Vermont Groundwater Management Plan
2018

The groundwater of Vermont is a *precious, finite, and invaluable resource* upon which there is an ever-increasing demand for present, new and competing uses
10 V.S.A. 48 §1390

Statutory Tasks (10 V.S.A. 48 §1392)

The Vermont legislature created Title 10, Chapter 48 to protect groundwater, set the policy for the management of groundwater, regulate its withdrawal as a public resource for the benefit of the people of the state, and minimize groundwater quality deterioration by regulating activities that pose a risk. This management also requires the balancing of the state's groundwater policy with the need to maintain and promote a healthy and prosperous agricultural community while holding groundwater resources in trust for the public. To that end, the Secretary has been charged with the duties described below:

> *The secretary shall develop a **comprehensive groundwater management program** to protect the quality of groundwater resources by:*
>
> 1) *developing a **strategy** for the management and protection of the state's groundwater resources;*
> 2) *continuing **studies** and investigations of groundwater in the state;*
> 3) *cooperating with other government agencies in **collecting and compiling data** on the quantity and quality of groundwater and location of aquifers;*
> 4) ***identifying and mapping** groundwater currently used as public water supply sources and groundwater determined by the secretary as potential future public water supply sources;*
> 5) *providing **technical assistance** to municipal officials and other public bodies in the development of regional or municipal plans or bylaws, the purpose of which is the protection of groundwater resources;*
> 6) *classifying groundwater resources according to the provisions of this chapter and **adopting technical criteria and standards** for the management of activities that may pose a risk to their beneficial uses;*
> 7) ***integrating** the groundwater management strategy with other regulatory programs administered by the secretary;*
> 8) *developing **public information** and education materials; and cooperating with federal agencies in the development of programs for **protecting** the quality and quantity of the groundwater resources.*

The following Groundwater Management Plan (GMP) is intended to be a dynamic document, containing measurable actions over both short and long-term timeframes. These actions have the goal of providing forward progress within the eight proscribed tasks above. As our knowledge of groundwater increases, new technologies are developed, and new challenges arise, the goals and action items of this plan will need to be thoughtfully reevaluated. The expectation is that this GMP will be assessed annually and updated regularly, but no longer than once every five years.

This Plan was developed by Scott Stewart, Chair and Kasey Kathan, Co-Chair of the Groundwater Coordinating Committee with valuable input provided by the committee members. The members (listed in the appendix) are a diverse knowledgeable group including representatives from EPA, USGS, Vermont Rural Water Association, consulting hydrogeologists, engineers, advocacy groups and the public. The initial stages were based on previous surveys of members to identify topics of concern, and discussions at the monthly meetings. Additional input was gathered from Drinking Water and Groundwater Protection staff. We want to thank all those who helped shape this Plan with their insights, expertise and critical review.

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Introduction: Vermont's Groundwater

Nationally, groundwater is the primary source of drinking water for about half of the population; however, approximately 60% of Vermonters are currently using groundwater for drinking water. This unseen, and often forgotten resource also replenishes rivers, lakes and wetlands, particularly during dry periods, helping to sustain and support Vermont's healthy ecosystems.

A key component of the hydrologic cycle, groundwater resides within Vermont's bedrock, fractures within the bedrock, and within the voids or pore spaces between particles of soils, sediment and loose rock. The geologic processes of mountain building and glaciation that produced the landscape of our Green Mountains also developed three primary zones that can store and yield groundwater within Vermont. Simplified, these aquifers consist of:

1. stratified drift deposits – sand and gravel that was sorted by glacial meltwaters;
2. till – dense, unsorted materials, mostly clays and boulders deposited by the glaciers and;
3. bedrock – fractured and crystalline, often highly altered due to our geologic past.

In terms of their ability to produce water, the stratified drift deposits are the most favorable for development of large volume water supply wells. But, these deposits are limited in size and distribution and cover less than approximately 11% of the state. Till does not generally yield large quantities of water, but rather due to a high clay content and limited pore space availability, acts as a confining layer slowing the movement of groundwater while also providing considerable storage to underlying bedrock aquifers. Bedrock underlies the entire state, but the fractures that store and transmit groundwater within bedrock can be small or discontinuous. Quantities of water sufficient for use require interconnected fractures and bedrock aquifers in most areas of Vermont only have enough available groundwater to supply single family homes and small businesses. Less common, but very desirable, higher yielding aquifers commonly serve, commercial, industrial, agricultural, and public system uses (e.g. municipalities, schools, and restaurants).

Groundwater is intricately connected to surface water and wetlands, essentially serving as a single resource. Groundwater flows away from areas of high pressure and elevation. As the groundwater moves in the subsurface it can feed into and receive water from streams, rivers, lakes and wetlands. Nearly all surface water interacts with groundwater in some capacity and as this happens, surface and groundwater can transfer qualities and quantities from one to another. The ability for small streams to maintain some flow during dry periods and droughts comes from steady and reliable groundwater discharge, and groundwater aquifers also serve as storage areas during flooding events helping to minimize impacts. Groundwater also carries important solutes from the earth's subsurface to surface water while the recharge of groundwater from surface water provides the opportunity for pollutants to become bound in the sediments and filtered from the water. This link between groundwater and surface water may seem intuitive, but it is often poorly considered in management decisions.

Groundwater exploitation has risen in tandem with competition for our surface water resources. This along with increasing pressures from development and climate change can have long lasting consequences that will propagate through the environment with time. It is essential that groundwater be more thoroughly investigated and considered, not only in its own right as a valuable resource in need of management and protection, but also as part of an integrated systems approach to understanding and preserving Vermont's environmental health.

The protection of Vermont's groundwater is an issue of concern at local, regional, state and federal levels; however, it is often only carefully considered during problematic times, such as drought or serious groundwater contamination. As an unseen resource, however, consistent monitoring and evaluation of both the quantity and quality of the state's groundwater is necessary to understand the resource and implement effective management.

Quantity

Fluctuations in rain and snow volumes have direct consequences on recharge of our groundwater supplies. The frequency of extreme weather events has increased in recent years (Melillo et al., 2014), and these extreme events of both drought and intense precipitation, have implications for the sustainability of Vermont's groundwater resources.

Our management and infrastructure must be able to adapt and accommodate these changing weather patterns and corresponding changing groundwater resources to remain resilient.

Quality

Historically, many of the contaminants impairing water resources and impacting groundwater quality were significant, visual and of urgent environmental or human health concern. While pollution awareness and preventative action may be higher than it has been in the past, many of the emerging groundwater contamination issues are often more difficult to detect and remediate.

Comprehensive studies regarding the quality of Vermont's groundwater are limited and will need expansion to successfully address the complex issues that are likely to be a concern in the future.

A significant drought in the mid-1960s spurred Vermont to begin evaluating the availability and sustainability of groundwater resources, particularly within sand and gravel aquifers. In 1965 10 V.S.A. Chapter 48 was adopted, which required licensing of well drillers and submission of well completion reports to the state. Over the years 10 V.S.A. Chapter 48 has been incrementally expanded, with added requirements to protect groundwater resources (regulation of water bottling operations, permitting of groundwater withdrawals, etc.), but it saw the greatest development when the legislature applied a public trust doctrine to the state's groundwater resources.

Public Trust and Statutory Authority

In 2008, the Vermont legislature amended Chapter 48 to designate groundwater as a public trust resource by enacting 10 VSA §1390. This public trust doctrine requires that Vermont, through the Agency of Natural Resources, act as steward of the state's groundwater and regulate use and impact to groundwater in a way that preserves the natural resource with all Vermonters, present and future, as the beneficiaries.

This effort was a proactive attempt to provide long-term protection for both the quality and quantity of the state's groundwater. This plan, in conjunction with the adopted Groundwater Protection Rule and Strategy (GWPRS), demonstrates the value that Vermonters place on their groundwater. However, there is still progress that can be made towards fully implementing the policy, integrating it with sound science, and continuing to make progressive actions targeted at protecting groundwater.

The four goals for groundwater management declared within 10 VSA §1390 are briefly summarized as follows:

1. Withdrawal of groundwater should be regulated in a manner that benefits the people of the state;
2. The state shall protect its groundwater resources to maintain high-quality drinking water;
3. Groundwater resources shall be managed to minimize risks to groundwater quality deterioration; and
4. Groundwater resources are held in a trust for the public.

