Proposal to create the Michigan Hydrologic Framework

Introduction

The Michigan Hydrologic Framework (MHF) will facilitate statewide sustainable water management of both surface and groundwater through centralized access to integrated hydrologic models, up-to-date hydrologic data, and comprehensive hydrologic analysis. The creation of models will be expedited by GIS linked data bases, existing models input and output, and a statewide interpretation of the water table surface. To assist professionals and the general public understand and use hydrologic information, the MHF will function as a statewide "smartmap" that describes the distribution, abundance, status, and trends of the linked atmospheric, surface water and groundwater systems.

To envision how the MHF will work, consider the physical world: hydrologic data (such as streamflow, precipitation, water withdrawals and groundwater levels) can be measured, and physical attributes (such as soils, land use, water bodies, and topography) can be geographically described. These representations of the physical world can be stored in a series of GIS data layers. The geographically located data and spatial analysis can be used to create input for integrated hydrologic models. Output from the models can be analyzed and stored in GIS layers. The GIS mapping capabilities and linkage to a wide range of hydrologic data and analysis will not only make water resource data truly accessible, but also understandable (see Figure 1).

Our three-dimensional world is frequently modeled in two dimensions, and because of the great difference in time scale, precipitation/runoff models are generally run separate from groundwater models. But these components can never be completely separated without incurring significant errors. Part of precipitation becomes recharge to groundwater, and groundwater eventually discharges to streams or to the atmosphere through evapotranspiration. In recent years, the ability to account for these transfers has improved, and some modelers are now coupling atmospheric, runoff, and groundwater models. Typically, the emphasis of the modeling effort is weighted either toward surface water processes or groundwater processes. And the mechanisms that account for transfer to the other domain, either to surface or groundwater, are simplified. A few model codes are fully coupled and simultaneously solve process-based equations for all domains. Figure 2 provides an example of how surface and groundwater models can be coupled through an interconnected grid.

Water Resources Management

There is an old management adage "You can't manage what you don't measure." In water resources management, perhaps the adage should be re-stated "You can't manage what you don't understand." We need measurements to start the process, but our understanding is expressed through models. Models then also become our management tools. For management purposes, it is recognized in Sustaining Michigan's Water Heritage that surface and groundwater must be managed to support sustainable human uses and ecological function. Some identify a universal human need for "water security," which incorporates economic development, sustainability, and protecting natural resources. To manage water, there is a need for data to adequately define water resources in Michigan. Because of the abundance of water in Michigan, this has not historically been a high priority. In developing the MHF, the state should also recognize the need to gather hydrologic data on an ongoing basis, as part of the effort to properly manage and protect Michigan's water resources.

We need models to quantify our water resources and how they respond to external changes. Models also allow evaluation of management options. There are several existing state water management programs that will benefit from the enhanced modeling capabilities and data accessibility planned through the MHF: protecting property from flood damage; designing and evaluating the resiliency of critical public infrastructure to water extremes (floods and droughts); improving stormwater management; management of sustainable irrigation practices; protecting residential water supplies; understanding sediment transport; protecting aquatic ecosystems from adverse resource impacts; and protecting and improving water quality. The MHF will benefit companies, communities, and individuals interested in economic development and assuring there will be adequate water supplies for their current and future needs. The MHF builds on earlier investments to define groundwater resources in Michigan, such as the Groundwater Inventory and Mapping Project, and development of the Water Withdrawal Assessment Process, and allows us to expand our capabilities to address water issues in an accurate and timely manner.

A Framework – not one model

There are varied objectives associated with water resources development, one model cannot answer all questions. It also doesn't make sense to build one statewide model with enough detail to evaluate the streamflow depletion from one proposed well. The computational, development, and operational costs are prohibitive. However, models can be efficiently developed at many scales to answer a wide range of management questions. There are inherent complexities with water resources, because much of the resource is hidden (groundwater). It is an integrated system (the hydrologic cycle) that is driven by unknown and highly variable future events (climatic inputs). Therefore, we need a systems approach, and a variety of modeling techniques, to understand, manage, and protect Michigan's water resources.

