and for different subsets of wells. The project also recognizes that there are broader and additional concerns associated with HVHF, hydraulic fracturing, and unconventional gas development more generally. The technical reports cover a broad range of topics related to hydraulic fracturing in Michigan, including general discussion of oil and gas and HVHF specifically. In the IA report, Appendix B considers the broader context around HVHF by providing an overview of issues important at geographic scales beyond Michigan and/or for unconventional shale gas development more generally. Appendix C discusses additional topics that are relevant at the state and local level and that, while not exclusive to HVHF, do occur within the context of HVHF wells and shale gas development more generally. This information was retained within the report but placed in the appendix to emphasize more clearly the report's key areas of analysis.

Additional comments

- Internal references were added to direct readers to health-related information in both Appendix B and Appendix C.
- Additional references to the technical reports were added to the IA report in order to strengthen the analysis of policy options and direct readers to additional background information underlying the final report.
- Chapter 3 provides a detailed discussion of rationale behind using the water withdrawal assessment tool for HVHF, despite its not being originally designed with those withdrawals in mind, and it presents a number of policy options aimed at updating and improving the tool in general and for HVHF.
- Options regarding wastewater recycling (3.3.6.3.2) and disposal in Class I wells (3.3.5.2.4) include the strengths and weaknesses identified by the review panel.
- Options considered for chemical use disclosure in Chapter 4 include using FracFocus and a state database. The ability to search and use the information is discussed.
- Additional weaknesses were added to the analysis tables to highlight negative impacts on mineral rights (e.g., 2.2.3.5 Moratorium on HVHF and 2.2.3.6 Ban HVHF).
- Throughout the report there are references to limited data and the need for additional research. Additionally, there are policy options in each of the main chapters that discuss collecting more data and ensuring data transparency and accessibility.
- Infrastructure associated with gas development has potential short and long-term impacts and is mentioned in Appendix C.
- Market-based mechanisms can be an effective approach to environmental policy approach. The analysis includes a number of such options (e.g., 3.2.4.2.3 modify fees for water withdrawals; 3.2.6.2.2 transfer/sell/lease withdrawals; 4.2 better information; 4.4 bonding and liability).
- The adaptive and precautionary policy framing presented in Chapter 5 was revised to highlight select examples of the different approaches from the options analyses, rather than presenting a strict categorization of every option.

D.3 REVIEW PANEL INDIVIDUAL REVIEW FORM

October 8, 2014

Hydraulic Fracturing in Michigan Integrated Assessment

Integrated Assessment Report—Individual Review Form

Overview

There is significant momentum behind natural gas extraction efforts in the United States, with many 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 energy independence and a cleaner energy supply. First demonstrated in the 1940's, hydraulic fracturing is now the predominant method used to extract natural gas in the U.S.

As domestic natural gas production has accelerated in recent years, however, the hydraulic fracturing process has come under increased public scrutiny. Concerns include perceived lack of transparency, chemical contamination, new techniques, water availability, waste water disposal, and impacts on ecosystems, human health, and surrounding communities. Consequently, numerous hydraulic fracturing studies are being undertaken by government agencies, industry, non-governmental organizations, and academia, yet none have a particular focus on Michigan.

In response to that gap, a unique partnership involving several University of Michigan units, industry representatives, environmental organizations, and state regulators has formed to examine the multiple aspects of this gas extraction technique, with an emphasis on impacts and issues related to high-volume hydraulic fracturing in the State of Michigan. Using an engaged problem-solving approach called integrated assessment, the project compiled a set of technical reports last year on key topics and is now preparing a draft analysis of policy options for Michigan. This draft analysis of policy options is called the Integrated Assessment (IA) Report.

Review Panel

To ensure a rigorous analysis of the topic, the Integration Team (see attached IA plan for details about the IA organizational structure and process) will identify subject area experts representing multiple disciplines to serve on a review panel of 5–7 participants. As technical experts on the subject, reviewers will evaluate the credibility, rigor, and integrity of the assessment.

Panelists will receive the draft IA report and a summary of public comments. After preparing individual reviews, panelists will meet in person to discuss their reviews of the draft IA report. The panel will then provide a single, final written summary review of the draft IA. Reviewers will be reimbursed for travel expenses by the Graham Institute and receive a $1000 honorarium for their time.