The Groundwater Protection Rule and Strategy is a key component of groundwater management and protection as a public trust and aims to meet the requirements of the four goals from 10 VSA §1390. The rule provides the framework and requirements that all other Department of Environmental Conservation rules must attain to ensure adequate protection of groundwater as a public trust both by minimizing potential for contamination and restoring high-quality drinking water if contamination has occurred. Last substantially updated in 2005, the GWPRS is

managed by the Drinking Water and Groundwater Protection Division (DWGPD) and is under substantial revision to clarify the standards that other DEC rules must attain to implement the public trust doctrine and the actions to be taken at contaminated locations to restore high-quality drinking water.

The purpose of this Plan for Groundwater Management differs substantially from, but is meant to compliment, the GWPRS. The GMP is intended to describe a pathway towards fulfilling the requirements described by 10 VSA §1392, as highlighted in the charge at the beginning of this document. The broad scope of these duties, tasked to the Agency of Natural Resources, serve to provide guidance on the prioritization, context and approach that should be taken above and beyond regulation. This will provide sound science for better management decisions and integrate education and consideration of groundwater as a natural resource whenever our decisions and actions have a potential for impact.

Although achieving these goals has been tasked to the Agency of Natural Resources, particularly the DWGPD, it is important to keep in mind that maintaining groundwater sustainably can only be completed in collaboration with partners, individuals, businesses and other private sector institutions. As such, the expectation is that these partners and parties will engage with the Agency, not only in the development of this Plan, but also in its continuous reevaluation and assessment of its relevancy given the changing issues facing groundwater management within this state. The Groundwater Coordinating Committee is an additional partner in this work and was established as part of the Chapter 48. The Groundwater Coordinating Committee was established by legislature to serve as an advisory group to the Secretary and provides a forum for input by various stakeholders and as such should be a primary voice in the creation and implementation of this Plan.

Current Groundwater Use

Groundwater use and withdrawal in Vermont is only regulated through permitting of Potable and Public water sources and large (>57,600 gallons per day (GPD)) commercial and industrial withdrawals. While it is reasonable to assume that there is a sufficient supply of groundwater for our current uses, the impacts of groundwater withdrawal are not regularly or systematically evaluated.

Much of what we know about the use and impact of groundwater within the state is based on estimates, primarily from a report by the U.S. Geological Survey (Medalie and Horn, 2010). It should be noted that the thermoelectric power withdrawals reported within the 2010 study are largely attributed to use by Entergy Vermont Yankee which ceased operations in 2014, thus current surface water withdrawals are reduced from the earlier estimates. Additionally, the closure of Entergy Vermont Yankee has significantly shifted the ratio of surface water to groundwater withdrawals within the state, further emphasizing the general importance of groundwater resources for water use within Vermont (Figure 1).

Table 1: Groundwater withdrawals in Vermont

Withdrawn from VT groundwater for: *(Medalie and Horn, 2010)*	
Domestic Consumption	23 million GPD
Community Water Systems	15 million GPD
Fish Hatcheries	5 million GPD
Commercial and Industrial Use	4 million GPD
Agricultural Use	3 million GPD
Thermoelectric Power	0.5 million GPD
Total estimated groundwater withdrawals	**50.5 million gallons per day**
Percentage of Vermonters dependent on groundwater for drinking water	60%
Percentage of farms dependent on groundwater for agricultural purposes	85-90%

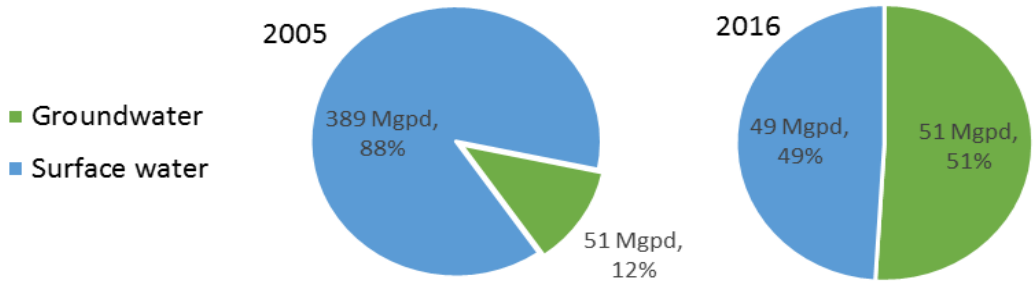

Figure 1: Percentage of Vermont water withdrawals from groundwater and surface water in millions of gallons per day. Estimate prior to (2005) and following (2016) the decommissioning of Entergy Vermont Yankee shows a significant shift in the ratio of surface to groundwater withdrawals. (Medalie and Horn, 2010)

Current Groundwater Management Structure

Much of Vermont's direct management, through regulation, of groundwater currently focuses on:

A) maintaining safe drinking water; and
B) regulating activities or land uses that may, or are, acting as a threat to groundwater.

A. Maintaining Safe Drinking Water

Despite over 60% of Vermont's population dependent upon their private wells and springs, our understanding is inherently limited regarding the quality of groundwater being consumed by many Vermonters. Single family homeowners are not required to have their water quality tested; however, it is recommended that private water supplies be tested every one to five years for bacteria, inorganic chemicals and radiation. The presence of naturally occurring contaminants may impact even the most rural and 'pristine' water supplies, and changes in water quality will often be undetectable to the user. Notwithstanding these recommendations, and the potential health implications of consuming contaminated water, the Vermont Department of Health (VDH) estimates that only 5% of homes on private water supplies have utilized the water testing program provided through the VDH Laboratory. The number of private supplies tested is likely higher, due to private labs also providing analytic services, but it is evident that only a small percentage of Vermonters drinking water know the quality of the water they are consuming from private supplies. Even when tested, it is likely that Vermonters are not testing their water frequently enough to remain informed of changing conditions.

Potable water supplies that are not serving single family homes (e.g. subdivisions, public buildings serving fewer than 25 people), are required to have the water quality tested as part of getting a permit; testing covers arsenic, nitrate/nitrite, total coliform, uranium and secondary contaminants. Additionally, public sources (Table 2; community and non-community) are routinely and systematically evaluated for a broad suite of analytes. Together, this testing program provides a limited view of the status of Vermont's groundwater quality (Table 3). It should also be noted that significant research has been completed by the Vermont Geological Survey (VGS) and partners attempting to characterize groundwater quality in targeted regions where natural contamination is significant. This research further serves to inform both public and private water supplies as to the type of testing that is recommended and potential treatment that is likely to be necessary upon installation of a water supply.

Table 2: Types of water systems, excluding domestic potable systems

(as of January 1, 2017)	**Active**	**Inactive**	**Proposed**
Community (serving over 25 residences year round or having 15 residential connections)	417	76	10
Non-Transient Non-Community (serving 25 or more of the same people more than 6 months per year) (e.g. schools, factories)	244	76	11
Transient Non-Community (serving 25 or more different people more than 60 days per year) (e.g. restaurants, hotels, campgrounds)	718	243	40
Vermont Based Water Bottlers	6	4	0
Industrial-Commercial Withdrawals	15	0	0

Table 3: Select Indicators of Vermont Drinking Water Quality

(as of 2016)	
Number of Public Water Systems Receiving Boil Water Notices	55
Number of Public Water Systems with Maximum Contaminant Level (MCL) Exceedances	61
Percentage of private water supplies tested through the Vermont Department of Health private well sampling program	5%
Number of Public Water Systems with treatment for listed contaminants:	
Arsenic	7
Radium	5
Uranium	5

B. Risk from Potential or Actual Sources of Groundwater Contamination

The vulnerability and susceptibility of groundwater to contamination depends both on the aquifer characteristics and the nature of land-use activity which has the potential for impairment. The GWPRS categorizes specific regulated activities as having high or moderate potential risk to groundwater and places limitations on the location and regulation of these activities appropriate to the risk level. The GWPRS also establishes Groundwater Enforcement Standards (GES) for contaminants of concern. Exceedances of a GES at the location of a permitted activity then requires implementation of specific actions such that the contamination is documented, monitored, remediated, if needed, and provisions can be made to protect human health and the environment.