A variety of models can be developed using the resources we plan to make available in the Framework. Surface runoff process models can use statewide historical precipitation datasets, climate change scenarios, standard design precipitation patterns (such as 100 year or probable maximum precipitation), or custom designed precipitation patterns. The models can use statewide grids developed by others, with the stream network already incorporated, or use a grid generator to develop a unique design, tailored to project needs. Statewide data layers are available for: topography, soils, land use, connected stream network, lakes and wetlands, watershed boundaries and baseflow. Table 1 summarizes the potential data we identified that will add value to the MHF. There are several categories of data layers:

1. Climate/Weather Data includes real time precipitation data; historic precipitation data; data that have been synthesized, reanalyzed, or corrected; and climate change scenarios. There can be errors in how precipitation data are measured, especially snowfall under certain wind conditions, and at some gage locations that do not have appropriate equipment or procedures.
2. Surface process model data include static landscape data that do not readily change over time such as topography, soils, the stream network, watershed boundaries, and wetlands; and time varying landscape data that may change seasonally or annually, such as crop cover, irrigation water use, irrigation return flow, and leaf area index. Channel characteristics are important to accurately route flows through the stream network.
3. Groundwater model data includes aquifer hydraulic properties; geologic strata; water table elevations; and recharge. Models that feature groundwater/surface water interaction incorporate streambed conductance.
4. Water use/water return includes water use routing; alteration of the hydrologic landscape by importation of water supply, or artificially moving water through a system of reservoirs and channels; and water intakes.
5. Water infrastructure could include county drains, tile drains, and urban stormwater systems.
6. Hydrologic data include flow measurements made at gaging stations, as well as analysis of those data to develop, for example, design flows for floods and droughts.

Possible sources for these data sets are researchers and agencies working with these types of data. It is important information and efforts will be made to make it available through the MHF.

Groundwater

Because of the importance of groundwater/surface water interaction, and lack of detailed information, a water table surface will be an important feature in the MHF. It can be generated with topography, the connected stream network, and static water levels from wells. This can be linked to surface runoff process models, or groundwater process models, and can provide initial and boundary conditions. Statewide water table surfaces were separately developed by Dave Lusch and Shuguang Li, both are at MSU. These will be reviewed for possible inclusion in the Framework.

MODFLOW is widely used as a groundwater process model. A recent version, MODFLOW6, will be used as the default model that incorporates flexible grids, allows nested scale modeling and multi-model design that can “stitch” separate groundwater models into one simulation, and can be coupled with surface water models. The model can use state wide grids already developed by MSU and others. A finite difference grid generator will develop input from connected databases and the water table surface. The supplied statewide data sets (such as transmissivity and top of bedrock) can be used to start with a simple one-layer model. Complexity can be added as needed for a project, or as data become available. Because the modeling code is open-source and freely available, communities and the private sector will be able to use the default model for low cost and then invest in further model development or data collection to refine the model for particular needs. Data input and output are in specified formats and could be readily converted for use in other numerical modeling platforms, if deemed appropriate.

Surface water runoff

There are many surface water runoff models available. They each have different ways to calculate and route runoff in response to precipitation events, and they may or may not track the water that infiltrates into the ground. Figure 3 illustrates how different surface process models handle the physical processes and interact with groundwater. One was developed by USGS, Precipitation and Runoff Model System (PRMS). It averages runoff characteristics over a Hydrologic Response Unit (HRU). It incorporates vegetation interception, evapotranspiration, snow layers, impervious layers, and multiple soil zones, calculating surface runoff, interflow and groundwater recharge. USGS has coupled it to MODFLOW in their Groundwater and Surface water Flow model (GSFLOW). Another, the Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model, was developed at the University of Washington. It maintains a mosaic of vegetation coverage in each cell as it partitions between runoff and infiltration. It incorporates vegetation interception, evapotranspiration, snow layers, and three soil layers, calculating surface runoff and returning a portion of the infiltrated water as baseflow to the stream. There are many model codes available that can fit a wide range of study objectives.

Statewide Models

Several models have been applied statewide and link surface and groundwater processes (summarized in Table 2.) Each uses a different approach, and they are developed to answer different questions. There are also several more model codes that are capable of integrated hydrologic modeling at this scale. The Framework can be used to apply these models statewide, or facilitate the development of smaller scale models to use their capabilities for a detailed simulation with more refined results. Portions of the models, such as the numerical grid, or stream network simulation, could be used with different model codes to address other water resources issues.

The model developers in Table 2 have agreed to cooperate with the development of the Michigan Hydrologic Framework and make elements of their work or outputs available through it.

Regional Models

Significant models that are used by water management programs can remain resident within the Framework. An example of this will be regional scale groundwater models (watershed based, roughly a county or two in size) used to refine the understanding of the water resources in the area. In this case, specific model goals are to estimate the impact of new groundwater withdrawals on streams in an area. Models can be rerun as major groundwater development is planned, and/or as new data are gathered. By maintaining these in the Framework, the analysis is readily available to consultants, local planners, and major water users.

As a first step in creating the Framework, regional coupled groundwater/surface-water models should be developed in areas of the state where heavy groundwater development is occurring. Examples: St. Joseph County, Montcalm County, and Branch County.

To meet a need in the Water Withdrawal Assessment Program (WWAP), the results from the regional models should be transformed and refined so they can be used in the Water Withdrawal Assessment Tool (WWAT). We want to improve the information level available in the screening tool, so it is able to automatically authorize new withdrawals based on the hydrologic knowledge developed in the regional model when appropriate, and provide better screening results. The updated screening tool should still be conservative, so if there are questions about the appropriateness of the withdrawal, it will be referred to the SSR process.