Based on the review panel input and other comments, the Report Team will prepare the final IA report. Responses will be prepared to address major issues raised by the review panel and other comments received, and to explain how comments were utilized for the final IA report.

Peer Review General Guidelines

Transparency. This stage of the process will involve a high level of transparency. Individual reviews by panelists (using the form below) will be shared only with other panelists, the Report Team, and the Integration Team. Reviewer's names will be associated with their reviews. The single final written review by the panel will identify all the panelists but not attribute comments to individuals, and it will be published with the final IA report.

Timeliness. Prompt reviews are important to all participants in this project. Please complete and return your individual review within four weeks of receiving it. This deadline will be in advance of the panel meeting so that these reviews can be shared with other panelists.

Objectivity. Your review should be objective. If prior connections with the authors or personal involvement with the subject matter would affect your objectivity, please alert John Callewaert (jcallew@umich.edu) at the Graham Institute.

Courtesy. Whenever possible, include constructive comments on how to improve the report. When negative remarks must be made, avoid sarcasm and insulting language. Criticize the report or the science, not the author of the report.

Individual Review Submission

All major individual comments should be addressed on the Individual Review Form provided below. Minor comments and corrections may be inserted electronically within the manuscript or itemized separately in the Individual Review Form. When possible, refer to the page and line number in the comments.

Panel Review Meeting and Written Review

Based on availability of review panel members, an all-day meeting will be scheduled at the University of Michigan in the winter of 2015. Individual reviews and comments on the draft IA report will be discussed and a single written review reflecting the views of the panel will be prepared within 2 weeks of the meeting. Graham Institute staff will assist with facilitating this meeting and preparing the summary review but the review will only reflect the views of the panelists.

INDIVIDUAL REVIEW FORM

REVIEWER'S NAME:

Points to Consider for the draft Integrated Assessment Report Review

1. PRESENTATION. Is the report written clearly and concisely, in a style and organizational structure that is easy to read and understand?

COMMENTS:

2. BACKGROUND. Is the purpose of the report adequately addressed? Are the objectives stated clearly?

COMMENTS:

3. METHODS. Are the methods (analysis of policy options) appropriate? Are they described in enough detail to permit others to evaluate the credibility of the work? Do you have suggestions for strengthening the methodology?

COMMENTS:

4. DATA. Were the data/information retrieved from credible, reputable sources? Should other types of data/information be included?

COMMENTS:

5. RESULTS. Are results presented in a straightforward manner? Are tables and figures well planned and used appropriately? Are there additional figures or tables that would have helped better illustrate the text?

COMMENTS:

6. SOUNDNESS. Are the methods, principles, interpretations, and conclusions based on current and sound scientific/legal knowledge? Based on your professional experience and the focus of the Integrated Assessment, is the discussion of the issue comprehensive? Should additional information or perspectives be considered?

COMMENTS:

7. CONCLUSIONS. Do the data/does the information support the conclusions? Is conjecture clearly identified? Is the level of certainty discussed clearly and appropriately? Based on your professional experience, are the policy options reasonable?

COMMENTS:

8. TECHNICAL ERRORS. Please correct any errors in terminology, spelling, punctuation, or grammar.

COMMENTS:

9. OTHER COMMENTS.

Thank you!

Questions about the review process may be addressed to John Callewaert (jcallew@umich.edu) Graham Institute Integrated Assessment Center Director. Please return review form as an email attachment to John Callewaert (jcallew@umich.edu).

PUBLIC COMMENT SUMMARY + RESPONSE

Appendix E

Stakeholder input is an important part of any Integrated Assessment (IA) and has been a key component of this assessment. Key points of stakeholder engagement have included the following:

- An online comments/ideas submission webpage (http://graham.umich.edu/knowledge/ia/hydraulic-fracturing/comment) was established in the fall of 2012 at the start of the project to direct public input to the teams working on the IA, and it will remain open until the IA concludes in the fall of 2015. At this time, a contacts database for the project includes more than 1,000 individuals from primarily Michigan, but also other states and Canada, and from a variety of sectors: state government, nonprofit organizations, business associations and industry, federal agencies, academia, consulting firms, and the general public.
- During the preparation of the technical reports, the Graham Institute convened a meeting in Lansing, Michigan on March 5, 2013 to present research plans to nearly 100 decision makers and stakeholders.
- A public webinar was held on September 6, 2013 following the release of the technical reports.
- More than 200 comments were received following the release of the technical reports. They were carefully reviewed, organized, and shared with the technical report authors, Integration Team, Report Team, and Advisory Committee to aid in developing the IA plan.
- A public webinar was held on February 26, 2015 following the release of the draft IA report.
- Summaries and recordings of these public events can be found at: http://graham.umich.edu/knowledge/ia/hydraulic-fracturing.
- Public comments on the draft IA report were collected through a publicly available web-based form and through direct solicitation of experts who represent a balanced mix of sectors with significant expertise and interest on the topic (e.g., industry affiliates, environmental organizations, academics, policymakers). More than 150 comments were received through these methods. As with the technical reports, these comments were carefully reviewed, organized, and shared with the technical report authors, Integration Team, Report Team, and Advisory Committee to aid in finalizing the IA report. A summary and response for some of these comments is included below. This is not an exhaustive list of all the comments but addresses key themes and comments identified through this process. Specific questions about comments that were submitted during the process can be directed to: grahaminstitute-ia@umich.edu.

Questions about the number of chemicals used in hydraulic fracturing.
A March 2015 U.S. Environmental Protection Agency report is now cited for general information on this topic. Following a national review, the report states that nearly 700 chemicals are used with an average of 14 per completion.

Concerns about the characterization of water volumes used for high volume hydraulic fracturing (HVHF) completions and bias in reporting that a completion in Michigan used over 20 million gallons of water.
A 2012 well completion required 21.2 million gallons, and there are multiple HVHF permits in Michigan noting ~20 million gallons of water, many of which required a site-specific review. See http://www.michigan.gov/documents/deq/deq-oogm-HVHF-waterwtith2014_458288_7.pdf. Activity in Michigan is too limited at present to suggest an average volume of water for HVHF.

General concerns about climate impacts.
See Appendix B for a discussion of the literature on this topic.

Suggestion that the option to develop a multi-stakeholder advisory commission to study HVHF impacts and identify best practices for mitigating them should include a public engagement component.
This option was revised to include public input.

Suggestion that full permit applications be available online for public review.
This idea was added to the discussion of option 2.4.3.2 Increase notification of permit applications.

Calls for greater input from neighboring property owners.
Each of the policy options chapters address options for more input, and Appendix C provides additional information on landowner and community impacts.

Concern about some options being presented as recommendations suggesting a lack of objectivity.
Multiple statements are provided throughout that the report is providing an analysis of options, not recommendations, and additional modifications were made to the report to further clarify this.

Suggestions to include additional information regarding the position of certain groups on the topic of HVHF.
Examples of changes made to the report include adding the names of groups which oppose a ban on HVHF and revising the list of groups which support a ban.

Multiple comments in support of policy options regarding water withdrawals.
Noted.

Concern that the section on wastewater management presents human health impacts from produced water as fact, when human exposure to produced water is rare, even for oil and gas workers, and the potential consumption of produced water, as is suggested, is a vanishingly low risk.
This statement has been changed to indicate the possibility of health risk.

Question about the relevance of a study on Class I injection wells.
Clarification added to text that the study was referring to Class I wells and that Class II wells in Michigan have had a history of no failures.

Concern that the draft IA does not properly reflect DEQ's efforts to assume primacy for the regulation of Class II wells in Michigan.
The text was updated to reflect this activity.

Comment that equating HVHF with agricultural withdrawals is not a good comparison.
The report does not seek to equate them, but to compare them.

Disagreement with the statement that information on ecological and/or health risks posed by chemicals used in HVHF is limited because the majority of those materials are widely used and their fate and effects in other applications are well known and directly transferable to HVHF applications. Agreement that scientifically sound studies, which industry is actively engaged in efforts to develop, would help to validate these conclusions for HVHF-specific situations.
The reports' statement is based on the cited references. The text now includes a citation to EPA's draft external report, recently released, which notes that hazard information is not available for the majority of chemicals used in hydraulic fracturing fluids, representing a significant data gap for hazard identification.