Table 4: Examples of activities that may pose a risk to groundwater

(as of January 2017)	
Number of Active Hazardous Sites	1,284
Average number of new spills reported every year	650
Number of Open Solid Waste Landfills	2
Number of Indirect Discharge Disposal Systems	215
Number of towns with completed geologic surveys where contaminant concentrations exist for arsenic, fluoride, nitrates and/or radioactivity	52

Table 5: Estimated number of potential hazardous sites requiring groundwater reclassification

	Factors Influencing Prioritization						
Reclassification Priority	Plume is Easily Defined	Bedrock Aquifer is Contaminated	Municipal Water Hookups Available	Contamination is Recalcitrant (>10 years of exceedances)	Contamination has Moved Offsite		Estimated # of Sites
Highest ↓ Lower	X		X	X	X		1
	X	X		X	X		10
	X			X	X		235
		X		X	X		55
				X	X		10
		X	X	X	X		5
				X			40
	X		X	X	X		100
	X				X		75
TOTAL							**531**

Management Considerations

1. Surface water and groundwater need to be effectively managed as integrated resources.
    a. Groundwater originates from and contributes as base flow to and storage for surface water.
    b. Changes in surface water flow can affect groundwater levels or quality.
    c. The legal system and our ANR regulatory programs generally consider surface water and groundwater management separately.

2. Groundwater quality and quantity are interdependent and need to be considered in an integrated manner.
    a. Groundwater may not be usable because of contamination either from natural or human sources.
    b. Monitoring and evaluating groundwater quality provides managers with necessary data for sound decisions.
    c. Numerous state programs monitor different aspects of groundwater quality.

3. Land use decisions can affect quality and quantity of groundwater.
    a. Little may be known about the location of regional or local recharge areas and discharge areas.
    b. Protection and preservation of recharge areas needs to be incorporated into land use decisions.

4. Groundwater science is more challenging given that the resource is not directly observable.
    a. Known points of data are essential to enabling interpolation and extrapolation.
    b. The completion of groundwater investigations independent of regulatory activities is vital to making effective long-term management decisions regarding the sustainability of groundwater use within the state.

5. Funding to assist in state and local groundwater management and expand groundwater investigations is currently limited.
    a. Funding should be increased for additional studies, hiring staff and use of contractors for specific projects.

6. Few mechanisms are in place to support and encourage coordination of groundwater management and protection efforts within groundwater basins. Vermont's surface water tactical basin plans may provide a good framework for a similar approach for groundwater management.

Objectives

The primary goal of this Plan for Groundwater Management is to:

> Make actionable suggestions that work towards ensuring groundwater resources are sustainable in both quantity and quality and that groundwater use does not harm water quality or the ability of future Vermonters to have access to groundwater resources.

To accomplish this goal, three broad objectives (A-C) have been identified, namely:

- improve information available for groundwater management decisions,
- protect public health and the environment and,
- expand communications.

The development, revision and fulfillment of tasks within this document fulfills the requirement to develop a plan for groundwater management as described in task 1. The statutory tasks (2-8) in the charge of this document are grouped within these three objectives.

In the remainder of this document you will find a narrative description of the work that has previously or is currently being completed within each of the tasks. This work builds the foundation for moving forward and completing the work proposed within this Plan. Following the narratives, the appendix of the document includes implementation plans for each of the tasks. These implementation plans identify specific measurable actions and generalized timeframes for completion. These task implementation plans are each organized as Gantt charts such that progress towards completion can be regularly documented and evaluated as part of the annual review of the success of implementing this plan.

It should be noted that a significant milestone for many of the actions is obtaining staff resources or funding to support completion of the action, and as such the timelines included within this document are likely to change dependent upon achieving that milestone. Much of the funding and staff resources are needed to add a component of systematic monitoring, assessment and planning to the management of groundwater within the state. Historically, groundwater management has occurred through regulatory programs. However, without fundamental monitoring and assessment of indicators pertaining to groundwater quality and quantity, it is not possible to effectively develop plans and policies that can target preservation of this resource. Similar work has proven successful in managing and improving Vermont's surface water quality preservations efforts.

OBJECTIVES

A. Improve Information Available for Groundwater Management Decisions

Continue Studies of Groundwater Resources (2)

1. Update Vermont water use information
2. Expand inorganic investigations (primarily Fe, Mn, As, radionuclides)
3. Evaluate regional impacts from well interference
4. Evaluate contamination issues as requested
5. Explore funding sources

Interagency Collection and Compilation of Data (3)

1. Determine sources of useful data
2. Identify data needs
3. Develop quality assurance and quality control protocols
4. Improve existing databases and expand access
5. Develop additional tools (databases, online submissions etc.)

Identification and Mapping of Groundwater Resources (4)

1. Develop additional regional groundwater favorability maps
2. Map-base aquifer and water quality data interface
3. Statewide recharge rate and area assessments
4. Assess aquifer storage capacities

B. Protect Public Health and Safety and the Environment

Adoption of Technical Criteria and Standards (6)

1. Evaluate unpermitted activities
2. Work with non-Agency permitting groups
3. Review of technical standards that meet public trust test
4. Maintain Agency fluency in best management practices for groundwater

Integration of Groundwater Protection Consideration into Regulatory Programs (7)

1. Establish system for rule review
2. Coordinate communications between DWGPD and watershed programs
3. Facilitate legislative and rule review

C. Expand Communications

Technical Assistance and Planning for Municipalities (5)

1. Incorporate source protection plans into town plans
2. Provide outreach on new technical standards from rules (GWPRS, potable and water supply rules)
3. Establish a system of regular muncipal and regional outreach on groundwater protection strategies.

Compilation of Information and Educational Materials for the Public and Cooperate with Federal Agencies (8)

1. Improve accessibility to resources
2. Coordinate private well conference
3. Actively participate in well drillers meeting
4. Promote activities of Agency technical groups.

GOAL

Make actionable suggestions that ensure groundwater resources are sustainable both in quantity and quality and that groundwater use does not harm water quality or unreasonably limit future Vermonters access to these groundwater resources.

A. Improve Information Available for Groundwater Management Decisions

Continue Studies and Investigations of Groundwater Resources (Task 2)

Efforts to protect and manage groundwater are intrinsically linked to understanding the scope and nature of the resource. To that end, the Vermont Geological Survey (VGS) has been coordinating the completion of systematic groundwater characterization work. Data from drilled wells (private and public), geologic maps and documented land uses can be used to develop aquifer favorability maps and identify priority areas needing more detailed groundwater resource mapping. The completion of these favorability maps and more detailed studies is a significant undertaking due to inconsistent and incomplete data availability. To date, approximately 20 town groundwater projects have been completed. VGS regularly coordinates with regional and local planning groups to establish priorities for conducting further work. At the current VGS staffing, it is estimated to take over 100 years for this work to be completed across the state (2003, Report on the status of groundwater and aquifer mapping in the State of Vermont).

In 2011, the VGS also unveiled an updated geologic bedrock map for the state of Vermont. This map provided significantly more detail than the previous version and provides scientists, regulators and the public with a greater potential for understanding of the subsurface environment. This higher resolution mapping is a valuable resource providing potential for more precise contaminant site characterization, exploration for high yield water sources and better targeting of areas for improved geochemical and geophysical analysis. VGS recently initiated a project to compile surficial geologic maps, till geochemistry, groundwater information, and hazards by region (one-degree sheet).

