Vashon-Maury Island GWPC Overview and Comment - July 28, 2010: Vashon-Maury Island Phase II Hydrologic Model

SUMMARY

The Vashon-Maury Island Groundwater Protection Committee (GWPC) has reviewed the Vashon-Maury Island Hydrologic Modeling Technical Report (Report) (DHI Water and Environment, 2009). Development of a hydrological model is a part of the Vashon-Maury Island (VMI) Water Resources Evaluation (WRE) and was undertaken in 2004 to evaluate ground water and surface water quantity and quality and to refine earlier efforts at developing an island-wide water budget. The Report describes a Phase II model (MIKE SHE) containing improvements over an earlier version (MOD FLOW). The Phase II model was run to attempt to assess the impacts of partial buildout[1] under local zoning, climate change, and combinations thereof in future years. This overview summarizes the GWPC's perspective on the model's use, its limitations, and future work that needs to be done. Key points are:

- The MIKE SHE model is a step forward in simulating the Island's water budget. It contains improvements over the earlier model such as being linked to a surface water model.

- The model is useful for gauging the relative differences in outcome that result from various assumptions about precipitation, land use and climate, for the island as a whole.

- Being a highly simplified representation of complex island geology, the model is not a useful tool for predicting the location of water or resolving localized water issues.

- The current model and report do not address what happens to the water budget during drought conditions and this is viewed as a significant gap and high priority. The Committee would like discuss steps to address this concern with staff.

- The Committee encourages increasing and improving water data collection and model input in the near term, and does not recommend further work on the model at this time.

BACKGROUND

Publication of the Phase II modeling report is a significant marker in a seven year monitoring and modeling project undertaken by the King County Water and Land Resources Division. Vashon is unique in King County in its reliance on a sole source aquifer. The only source for recharge of the aquifer system is rainfall. Every component of the island's hydrologic system depends on precipitation. While the singular term "aquifer" is used, the VMI aquifer is comprised of multiple smaller aquifers, and groundwater occurs in many discrete and discontinuous locations.

Because of the vulnerable nature of reliance on a sole source aquifer, managing island water resources in a sustainable manner is crucial to the health and well being of Island residents, businesses and ecosystems. This is the focus of the VMI Watershed Plan (Plan) that has guided the GWPC work since June, 2005.

---

[1] *Note: Future pumping scenarios in the model represent ~1,000 people or ~9% over 2000 population in one scenario run and ~2000 people or ~18% over 2000 population in a second scenario. Zoning buildout capacity was estimated (source: Bob Powell) as 1,477 dwelling units or ~3,500 people at 2.4 persons per household, representing ~ 29% growth with present water restrictions. With unlimited water the zoning buildout was estimated to be 2,153 dwelling units or ~ 5,156 people and ~42% growth.*

Vashon-Maury Island GWPC Overview and Comment - July 28, 2010: Vashon-Maury Island Phase II Hydrologic Model

Among other tasks, the Plan describes a seven-year water monitoring program to build a data base to be used in tracking water use, availability, and quality. The Plan also sets out objectives for development of a hydrological computer model that can use this data to develop an island-wide water budget. The model can also be used to estimate possible impacts from population growth and shifts in climate.

The Phase II model and three earlier modeling efforts have generated estimated groundwater supply budgets. The earliest estimates were completed in 1983 (VMI Water Resources Study by Carr) as part of a community planning effort, then as part of the1998 VMI Groundwater Management Plan. In 2003, the County consulted with the Groundwater Protection Committee and began the current WRE to prepare a scientific assessment of water resources and to develop the model to estimate our island-wide water budget. The WRE includes monitoring of stream flow, precipitation, groundwater levels and water quality. The data collected from this monitoring is used in the model. Updated geological maps were also produced in cooperation with the University of Washington. The WRE has produced two estimated groundwater supply budgets. A comparison of the four water budget estimates is shown in Table 1.

Table 1. Summary of estimated groundwater budgets for Vashon-Maury Island

(in/yr)	WRE Phase II Mike-SHE	WRE Phase I Mod-Flow	GWMP 1998	Carr 1983
Precipitation	**43.8**	**38.7**	**44.1**	**38.1**
ET	**19.9**	**16.7**	**17.5**	**19.1**
runoff	**11.1**	**9.2**	**10.3**	**14.3**
GW recharge	**13.5**	**12.8**	**16.4**	**4.8**
Outflows to				
Puget sound	**7.6**	**10.5**	**6.3**	**1.0**
Streams	**4.3**	**1.4**	**10.0**	**3.8**
Wells	**0.6**	**0.6**	**--**	**--**
Springs	**0.3**	**0.3**	**--**	**--**