Comment that the general protection of intellectual property rights, including valid trade secrets, is important to foster innovation. Innovation in the area of hydraulic fracturing has been critical to the success of shale gas development, and has resulted in the introduction of products that improve production and make it more efficient as well as products that offer significant environmental benefits (such as products that facilitate the recycling of flowback and produced water). Therefore, trade secrets associated with hydraulic fracturing should not be treated differently than in other industries. The suggestion that trade secret protection for chemicals used in hydraulic fracturing should be "very narrow" is unfounded and wholly inconsistent with well-established protections for trade secrets in Michigan. In addition, the report should recognize that trade secrets regarding hydraulic fracturing fluids are generally the property of product suppliers and service companies, not operators.
The trade secret paragraphs have been revised to clarify the treatment of trade secret claims, and the associated weaknesses are listed in the tables.

Comment that the report fails to acknowledge that a description of chemical constituents and alternatives may contain trade secret information that could not be made publicly available on the state's website. Moreover, any requirement to list chemical alternatives would probably be of little utility to the public and would create significant potential for confusion and misunderstandings given the many factors that go into designing a hydraulic fracturing fluid system. Again, the focus on chemicals used in hydraulic fracturing is misplaced given the lack of any evidence of significant human exposure to these chemicals.
The sentence has been revised to exclude trade secret information. We do not agree that the alternatives would be of little utility to the public.

Assertions that policies or rules should inform and protect the public to the greatest extent possible.
The options analyzed in the report range from no-change in policy to very demanding alternatives. The analyses identify key strengths and weaknesses of the different approaches, but it is not within the scope of the work to recommend policy options.

Suggestion to add technologically-enhanced, naturally-occurring radioactive materials (NORM) as a "policy area."
According to the Geology/Hydrogeology technical report, NORM is unlikely to be an issue in Michigan.

Concern that an adaptive approach (one in which "states continually collect information so that over time they can better understand risk and refine their HVHF policies") assumes that the DEQ has the resources and inclination to carry out ongoing and systematic analyses—something that is not readily apparent currently and may be a potential weakness of this approach.
A sentence was added that goes to this point.

Suggestion that bond levels should be increased for all wells in the state, whether or not they are hydraulically fractured
This report focuses on HVHF, and options in Chapter 4 address bonding for those wells

Observation that no cost estimates are provided for the additional areas of study identified in Chapter 6.
This is beyond the scope of the report.

Comments that natural gas is still a fossil fuel with negative environmental impacts and more development is needed in "complementary" green energy technologies like solar and wind.
Appendix B includes a discussion of the relationship between natural gas and renewables.

Questions about why the U.S. would export natural gas if the development of domestic energy sources were intended to reduce dependency on "foreign oil."
Appendix B explains that expansion in exports is motivated by the price difference that makes exports profitable for industry, and that that there are net benefits to exports.

Comment that Appendix B relies primarily on more bullish predictions of the impact of natural gas on the economy, with only minor hints that other opinions exist, and is missing any discussion of the rapid drop-off in production from HVHF wells and the degree to which companies are on a "drilling treadmill" in order to maintain production.
The section was reworked to better clarify upfront that there are significant concerns with those economic projections and estimates. While significant, changes in the lifetime recovery of shale gas wells and effect on companies' long-term sustainability is beyond the scope of this section.

Concern that not all deficiencies identified in the 2013 Office of Oil, Gas, and Minerals (OOGM) audit are summarized, including finding 4 which notes deficiencies in OOGM's tracking of violations. Numerous places in the IA discuss an increased role for the OOGM, and the OOGM is currently in the process of expanding their responsibilities by assuming primacy for the regulation of Class II disposal wells in Michigan; if the OOGM lacks the staff, information systems, and funding to do their present job, it is difficult to see how they can take on additional responsibility.
Finding 4 was added, as well as specific mention of the technology upgrades OOGM planned to address a number of the findings. An assessment of the current or future capacity of the OOGM is beyond the scope of this appendix and the IA report more generally. Increased administrative burden is noted for some of the policy options presented in the report.

Assertion that the 2002 State Review of Oil and Natural Gas Environmental Regulations (STRONGER) audit of Michigan's oil and gas program, which used guidelines that did not address hydraulic fracturing specifically, is not relevant and the report should include the benefits of another STRONGER audit which considers the unique characteristics of HVHF wastewater.
Another paragraph was added to describe the updates to STRONGER's guidelines since Michigan's 2002 review. It also notes the number of states that have had, or have scheduled, follow-up reviews including those specific to hydraulic fracturing.