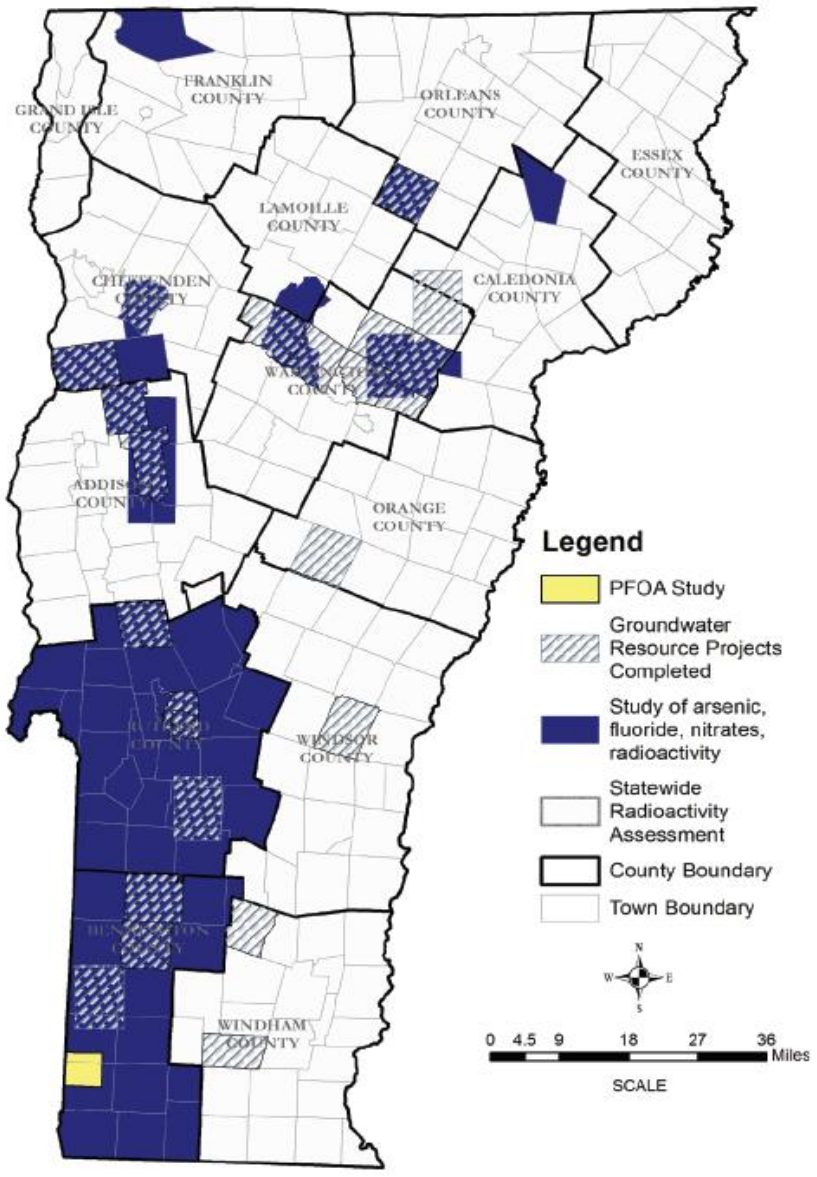

Figure 2: Locations of completed VGS studies on groundwater resources and contamination.

Despite the substantive nature of the work that has been completed, the need for additional and/or supplemental information continues to grow. This was demonstrated in 2016 with the detection of per- and polyfluorinated contaminants (PFOA/PFOS) in North Bennington, VT. As new chemicals are created, or new contaminants of concern are identified, able to be sampled for, and detected, the Agency's ability to act in a responsive but focused manner depends on having some existing understanding of regional and local groundwater conditions.

These instances where understanding the groundwater system intersects with human health conditions are prime examples of why foundational information on groundwater quality and quantity needs to be documented, assessed and accessible. Other considerations such as rapidly changing land use and development, climate change, flood and drought planning, and understandings of groundwater impacts on surface water conditions all require expansion of the work already completed and active integration of that work into management decisions. Continuation of this work will benefit many, but will require active participation by many partners, including the Department of Health (VDH) and the Agency of Agriculture, Food and Markets (AAFM).

Efforts to improve continuation of groundwater studies and investigation of groundwater resources must focus on documenting current groundwater conditions, maintaining and continuing historic data collection for trend evaluation and prioritizing areas of higher concern for studies to aid in protection of potentially limited groundwater resources.

	Approach
Short-Term	• Update the USGS study on water use in Vermont – A competitive USGS Grant (G15AS00001) to assist in completing this work has been granted. • Addressing contaminant issues in public and private water supplies, particularly expanding the work on nitrates and inorganic contaminants. Work will require partnership with VDH and AAFM. • Expand accessibility and assessment of the DWGPD's groundwater well interference data.
Long-Term	• Increase the support and funding for the VGS in completion of groundwater aquifer characterization work. This could be completed by providing for line items within Division budgets and/or state revolving fund set-asides. • Maintain flexibility to investigate new groundwater contaminants or regions of contamination as issues are identified.

Further development of groundwater resource data will increase the possibility of assessing and mapping groundwater favorability and sustainability within individual aquifers and, as the work expands, on a regional groundwater-shed scale. Such information will prove increasingly valuable not only for use in state agency management decisions, but also in municipal decisions regarding development and identification of potential zones of limited use for water supplies.

Interagency Collection and Compilation of Data Related to Groundwater Management (Task 3)

Groundwater management decisions require observation of trends in both quantity (groundwater levels) and quality (geochemistry). Long-term monitoring would allow for questions of sustainability to be answered, whereas snapshot analyses can only address specific targeted questions. Generally, the characterization of Vermont's groundwater resources has progressed slowly relative to the increasing pressures of contamination and land development. While the development of a monitoring network solely for use in groundwater management would be an expensive proposition, numerous programs within various state agencies are already collecting data related to various aspects of groundwater management, and these data, if compiled and coordinated could serve this broad function.

An obvious first step in this compilation process lies in reviewing, updating and making available information that lies within the Drinking Water and Groundwater Protection (DWGP) Division. There currently are two primary databases of general use: Safe Drinking Water Information System (SDWIS) with source yield, construction and location information and the well drillers completion report database. The Groundwater Interference Database has been completed with data entered up to 2008; however, further data entry is required to be brought current. These databases serve as the core of our knowledge regarding groundwater use, well

locations and aid in defining relationships between geology and groundwater within a specific location. However, each of these databases require significant updating, evaluation and correction for accuracy, and regular maintenance.

Other organizations, such as the permitting programs regulating discharges to groundwater, those managing contaminated groundwater sites, the Department of Health and Agency of Agriculture all collect data to address aspects of groundwater (often quality) that concern the specific tasks of the organization. A systematic evaluation of all relevant sources of groundwater quality and quantity information needs to be completed with a targeted approach focused on acknowledging data gaps and determining how that data may contribute to the broader scope of statewide groundwater management and how data collection and compilation can systematically be made consistent, compatible and accessible.

The compilation of existing data will also make it feasible to begin exploring data gaps that exist within the state. This will allow for strategic development of a long-term monitoring network that will address remaining questions. The USGS manages 12 long-term groundwater monitoring locations within the state, but only one of which is installed into crystalline bedrock. As crystalline bedrock serves as a primary aquifer for private drinking water supplies, and no other data are systematically compiled regarding groundwater levels (quantity) it can be difficult to ascertain the long-term sustainability of our most used groundwater resources.

	Approach
Short-Term	• Identify sources of useful data and establish a system to maximize the accuracy, consistency and compatibility of any data that is to be collected (quality assurance and quality control protocols). • Evaluate, in coordination with the Groundwater Coordinating Committee, what the needs of the groundwater community are for data types. • Explore the need and usefulness of additional databases to compile any identified data sources that are not currently in a useful or accessible digital format. • Improve the existing databases (well completion reports, etc.)
Long-Term	• Expand public accessibility to groundwater data and enable methods for consultants to contribute corrections to data (i.e. locations within the well completion database). • Develop any needed new databases with in data entry.

Given that the collection and compilation of data are fundamental to monitoring, assessment and planning, the actions associated with progressing this task are all scheduled to occur early in the implementation of this Plan. The use of data is essential in building a sustainable approach to groundwater management. It should; however, be acknowledged that data compilation and management is an ongoing task and that the usefulness of any data set is dependent on it remaining well documented, current and accessible to an array of users.

Identification and Mapping of Groundwater Resources (Task 4)

Towns regularly request assistance with the creation of groundwater favorability maps to inform their town planning decisions. However, due to resource constraints the Agency has been unable to provide this service to all Vermont towns. Groundwater maps can provide information on well yield potential and the favorability of areas for drinking water supplies (Figure 3). Additionally, they can identify areas of potential contamination from either naturally-occurring contaminants, requiring an understanding of the geological framework of the area, or anthropogenic contamination, requiring an understanding of local land-use practices. Two to three towns request this service every year and as groundwater is increasingly recognized as a valuable and limited resource, it is likely these requests will increase.