***Summary of MHF capabilities*:**

1) Handle GIS data sets statewide (expand beyond what we are doing as part of the WWAP);
2) Incorporate results from detailed local or regional groundwater models into a statewide decision making framework (specifically, the WWAP screening tool should be upgraded as part of this);
3) Access hydrologic data, data analysis and interpretation results, model results;
4) Access these data and results through a GIS interface (smartmap); and
5) Incorporate new data and analysis into data sets as they become available.
6) Create a statewide “smartmap” that describes the distribution, abundance, and dynamics of the linked surface-waters and shallow groundwater system.
7) Facilitate creation of models that link climate, surface waters, and shallow groundwater, and can show past, present, and future scenarios.

Calibrated models are the primary science output of the Framework. Site data support the modeling.

Creation of the MHF and associated regional groundwater models will be largely accomplished using existing data from shallow groundwater monitoring wells, Wellogic information, gaged stream data, streamflow measurements, and lake level measurements to calibrate the regional models.

Data Collection

We need to remember that water resources data are the foundation of this work, and the future credibility and accuracy of the MHF requires adequate and accurate data. Data collection should be an integral part of implementing and maintaining the MHF, the state should also:

1. Implement a robust statewide network of shallow groundwater monitoring wells. Design a network to best complement existing calibration data points, in order to feed the models.

2. Upgrade the streamflow monitoring network to specifically address data needs for this effort. Build on the existing network, update and implement plans to expand the network with a mix of permanent gages, short term gages, streambed and stream channel data, and strategically collected miscellaneous measurements.

3. Initiate a long term 3-D groundwater resource mapping program. Establish priority watersheds for mapping based on locations with high water use, or potential for future high water use.

Data collection is a separate track from creating the MHF, but we want to emphasize how integral it is. The MHF will bring together these data collection efforts, together with many other data efforts (such as topography, water use, and weather data), to create an important tool in managing Michigan's precious water resources.

Work Plan

Based on the experience of developing the Water Withdrawal Assessment Process, to be successful, this project should be overseen by a **broad-based stakeholder group**. It will be responsible for developing policy recommendations to state government regarding this project. This includes overseeing the creation and implementation of the Michigan Hydrologic Framework. It is anticipated that this role would be served by the Michigan Water Users Advisory Council (WUAC).

We recommend the WUAC create a small technical oversight committee, or **"Core Team."** The responsibilities of the core team are:

1. Lead the development work.
2. Collaborate with a Technical Team.

3. Report to the WUAC on a regular basis.

The core team will also need to bring together technical experts to work on various tasks. This **Technical Team**:

1. Is led by the Core Team.
2. Shares, reviews, and determines options in the MHF development.
3. Recommends modeling, mapping, and monitoring data alternatives.
4. Collaborates in the development of the regional models.
5. Recommends how to incorporate model results into the Michigan Water Withdrawal Assessment Tool.
6. Has initially a broad membership but varies with time as functional needs change.
7. Membership carries a charge to operate in the interests of the team and the project mission, not individual research or program interests.
8. Includes collaborators or contractors working on elements of the framework.

Scope of Work to develop the Michigan Hydrologic Framework

A proposed Scope of Work, developed by MSU Institute of Water Research, is attached at the end of the report. It proposes five phases that would take three years to complete and cost an estimated $750,000. The first phase involves detailed planning to work with stakeholders to determine how the MHF is likely to be used, develop workflows and use case scenarios, create a mockup interface design, outline data storage and retrieval protocols and methods, and plan model and data inputs/outputs. The second phase is for design and development. A web interface will be built, develop scripting services (for example clipping and grid generation), develop mapping services and scripts to access and retrieve offsite data sets, and coordinate with other agencies to access data. These phases will be completed in the first year.

The third phase is testing with users, and ensuring all the services, protocols and data sharing methods work. It is anticipated that the MHF will be hosted on Michigan Department of Technology, Management and Budget (DTMB) servers after completion. Consequently, it will be tested on their servers and DTMB staff will conduct code reviews to make sure it meets all their standards. The fourth phase is to roll out version 1 (prototype). Training sessions will be conducted, digital training materials created, bugs and defects will be corrected, and enhancements created to improve usability and performance. Phases three and four will be completed in the second year.

The fifth phase will be completed in the third year when the final version will be designed, tested and rolled out. This will be based on information collected after the first six to twelve months operating the prototype version.

Much of the data we plan to incorporate into MHF was developed at universities. There may be costs to access and provide the data sets in suitable formats. An estimated $100,000 would facilitate this through hiring graduate students. This brings the total cost for developing and implementing the final version of MHF to $850,000 over the three-year process.