Note: Carr and the GWMP studies do not estimate well and spring extractions. Table adapted from Table 8 of the Vashon-Maury Island Hydrologic Modeling Technical Report

One can see wide variation in the 1983 (Carr) and 1998 (GWMP) water budget estimates. The GWPC supported development of the Phase II model to refine these earlier estimates, anticipating that over time with continuing addition of monitoring data, the model will enhance our ability to track trends and analyze impacts of changing conditions on water resources. Development of the model has been a learning experience, and there are many refinements and future considerations recommended in the Report. The Report also describes important limitations that must be taken into consideration when looking at model scenario outputs; it discusses how the model can be useful to our community, and applications that cannot be made at this time due to insufficient data or the structure of the model.

Vashon-Maury Island GWPC Overview and Comment - July 28, 2010: Vashon-Maury Island Phase II Hydrologic Model

MODEL DESCRIPTION

The Phase II model was scoped to provide a regional (island wide) assessment of water resources including water balance and potential effects of growth and climate change on the modeled water balance. The Phase II model simulates all of the major components of the land-based phases of the hydrologic cycle: evapotranspiration, overland flow, unsaturated flow, and groundwater flow. This model was linked to a surface water model to represent surface water flow and the interactions between this system and the groundwater system.

The model represents the island as a series of eight different continuous layers of sediments with variable thicknesses and hydraulic properties. Each layer extends across the entire island area. Four of the layers are aquifers which store substantial amounts of water. The other layers are aquitards, which are less permeable and allow flow, but do not store much water. It is important to note that while the fine grained units can hold large amounts of water, the ability to get a useful yield is quite low.

The model uses a record of daily precipitation, onsite sewage returns and interaction with surface water to provide inflow to the groundwater system. The precipitation moves through the system as evapotranspiration, runoff, or groundwater recharge. Outflow includes discharge to springs and streams, evapotranspiration, and groundwater pumping; however, the majority of the water that is infiltrated in the model ultimately goes to Puget Sound. The model simulates groundwater levels, flow and stream flow for the period from October 1, 2001 to September 30, 2004.

MODEL ASSUMPTIONS, OUTPUT AND QUESTIONS

Island-wide Water Budget Estimate:

The model was scoped to provide an estimate of the water budget for all of VMI that could be compared to previous water budgets. One significant difference in the water budget estimates is the amount precipitation assumed. Across the four estimates the precipitation assumption varies up to 6.7 inches per year. Precipitation assumed in the Phase II model is 43.8 inches per year average. This is a key assumption that affects all other parts of the water budget[2].

The GWPC observes that the 2002 and 2004 above-average water years occurring within the model simulation period would mask drought conditions. The current model and the Report do not address what happens to the water balance during drought, and looking at what happens during drought conditions should be a priority in any future work.

---

[2] *Note: The VMI annual average precipitation amount assumed in the model - 43.8 in/year - is significantly more than recorded short and long term SeaTac averages (37.4 in/year and 37.3 in/year respectively). VMI WRE precipitation data for years 2005-2007 was used and a complicated series of steps to calculate a VMI island wide estimated annual average and "scale" the model to represent VMI. The annual precipitation assumption is so central that it may be worth revisiting at some point. This assumption directly affects every other component of the water balance and even a difference of a few inches represents a huge water volume.*

***Future work/discussion**:* In order to insure sustainability of our water resources, the GWPC would like consideration of future work to analyze what happens to the water budget during drought conditions. For instance, what would our water budget be if it were based on the three driest consecutive years of record? How does this compare to the current model estimates? We understand "drought" would need definition for the purpose of the analysis, and that temperature is an important variable. Also, there are questions about how well the model captures seasonal variation that may need examination (see below).

Local Water Resources:

The Report offers detailed explanation of how features in the landscape and underlying geology combine to affect groundwater flow and storage from area to area. As noted above, the model represents the island as a series of eight different continuous layers. These continuous layers assume groundwater flow through very large areas, offering an abstract and greatly simplified representation of island-wide versus localized conditions.

This is illustrated by looking at examples of actual well log data from specific areas and comparing them to the model. See attachment: Comparison of deep well log data to model assumptions. The well log data does not synch up very well with model inputs in these locations. The model layering provides an island-wide rather than local approximation of conditions.

The model, because of its hydrological framework, also averages recharge and discharge (including pumping) over a much larger area than is likely to occur because of uniform hydraulic conductivity values. The GWPC is interested in whether this could lead to significantly underestimating local changes in water levels resulting from additional groundwater withdrawal.