The analysis and interpretation of diverse data sources is at the core of any mapping project. As active management of groundwater expands, the availability and variety of data will inherently drive the potential for production of more informative groundwater resource maps. Although basic groundwater favorability maps are available for many regions, detailed maps, useful for municipal planning or residential considerations, are limited.

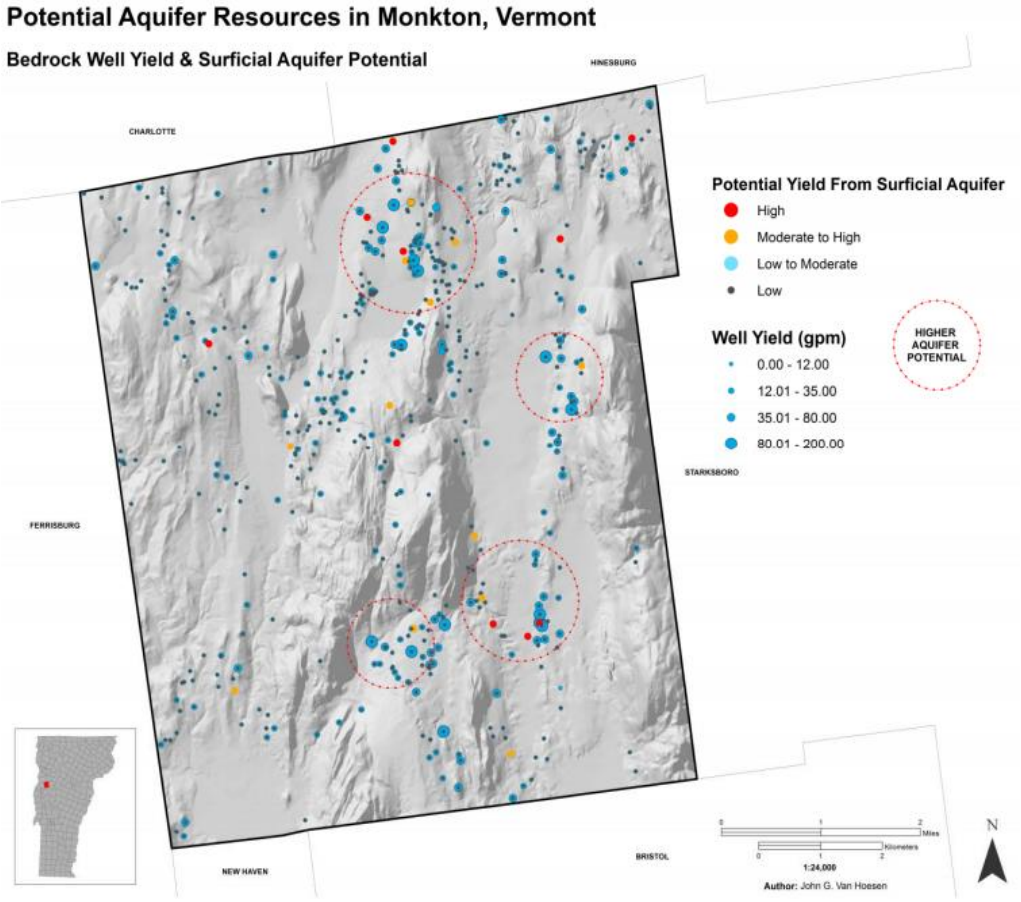

Figure 3: Example of an aquifer resource map for Monkton, VT. *From: Van Hoesen, 2016.*

Relatively little information is available in Vermont on recharge rates, recharge areas and aquifer storage capacities. Understanding these three components is necessary to understand the sustainability of groundwater quantity. The calculation or determination of these groundwater factors is not necessarily complicated, if sufficient data are available; however, alternative approaches can be developed to approximate recharge and storage when data are limited. Continuous groundwater level and streamflow data are highly valuable in calculating recharge, particularly streamflow data. Expanding the regional coverages of such data would allow for improved regional recharge estimates.

Emphasis on documenting and monitoring aquifer recharge and storage takes precedence in regions like the American southwest, where water scarcity has been a long-term pressing issue. As climate dynamics and land-use changes place increasing demands on Vermont's resources, it is important that we complete this type of analysis, potentially expanding it in the future to consider both quantity and quality hand-in-hand to determine usable storage capacities for Vermont's identified aquifers and determine functional groundwater budgets.

	Approach
Short-Term	• Continue the development of regional groundwater favorability maps, currently in the data acquisition and analysis phase by the VGS. • Evaluate a map-based system of delineating aquifers (bedrock vs. surficial) and methods of incorporating corresponding water quality data.
Long-Term	• Initiate statewide assessments of groundwater recharge rates and correlate with watershed basins. • Assess the development of an approach for determining aquifer storage capacities within the state.

The ability to successfully identify and map groundwater aquifers and resource areas depends on having high quality, detailed data available for assessment. For this reason, many of the action items associated with this task are scheduled to occur after initial work is completed on data compilation and collection (see Task 3).

However, it is likely that in order to complete the actions of this section additional data may be needed, which may delay completion. However, as this Plan will be regularly revisited, adjustments to the scheduling can be made as needed.

B. Protect Public Health and the Environment

Adoption of Technical Criteria and Standards for Groundwater Protection (Task 6)

The regulation of activities that pose a risk to groundwater occurs under the purview of the Groundwater Protection Rule and Strategy (GWPRS). As previously discussed, the GWPRS is currently under substantial revision to clarify the obligations of regulatory programs and the standards that they must achieve in setting technical standards to protect groundwater from the risk by the regulated activities. The adoption of these changes to the GWPRS will drive the improvement of technical standards for regulated activities. However, it is important that a system be established to evaluate whether regulatory programs have achieved sufficient protection or have considered groundwater thoroughly within their management decisions as a public trust resource.

Additionally, the GWPRS only applies to activities regulated by the Agency. There are other activities which either fall outside of the realm of the Agency (e.g. regulated by Act 250) or are currently unpermitted (e.g. pharmaceutical disposal). The technical criteria applied to these activities may not consider risk to groundwater at all or may only do so indirectly. The incorporation of groundwater consideration not only needs to be consistently applied across regulatory agencies but should be built into the structure of general considerations for protection of human health and safety and the environment.

	Approach
Short-Term	• Evaluate unpermitted activities and determine what systems for groundwater protection may be in place or should be enacted. • Work with permitting groups outside of the Agency to suggest additional protection criteria that may be relevant to groundwater.
Long-Term	• Support an ongoing effort to remain informed on technologies, topics and issues relevant to groundwater and establish an effective means of sharing and disseminating this information to relevant parties.

Consideration of groundwater and groundwater science in agency decisions not only supports sound decision making and informed policy, it also serves to raise public awareness of the importance of groundwater resources and conservation. As the public interacts with regulatory programs exposure to reasonable, scientifically based technical guidelines and standards addressing groundwater resource concerns will serve to raise general awareness and best management practices within the state.

Integration of Groundwater Protection Consideration into Regulatory Programs (Task 7)

For practical reasons, the approach to environmental regulation is often done one resource at a time. Resources are handled separately, and management programs are even further segregated based on uses, activities and permitting structures. Water issues, surficial and groundwater, are complex and extend across these artificial, but practical divides. Successful groundwater management requires significant coordination across levels of government and decision-making rarely can be completed in such a true interdisciplinary manner, for practical management reasons.

The integration of groundwater protection into all regulatory programs means that these artificial divides must be acknowledged and addressed. There must be voices representing groundwater within and outside of the regulatory system that are recognized and involved in decision making processes. The Groundwater Coordinating Committee (GWCC) is a useful tool in providing such a voice, but the goals and tasks assigned to this group need to be clarified and further defined, especially given proposed changes to the system for completing groundwater reclassifications within the state, which removes much of this review from the tasks of the GWCC.