Development of Three Regional Models and incorporation into MHF

We estimate it will cost approximately $1,200,000 to develop three regional models. The models will be designed to estimate streamflow depletion by large quantity wells. Existing data will be used to develop and calibrate the models. Work can begin immediately, it doesn't have to wait for the MHF development. The first model can be a test case and example of how models can be incorporated into MHF. Models can be used to assess how much additional data collection may help improve predictions, and what data will be of greatest value. They can be updated when more data are available, and if different water management issues need to be addressed.

Data Collection and Mapping

We believe that data collection and mapping activities are fundamental to the success of the MHF, but also, they are needed without the MHF. We anticipate that these tasks could require $500,000 to $2,000,000 per year depending on the level of data collection and mapping. One early project of the MHF could be development of a range of data collection alternatives with data-quality objectives, prioritized data needs, and refined cost estimates.

Long-term operation and maintenance requirements

We anticipate the final version of the MHF will be housed by DTMB. There will be typical IT costs such as maintain the internet connection, provide data security, and maintain backups. These costs are not addressed here.

In addition to these normal IT system costs, there are specific staffing needs to maintain and operate the MHF. A huge amount of data is maintained on the system, or readily available through web services. The data must be kept up to date. Much of the process will be automated, but still a person needs to make sure it happens. Protocols will be developed to collect new data and update old data. These need to be performed on a regular basis. There will also be users that may need help extracting data, or submitting data or models. Submitted data must be reviewed to ensure it meets protocol standards. Inevitably "bugs" will be found and must be corrected. And as technology advances, parts of the system will need updating or upgrading to maintain necessary connections and functions. This centralized work is estimated to require an FTE.

DEQ, DNR, and MDARD will probably want someone to act as a liaison for their department's programs to facilitate use of MHF, and ensure models and program specific data are reviewed and meet quality control standards before they are incorporated into MHF. This could be up to an FTE for each department.

MHF Team:

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- Andrea Munoz-Hernandez, DEQ
- Howard W. Reeves, USGS
- Jill Van Dyke, DEQ

MHF Work Plan Team:

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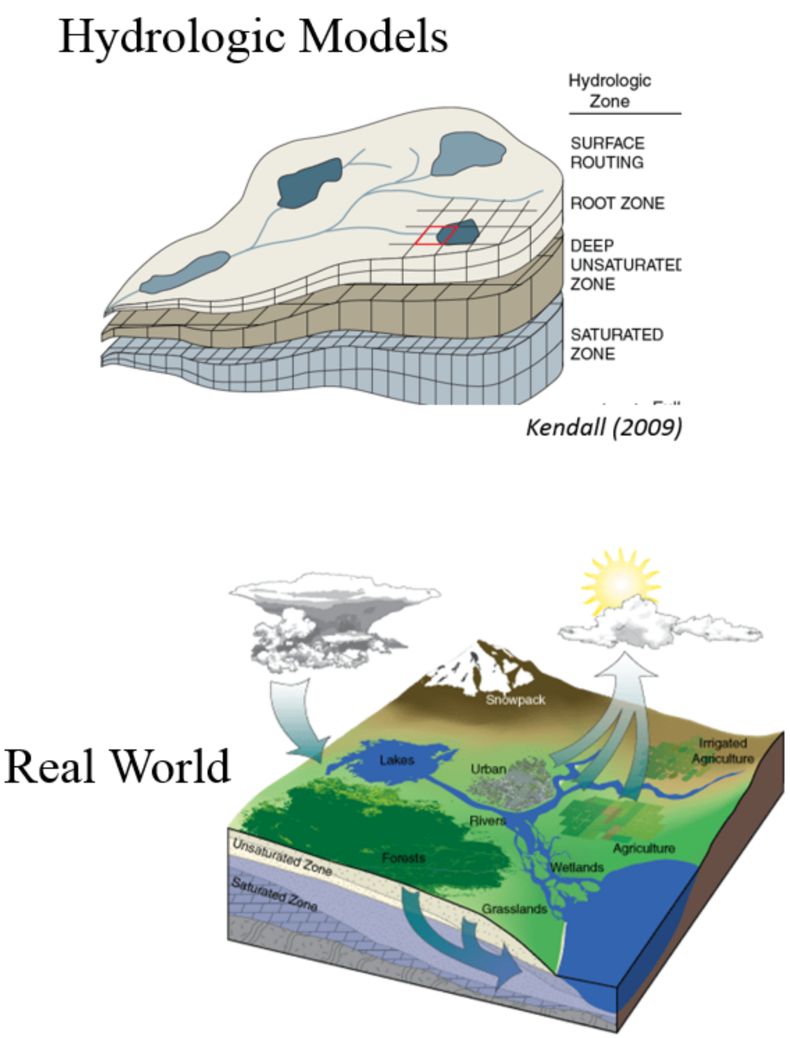