The model is a simplification of complex Island geology, and as such cannot be expected to replicate actual conditions or specific locations. It is a reasonable tool for island-wide assessment of the VMI water budget but it should not be used for "prospecting" or attempting to determine the likely location of water. It would be inappropriate for use in resolving local water availability issues. Given the simplification noted, an important question is whether the model could lead to significantly underestimating changes in water levels.

***Future work/discussion**:* The GWPC would like to gain a better understanding of how well the model functions to represent changes in water levels due to additional withdrawal, especially in the shallow layers.

Stream flow:

By design, the model calculates runoff and groundwater discharge to streams as part of the water budget and was calibrated for base flow conditions. This leaves open questions concerning summer variability and low flow conditions. The sensitivity of stream flow to groundwater conditions in the model during extended dry periods should be known. Summer variability of stream flow is critical when studying the impact of future development and climate change, and environmental impacts on stream ecosystems.

***Future work/discussion**:* Basin specific calibration of the model is needed to come up with more reliable estimates of low flow conditions in island streams.

Vashon-Maury Island GWPC Overview and Comment - July 28, 2010: Vashon-Maury Island Phase II Hydrologic Model

Seasonal Changes and Water Availability:

The model was calibrated to represent average conditions (input data based on daily weather conditions & pumping over a 3 yr period), though minimum summer and autumn water levels and the dynamic range of groundwater levels are important in assessing water availability issues and groundwater discharge to streams. While not all monitored wells show a seasonal variability, evaluation of the model performance under variable conditions is warranted.

Future work/discussion: Maximum and minimum water levels can be calculated and compared to model predictions of water levels, including the timing. We are uncertain whether this is possible using the existing model results, or if it would require new model runs, but would like to discuss.

Monitoring Water Resources:

The GWPC is developing ways to measure and monitor for early indications of problems with our water supply. This is essential for insuring sustainability of our water resources. Information from the model can be useful in choosing monitoring sites and improving the monitoring plan. Shallow aquifers that have low recharge and storage relative to outflow are of interest in accomplishing monitoring that provides "early warning" of impending trends. These aquifers are also likely to have greater sensitivity to changes in water level, water quality and contamination.

Future work/discussion: The GWPC would like to explore how the model can be used with existing data sets (Critical Aquifer Recharge Area (CARA) and Areas Susceptible to Ground Water Contamination (ASGWC) to identify areas that are likely to be most sensitive to future impacts from development and climate change.

Model Scenarios:

A limited number of model scenarios, based on available budget, were chosen to assess the impacts of a variety of possible future build-out and climate change scenarios on water resources for the years 2000, 2025, 2050, and 2075. The general results show minimal to modest declines in mean and maximum groundwater heads and reductions in total and base stream flow, especially when climate change is considered.

The GWPC would like to consider additional model runs if this would be useful in addressing specific questions pertaining to drought conditions. Also, the initial scenarios run did not include maximum build out and climate change in 2075, and this is of interest.

Future work/discussion: The GWPC is interested in how drought conditions affect the water balance, and would like to discuss possible additional model runs specifically to simulate drought conditions. This is the highest priority item falling into the category of potential future model work identified herein.

FUTURE WORK

The GWPC has identified discussion and possible work items above related to the Phase II model, with consideration of drought conditions being a primary area of concern. We also want to stress the importance of improving on data collection and entry in future years, and furthering development of sustainability indicators for island water resources as priorities.

The modeling report includes many caveats related to input data, including the lack of actual Vashon water use data, long term rainfall records for VMI, and very little information on water quality. Data collection needs to improve, particularly in the following areas:

- Vashon water use data, such as may be obtained from water purveyor records in addition to recruitment of additional exempt well users
- Water quality data including components of Class A and B purveyor monitoring results that are required but not currently reported by KC Health Department
- Stormwater runoff
- Streamflow and
- Exempt well withdrawals

The GWPC has recommended working with the Health Department and water purveyors to build on WRE monitoring efforts and anticipates discussion with both.

The GWPC's 2010 work plan includes completing a list of sustainability indicators and accompanying measures – some of which translate into monitoring parameters. Parameters that may be particularly valuable (and cost-effective) in gauging the impacts of land and water use on water resource sustainability should be priorities in updating the WRE water monitoring plan.

The draft sustainability measures identified to date include monitoring water quality and flow in five creeks (Shingle Mill, Fisher, Judd, Mileta, and Gorsuch Creek) and sampling groundwater level and quality in 10 monitoring wells plus 8 volunteer sites. Ten groundwater monitoring wells measure water level and water quality in multiple locations and aquifer layers as shown in Table 2.