Within the Agency efforts to expand communication and collaboration between the DWGPD and the Watershed Management Division (WSMD) may prove particularly beneficial. Recent work by the WSMD has largely focused on the development of a surface water management strategy targeted at addressing pollutants and stressors affecting the uses and values of Vermont's surface water. Recent progress on the Vermont Clean Water Initiative has demonstrate the success of their approach. However, within this work there is little to no direct discussion or consideration of the relationship between groundwater and surface water. Both programs would benefit from expanding conversation and collaboration.

One particular regulatory program is anticipated to see change and growth during the period of this Plan, and that needs to consider groundwater resource protection, is the Underground Injection Control (UIC) Program. Recent changes within the UIC Program resulted in promulgation of Rules (2014) and significant changes in practices. Following the implementation of these changes, it is now apparent that further refinement of the UIC Rules and of the program itself are called for.

	Approach
Short-Term	• Establish a system for the evaluation of whether the GWPRS has been incorporated into individual rules and that those rules meet the public trust test. • Increase communications between the DWGPD and the WSMD with the purpose of better defining the challenges surrounding groundwater and surface water interactions and effects on clean-up efforts. • Refine the UIC Rules and Program purpose.
Long-Term	• Ongoing legislative and regulation review.

C. <u>Expand Communications</u>

Technical Assistance and Planning for Municipalities (Task 5)

Since 1992, the State of Vermont has required most public drinking water systems to implement source water protection plans. This requirement has driven towns with public drinking water systems to take a proactive approach to preventing water contamination through protection which is far easier than having to replace or clean-

up a source once contaminated. However, the development of such a plan is dependent on having a sound understanding of the science and technical aspects regarding local and regional groundwater flow and contaminant sources and transport. Such technical background and knowledge may often be outside of the capacities of many Vermont towns.

As a non-profit organization providing training and technical assistance to public water systems, including on source protection plan development, the Vermont Rural Water Association (VRWA) is a valuable partner in this work. However, the Agency can do more to support this approach to groundwater protection by providing resources to towns (data and mapping) and evaluating what the technical needs of municipalities are and addressing those needs.

	Approach
Short-Term	• Complete analysis of the number of source protection plans or areas incorporated within town plans. In conjunction with the Vermont Rural Water Association (VRWA) the compilation of the data for this review was completed in the summer of 2016. • Concentrate outreach efforts in those areas identified by the above analysis as lacking significant planning regarding groundwater resources.
Long-Term	• Regularly complete outreach to municipalities and regional authorities of regulatory and technical changes which impact groundwater protection

Over the next five years of this Plan, efforts are primarily targeted at increasing communications from the Agency to municipalities and regional planning commissions. This communication needs to be centered on two topics: resources that the Agency can provide and best groundwater planning practices that the municipalities can pursue. Collaboration with organizations such as the Agency of Commerce and Community Development (ACCD) will be essential in making this communication effective and efficient.

Compilation of Informational and Educational Materials for the Public (Task 8)

Given the recent drought conditions and the per- and polyfluoroalkyl Substances (PFAS) detections, Vermonters are acutely aware of the value of groundwater as a resource. Given this, the time is ripe for education and proactive community involvement on issues affecting groundwater quantity and quality.

	Approach
Short-Term	• Re-initiate the private well conference, last held in 2011. • Continue and increase DWGPD staff involvement in annual Well Drillers meetings. • Increase accessibility to resources relevant to the public. • Promote the activities of technical groups within the Agency (science advisory committee, technical advisory committee, groundwater coordinating committee) particularly as related to groundwater consideration.
Long-Term	• Continue outreach efforts deemed appropriate and reevaluate as necessary.

This Plan outlines some specific actions that have been targeted for implementation within the coming years. However, it should be noted that public outreach and education depends on remaining flexible and addressing needs as they arise. By systematically incorporating outreach into regular operations, the Agency can maintain that needed flexibility and be able to complete outreach in a timely manner.

Cooperation with Federal Agencies (Task 8)

Consistent collaboration and cooperation with federal agencies is necessary for establishing regional cohesion and effective information sharing. Historically, groundwater management has regularly involved the Environmental Protection Agency (EPA) and the United States Geological Survey (USGS). The EPA has regularly been involved with GWCC meetings and has provided valuable input and insight to national studies and issues that inform the discussions. The USGS is a primary funding source for the VGS and they rely on Vermont data for many of their regional groundwater studies.

	Approach
Short-Term	• VGS/DWGPD conduct work in accordance with work plan under USGS Water Research and Use grant awarded August 2017.
Long-Term	• Apply for additional funding through the 5-year USGS Water Research and Use grant program. • Develop stronger partnership with the USGS in order to capitalize on their expertise in groundwater modelling, monitoring and contaminants. • Explore partnerships with FEMA to fund water data acquisition related to drought.

Although there are not many specific tasks within this five-year Plan period, ongoing communications with federal agencies will remain essential in remaining aware of potential changes to regulatory landscapes and federal or regional initiatives that may affect Vermont's efforts in increasing groundwater awareness and protection.

Resource Needs for Full Implementation

The proposed actions above and within the implementations plans of the Appendix are preliminary and generally broad in scope. Specific work plans will be developed for each of the tasks to assign responsibility (who will be completing the work), cost evaluation and prioritization. These work plans will help identify the specific resources and funding needed to fully implement each task. Funding or resource limitations may necessarily delay completion of a particular task or reduce the effectiveness or extent of the results.

As noted earlier, the timeline for completion of each task will largely depend on acquiring sufficient resources to complete the work. For example; in a 2003 report to legislature on the Status of Groundwater and Aquifer Mapping in the State of Vermont, it was estimated that nine dedicated staff positions would be needed for a period of four years to complete only a basic level of groundwater mapping across the State. Without these positions, the completion of this work is fit into regular program operations as time and funds are available, significantly delaying the completion of this work. Progress on some tasks is already occurring as part of base program operations within the Agency; however, numerous activities would be new initiatives and as such there will need to be lead in time for project development, prioritization, gathering resources and funding, before implementation.

Benefits of Plan Implementation

The protection and remediation of Vermont's surface water has been at the forefront of environmental response and action within the state in recent years. It is important that groundwater be given similar attention so that both resources can be managed together. Joint management of these two resources will allow the Agency and environmental planners to understand and plan for conjunctive uses of both groundwater and surface water and more completely understand the implications of doing so.

The dedication of additional resources specific to groundwater preservation and protection will have cascading effects within the Agency. Without the compilation and consolidation of groundwater data and resources available, efforts to document and develop sound scientific practices are often duplicative and lack historical context for the development of a complete understanding. Currently, the VGS is a significant partner to the DWGP Division in completing data collection and mapping projects essential to facilitating planning efforts; however, staffing is significantly limited within the VGS. The recognition of the need for this work to be completed in a timely manner and the provision of resources to do this will mean that VGS staff will also be able to remain flexible enough to address other matters of importance or respond to issues of pressing concern as they arise, such as the 2016 PFAS contamination response in North Bennington.

Implementation of this Plan will not only impact the functioning and capacity of the Agency, but will have impacts to regional planning commissions, municipalities and private residents across Vermont. The implementation will provide increased access to healthy, sustainable water and provide cost savings and increased efficiencies. Our reliance on groundwater as a resource for drinking water means that additional scientific understanding and increased monitoring will benefit all Vermonters.

Summary

There is a lack of a systematic statewide approach to understanding and protecting groundwater quality and quantity trends within Vermont. While there are many program efforts and significant data available, there needs to be a comprehensive strategy for compiling and providing access to this information and for assessing this information for incorporation into management decisions based on sound science. We need to ensure that the Agency focuses on groundwater as a resource and as a component of interrelated systems rather than protecting it through various programs' individual and often uncoordinated goals.

Appendix A identifies actions for each of the statutory tasks with associated timelines for implementation and completion. These will serve as the implementation plan for supporting the goals of this Plan in the coming years. Ideally, this Plan and the implementation should be evaluated regularly with the tasks in Appendix A updated for progress annually. The complete Plan for Groundwater Management should be revised and updated with new initiatives at a minimum of every five years.

Stakeholders, particularly through GWCC participation, should take an active role in regularly reviewing these implementation plans, and the progress made so that they can serve the function of providing advice to the Secretary, as originally intended by statute. Many of the steps identified within these implementation plans focus on expanding our knowledge and general capabilities for answering questions regarding Vermont's groundwater quantity and quality. These are only the preliminary steps towards having a functioning Plan for groundwater management and these first five years are building the base for successful groundwater planning and protection in the future.