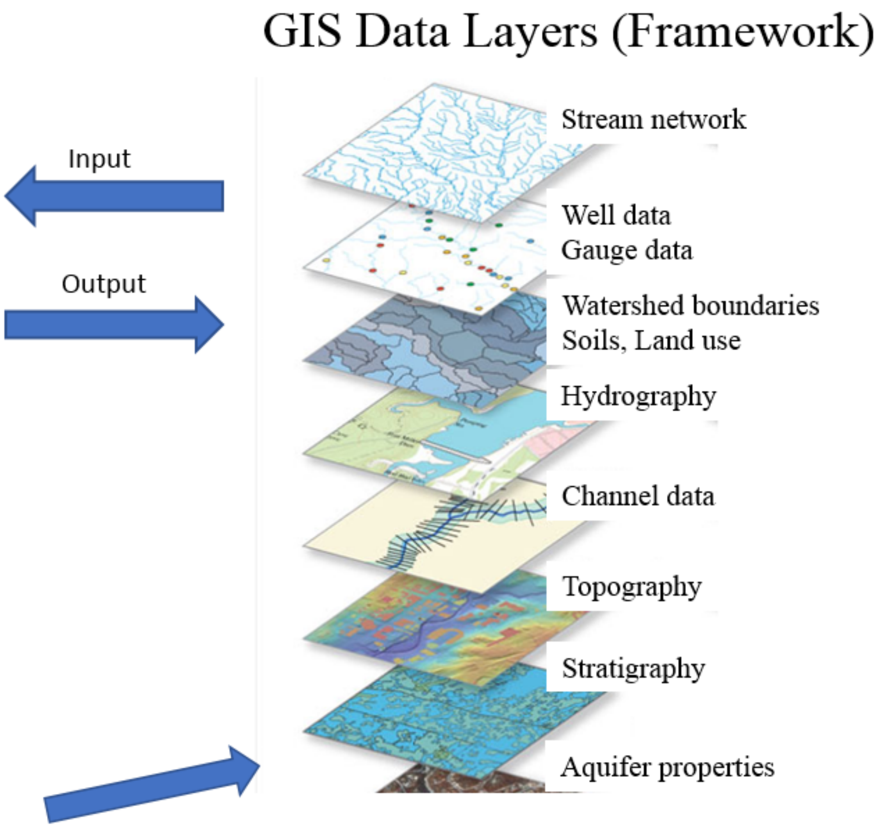
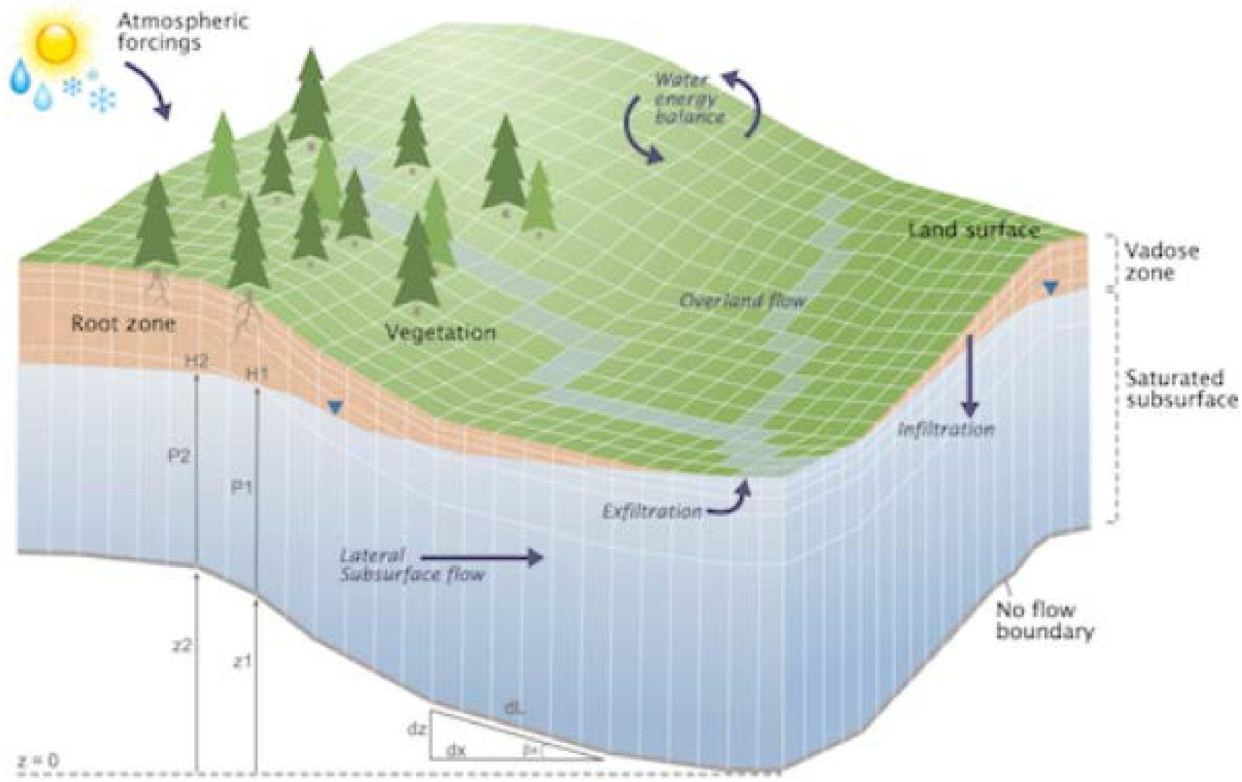