Table 2. Water Resource Evaluation groundwater monitoring wells sorted by Phase II Mike-She modeled aquifer layers (Note: source is Vashon-Maury Island Hydrologic Modeling Technical Report, Table 6)

Monitoring Well	Model Layer	Geologic Unit	Layer Type
MW 73	Lens	Qvr	Aquifer
	Layer 1	Qvt	Aquitard
MW 60, 61, 64, 65, 71, 72	Layer 2	Qva	Aquifer
No monitoring wells	Layer 3	Qpff	Aquitard
MW 64	Layer 4	Qpff	Aquitard
MW 63, 70	Layer 5	QAc	Aquifer
No monitoring wells	Layer 6	QBf	Aquitard
No monitoring wells	Layer 7	QBc	Aquifer
No monitoring wells	Layer 8	Qc	Aquitard

Vashon-Maury Island GWPC Overview and Comment - July 28, 2010: Vashon-Maury Island Phase II Hydrologic Model

The GWPC has requested increased sustainability monitoring data by collection of data from Group A and B water systems as available in the future. The WRE work plan includes collection of the sustainability measures in 2010 and in 2011. Synthesis, analysis and initiation of annual reporting of the sustainability indicators are scheduled to begin in 2011.

SUMMARY

It is important to recognize what the model was intended for: an island-wide assessment of water balance. It cannot provide guidance on conditions or decisions regarding specific locations on VMI and it cannot be used to predict the likelihood of successfully drilling for water at a certain depth at a specific location, or even a generalized area.

It also cannot resolve the fact that some areas of VMI have a lot of water and other areas have little. To use all the water the model says is available one would need to assume a much more extensive infrastructure of water storage, distribution and interconnections between systems to maximize theoretically sustainable use.

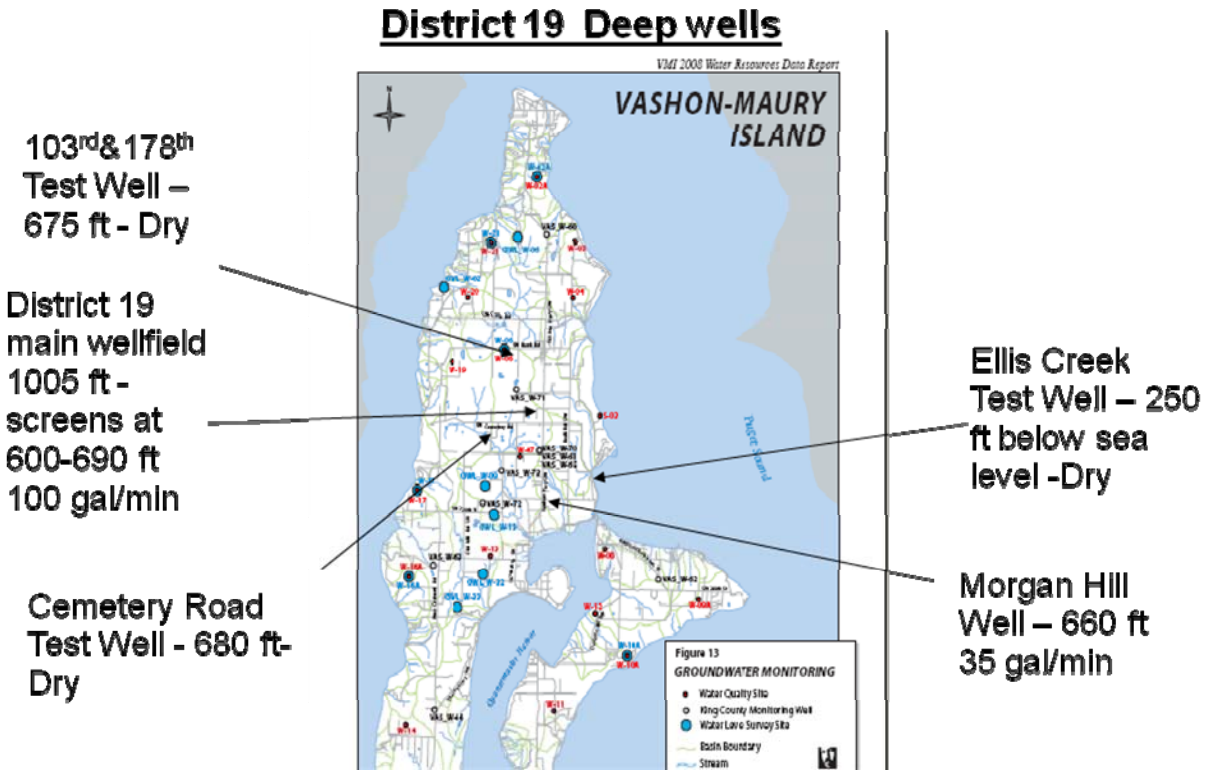
Data limitations must also be understood. While additional data and input may be collected and serve to improve the reliability of the model over time, there are currently significant data gaps, including but not limited to withdrawals from the many exempt wells serving approximately half of the island area that cannot be resolved by obtaining water purveyor data.