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Medalie, L., and Horn, M.A., 2010. *Estimated water withdrawals and return flows in Vermont in 2005 and 2020*. U.S. Geological Survey Scientific Investigations Report 2010-5053, 53 pp.

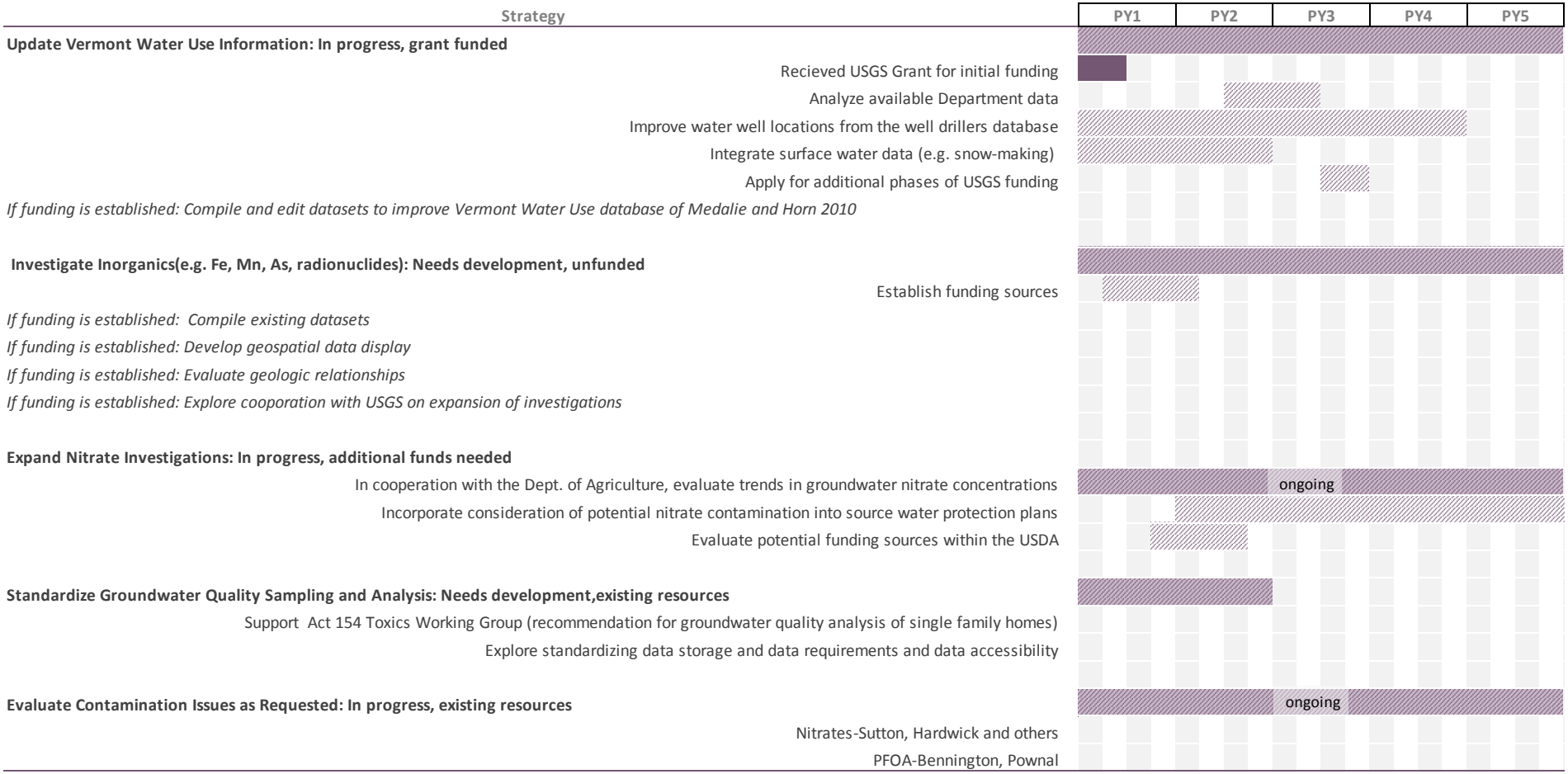
Van Hoesen, J.G., 2016. Surficial geology and hydrogeology of Monkton, Vermont. Vermont Geological Survey: Open File Report VG2016-2, 37pp., 11 plates

Vermont Department of Environmental Conservation, Division of Geology and Division of Water Supply, 2003. *Report on the Status of groundwater and aquifer mapping in the State of Vermont.* Submitted to Senate and House Committees on Natural Resources and Energy.

Appendix A

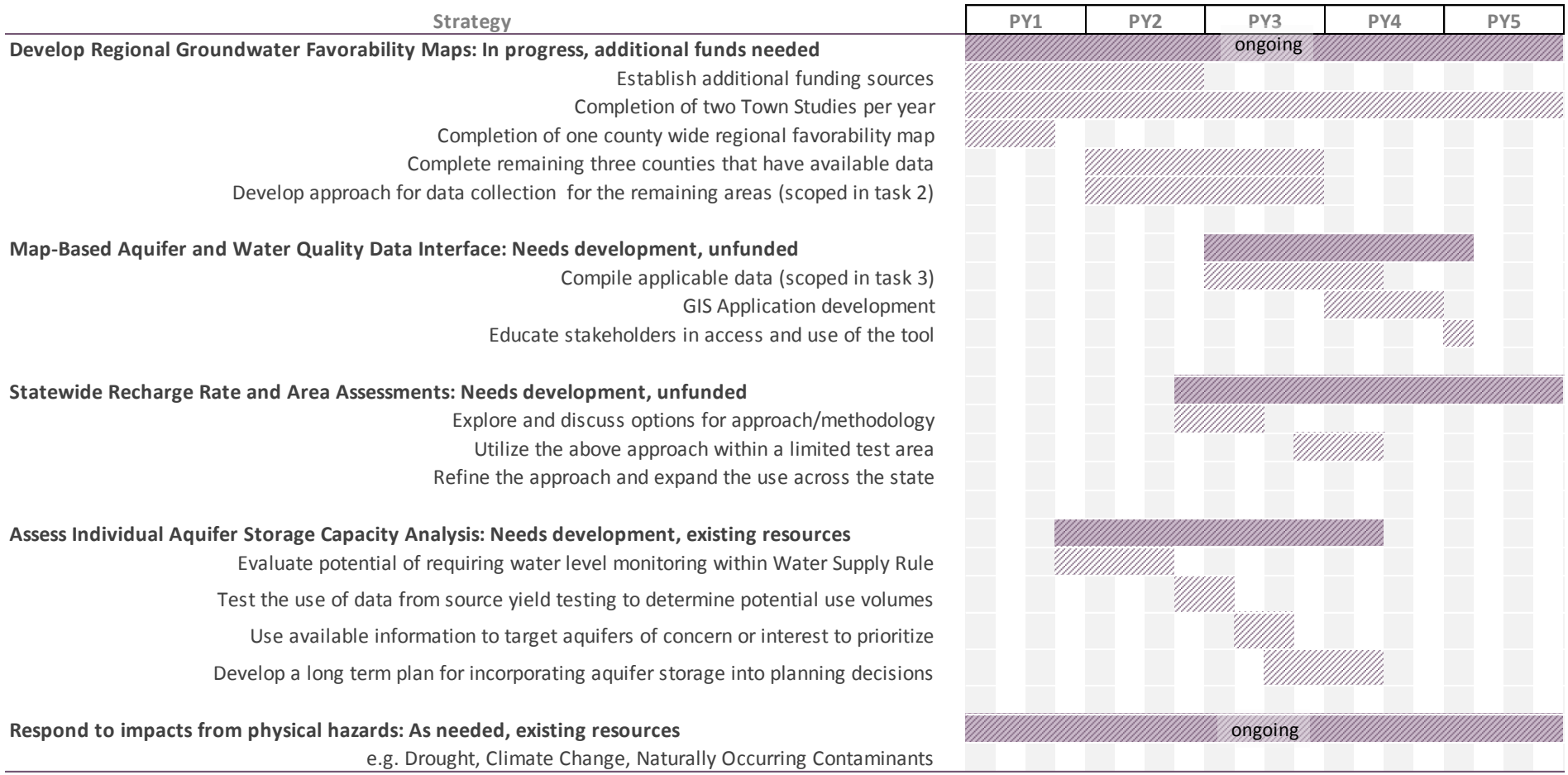
Task Specific Implementation Plans

Continue Studies and Investigations of Groundwater (Task 2)