Figure 1 From the “real world”, hydrologic data can be measured and physical attributes can be geographically described, and stored in GIS layers. These can be used to create hydrologic models, and the output can be analyzed and stored in GIS layers.



Parflow.org

Figure 2 An example of how surface and groundwater models can be coupled through an interconnected grid.

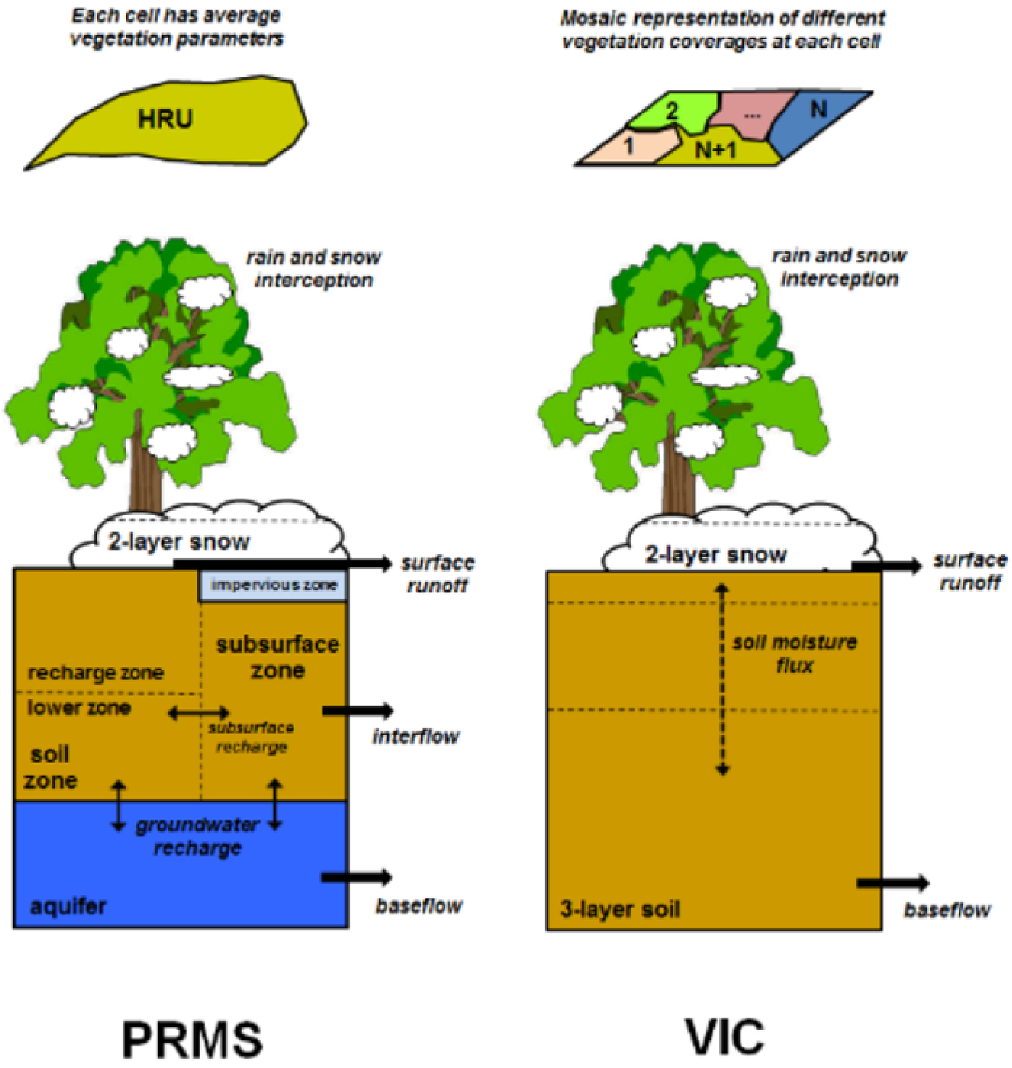


Figure 3 illustrates how different surface process models handle the physical processes and interact with groundwater. PRMS can be coupled to MODFLOW, while VIC returns part of the infiltration water as baseflow.