So far the model scenario outputs show that projected water withdrawals and assumed climate change will have modest impacts on Island water resources and stream flow over time, given average conditions. To better understand possible impacts of population and climate change, critical water years and low flow conditions must be analyzed. Also, additional focus on the model calibration process and climate change data sets may be needed to better understand sensitivity of the water budget to variations.

The GWPC appreciates the rigorous efforts undergone to construct the model. The VMI Watershed Plan is shaped by an emphasis on taking protective actions to ensure sustainability of a sole source aquifer system over the long term, and the focus of the Committee is on protection to avoid problems, not trying to solve them after the fact. The Committee would strongly object to interpolations for use in Island wide land use planning based largely or strictly on model outputs, or representation of the model as being a tool with value for resolving localized water issues.

Moving forward, the GWPC would like to stress: working with the WA Department of Health, island water purveyors and private well users to obtain and input data from available or under represented sources; increasing the exempt well monitoring effort such as by increasing recruitment efforts; continuing ongoing long term monitoring and data input; and considering model scenario runs that could realistically address the impacts of increased water withdrawal and climate during low water years and drought at some point in the future. While the GWPC encourages increasing and improving water data collection and model input in the near term, it does not recommend further work on the model at this time.

Attachment: Comparison of deep well log data to model assumptions

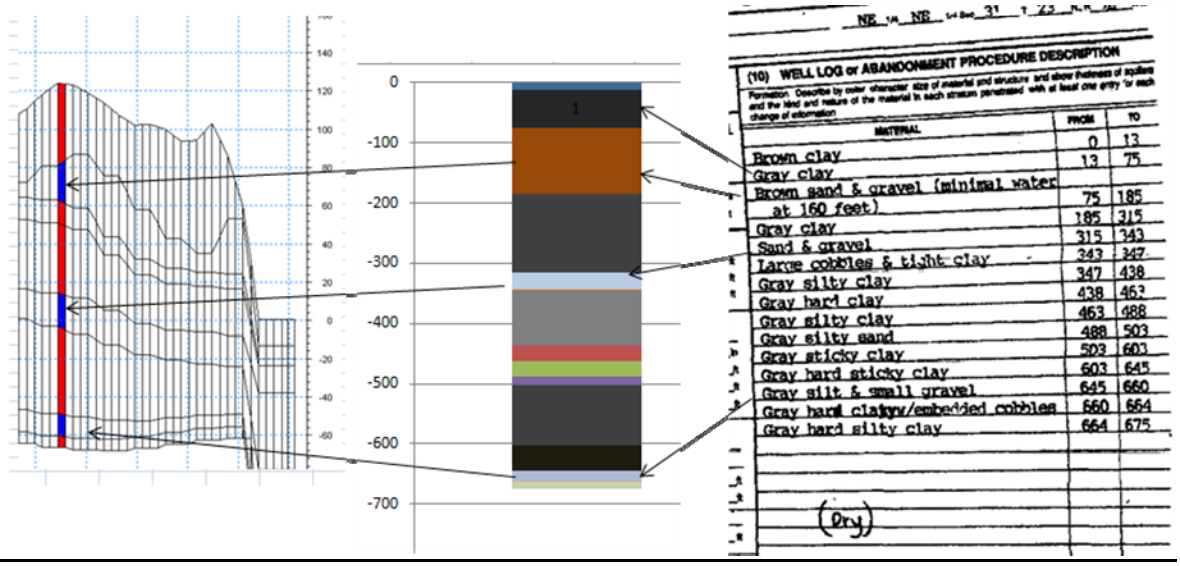


The Figure above shows the deep wells that were compared to the computer model, as a reality check. There are only a few deep wells on the Island. The deep well logs at these locations were entered in Excel and graphed, so that the scale of the layers could be quickly, visually assessed. Note that three wells are dry, which is the situation for a fairly large portion of the Island. The model is based on three hypothetical continuous aquifer layers that extend across the entire Island.

At 103rd and 178th: Comparison of computer model vs well log

Computer model shows 3 continuous water bearing layers

Well log shows a dry well, overlain with hardpan. Well has gravel, but little water



Morgan Hill – North-South Cross-section