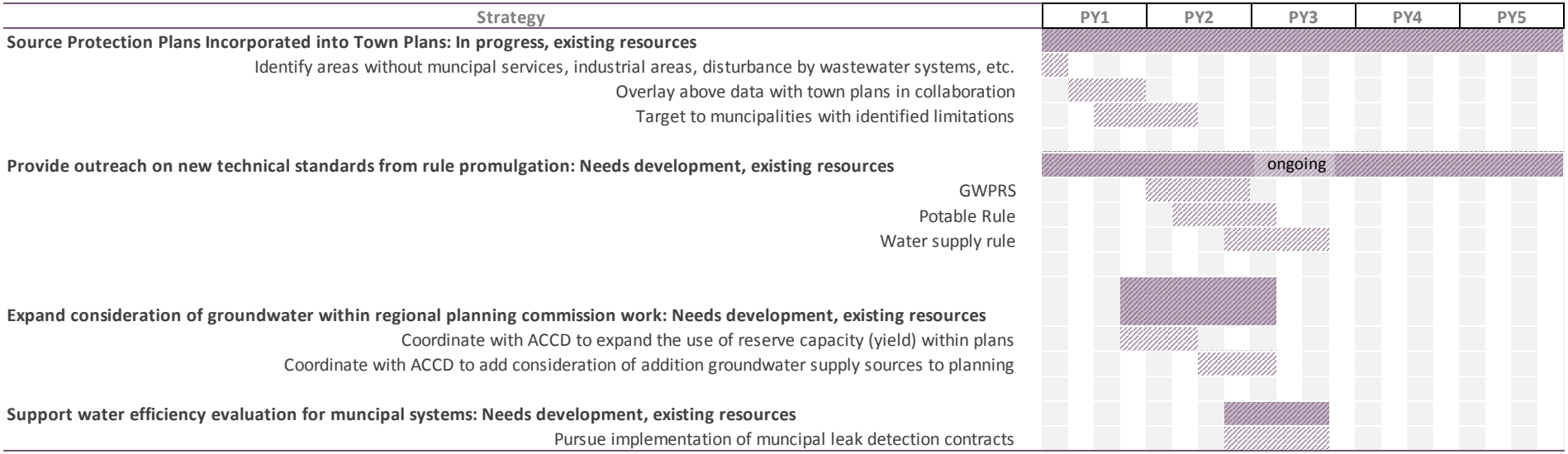


Interagency collection and compilation of data related to groundwater management (Task 3)

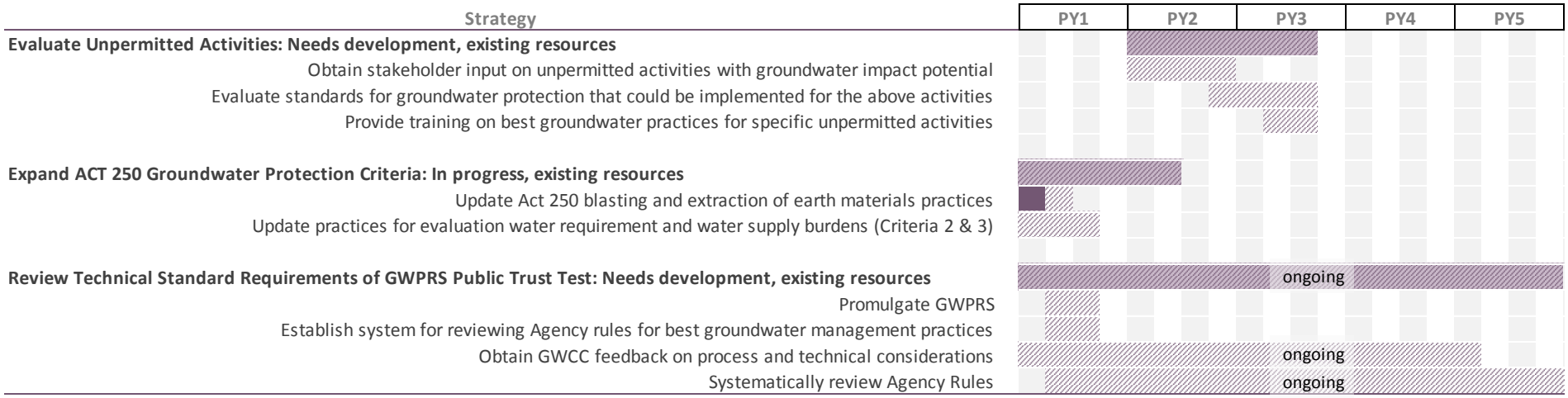
Identification and Mapping of Groundwater Resources (Task 4)



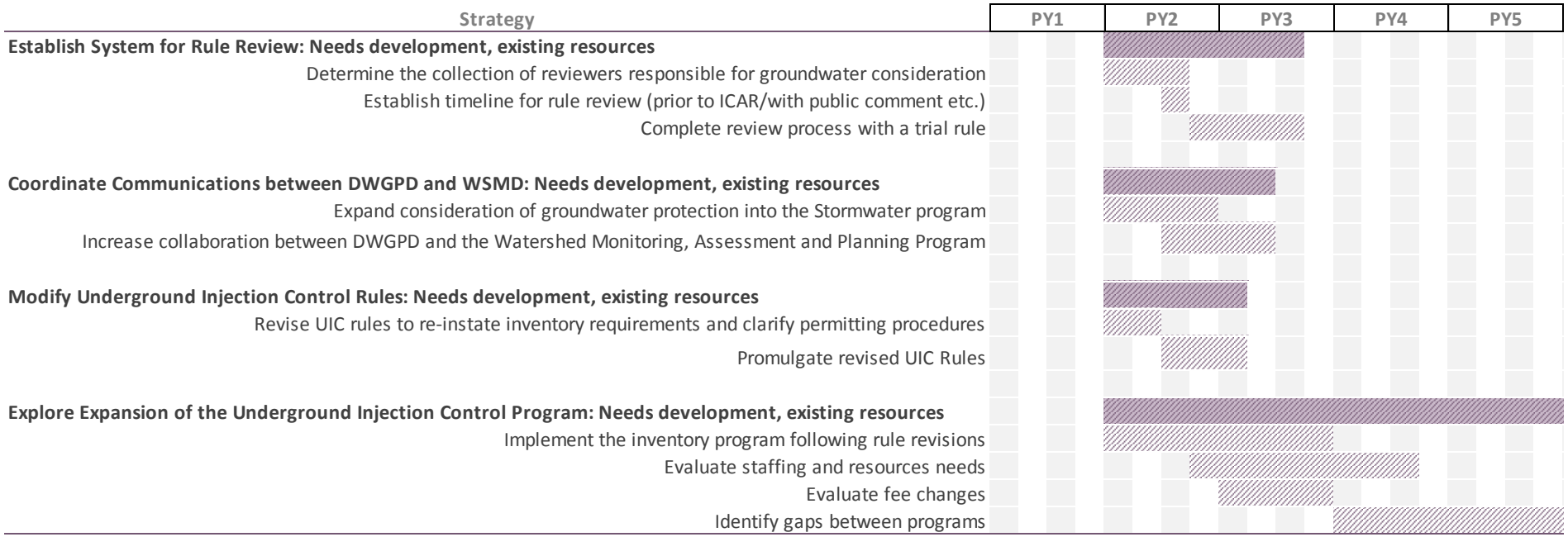
Provide Technical Assistance for Municipal Planning (Task 5)



Adoption of Technical Criteria and Standards for Groundwater Protection (Task 6)



Integrate Groundwater Protection Consideration into Regulatory Programs (Task 7)



Public Information and Federal Agency Cooperation (Task 8)