Table 1

Potential Data Sets

Climate/Weather Data:

- Real time precipitation (NWS)
- Hourly data:
    - weather stations and radar precipitation (NWS)
    - daily precipitation 1980- present (DAYMET – Oakridge)
- "Reanalysis" products that incorporate station and radar data to fill in the gaps in time and space.
    - Alan Hamlet (Notre Dame) – 100 year historic data set (cleaned)
    - Hyndman and Kendall (MSU)
    - Jeff Andresen (MSU) historic weather data (cleaned)
- Climate change scenarios.
    - Alan Hamlet (Notre Dame)
    - Hyndman and Kendall (MSU)
    - David Gochis (UCAR) – 4km grid, 13 years historic and 75 years future

Surface Process model data:

- Static Landscape Data:
    - Topography - Digital Elevation Model (DEM) from the National Elevations Dataset (10m, 30m) (Lidar)
    - Stream Hydrography from the National Hydrography Dataset (NHD+, high res.)
    - Wetlands classification from the National Wetlands Inventory
    - Soil Survey Geographic Database (SSURGO)
    - National Land Cover Data Base (NLCD) (30m)
    - Customized interpretations of land use and soils data to develop infiltration and runoff characteristics. (many have been developed, Hyndman and Kendall, …)
    - Watershed boundaries (DEQ; USGS)

- Time-Varying Landscape Data:
    - Land use land cover data from the NLCD (~5 year intervals)
    - Irrigation data from custom annual maps (Hyndman and Kendall)
    - Leaf Area Index (LAI) data every 4-8 days from NASA satellite platforms such as the MODIS instruments.
    - Evapotranspiration rates for different crops and land cover (this is done by many models, may have to develop a database)

- Channel characteristics
    - Manning’s roughness coefficients (this may have to be developed, NRCS may have some, FEMA floodplain studies include this in their models)
    - Streambed conductance data (needs development)

Groundwater Model Data:

- Hydraulic properties – GWIM (available in GIS layers)
- Geologic Strata
    - Top of bedrock (Dave Lusch; John Yellich working on)
    - 3-D (MGS – John Yellich; John Esch)
- Water table elevation – Shuguang Li; Dave Lusch
- Recharge (USGS?; may need to develop)

Water Use/Water return

- Water use routing
- Alteration of hydro landscape (UP mines, Detroit water system)
- Water intakes (not for public release)

Water Infrastructure

- County drains
- Urban stormwater systems

Hydrologic data

- Streamgage data (USGS)
- Hydrologic Studies data (DEQ)

Table 2

Models Applied to Entire State (Region)

Model	**Modeler**	**Description**
Landscape Hydrology Model	Hyndman and Kendall (Michigan State Univ)	MODFLOW base model for Michigan, uses process equations to partition flow.
Variable Infiltration Capacity (VIC) Hydrologic Model	Alan Hamlet (Notre Dame)	Uses VIC to model surface hydrology from precipitation input, it uses three soil layers to partition flow. Base model covers US Great Lakes states. Can integrate SW/GW in finer scale modeling.
National Water Model	Dave Gochis (UCAR)	Uses WRF-Hydro, covers continental US. High resolution, physics based surface hydrology model that runs on a super computer. Uses shallow soil column to partition flow.
Multi-scale Adaptive Network	Shuguang Li (MSU)	Generates MODFLOW like models that can be nested. Source data sets have been developed for Michigan.

Scope of Work for Michigan Hydrologic Framework (MHF)

Description

The following tasks and activities will be required to develop, test, and delivery the first version of the MHF.

Overview of Tasks and Phases

Phase 1: Planning – 160k

1.1 Developing use cases with end users

Hold 1-2 sessions working with stakeholders and prospective users of the MHF to sketch out specific work flows and likely ways the MHF will be used.

1.2 Developing workflows

Using the sketches developed in the use case scenarios, work flow diagrams will be created to inform how the system interface should be designed.

1.3 Mockup Interface Design

A non-functional interface design illustrating the look and feel along with the paths of information will developed in *Moqups* or related design software.

1.4 Outline data storage and Retrieval protocols and methods –required web services, etc.

Conduct an initial review and catalog of required datasets, who houses them, how they are stored, how they are accessed, what the permissions are, and how they should be included in the MHF. e.g. Should a data set be duplicated, can it be consumed via mapping service, etc.

1.5 Review and plan model and data input/outputs

Review materials for data input/outputs for models. Develop a diagram and matrix indicating sources for inputs and outputs along with their formats. Identify any third party software that can generate data inputs/outputs in a specified format for the models. Establish a short written plan for these.

Phase 1 Deliverables

1. Use case document
2. Workflow diagram
3. PDF mock design of the MHF
4. Data storage and retrieval method document
5. Short written plan for data retrieval and recommendations for software capable of producing input/output files for models

Phase 2: Design and Development- 160k

2.1 Build web interface from Mockup

Using the mockup design established in the planning phase, a web-based interface will be built with placeholders for anticipating/identified features and functions.

2.2 Develop scripting services for clipping, grid generation, etc.

Using the planning documents for data storage and retrieval protocols, required ArcGIS geoprocessing services will be created to clip and generate output files for models. These may include a grid generator and/or text output files for models.

2.3 Develop mapping services
Using the planning documents for data storage and retrieval protocols, required ArcGIS map services will be created for utilization of the MHF. Additional scripts for accessing and retrieving any essential offsite datasets will also be created at this time.

2.4 Data center hosting (new services fees for MSU new data center where we need to temporarily host)
Host fees have not been established yet for the data center. During the development of the system hosting fees will be covered by the Institute of Water Research (IWR). Within 30 days of the end of the project, the MHF will need to be hosted outside of MSU or a hosting contract and associated charge will be established to support and maintain the site until an agreed upon date. MSU/IWR can host the MHF long-term through an additional hosting contract if desired.

2.5 Coordinate and access data from other agencies providing map services or shapefile GIS layers
Meetings with external agencies housing data that has been identified for use in the MFH will be scheduled to determine standards, permissions, etc. for accessing data. If data will be redundant on MHF and external agency, then update protocols and timing of updates will be established and documented.

Phase 2 Deliverables

1. MHF web application
2. Smartmap - an interface that presents data to describe the distribution, abundance and dynamics of the linked surface water and groundwater system
3. Document of protocols and methods for sharing data and timing of updates
4. Statewide water table surface map
5. Finite difference grid generator – data taken from the Framework can be posted to a grid for people to use in their models (not on the website).
6. MODFLOW6 – available for people to download, data downloaded from the MHF are readily compatible as input files.
7. Surface water runoff model (possibly PRMS from USGS) – available for download, it can be readily linked to MODFLOW6, and data downloaded from the MHF are readily compatible as input files.

Phase 3: Testing– 160k

3.1 Regular user testing
Through the Design and Development phases, bi-weekly meetings will be held with subcommittees, project team, and end users to test and review functions and features on the MHF as they're created. This will help streamline the development process and make required modifications and changes easier and faster.

3.2 Testing of map services, geoprocessing services, and general usability

After the geoprocessing and map services have been created, they will be tested under a variety of scenarios by the developers and stakeholder testing group. Required modifications will be made to fine tune service performance.

3.3 Testing of protocols and methods for data sharing

After working with external agencies or groups that manage data that the MHF may utilize, and establishing data sharing agreements and methods, we will conduct tests under a variety of scenarios with the developer and stakeholder testing groups. Required modifications will be made to fine tune service performance.

3.4 Testing on Michigan Department of Management and Budget (DTMB) servers and code review by DTMB

It is anticipated that the MHF will be hosted on Michigan DTMB servers after completion. Regular code review will be conducted by the DTMB and look and feel standards will be followed to help streamline the MHF transfer process at the end of the project. IWR will work with DTMB through a project manager to schedule meetings and review schedules.

Phase 4 Deliverables

1. Testing results document and related fixes
2. DTMB code review and defects log and related fixes

Phase 4: Rollout Version 1 (prototype) – 160k

4.1 Tracking bug, defect, and enhancements log

During testing, a database will be created and used to document and track bugs, defects, and enhancements.

4.2 Fixing tracked bugs and defects

The development team will work through the defect database and address all the identified issues. Critical defects will be addressed first, and enhancements will be set aside for version two development.

4.3 Training and user feedback

IWR will conduct three training workshops and develop an online training document and supportive help videos. During these trainings, users will learn about the MHF and how to use it. After training is completed the development team at IWR will continue gathering feedback regarding updates/enhancements, etc. Identified by users of the system. These will be collected both informally and through a formal request process.

Phase 4 Deliverables

1. Defect log and solutions database
2. User feedback forms
3. Three training sessions
4. Digital training material and how-to video

Phase 5: Shortened version of Planning, Design, Testing, and Rollout for version 2 (Final version) – 110k

IWR will run through a shortened version of all phases of development to put into place a second and final version of the MHF. Some of the most important features and functional changes needed in newly developed applications are identified after the first version has been released and tested with actual users of the system. The information collected after the first six to twelve months of use will be brought back and put into a second version during this phase.

Phase 5 Deliverables

1. Updated MHF that includes identified enhancements, updates, and bug fixes
2. Abridged version of previous documentations and database logs in phases 1-4.