Pump Test and Delineation Plan Guidance
New Well Sources for
Large (>250 served) Community Water Systems

This document is intended as guidance in the preparation of pump test and delineation plans. The recent revisions to the Drinking Water Regulations, Section 3 G adds requirements for community wells. The goal of the process is to reliably identify the sustainable yield of the well and the location and extent of its contributing area. Applicants are encouraged to develop site-specific plans based on the local hydrogeologic conditions. The guidance in this document represents the minimum acceptable practice for pump testing and delineation. While this document is intended for large community sources, and is focused on unconfined sand and gravel wells, it is also generally applicable to large-capacity bedrock well development and testing. Confined aquifers may require different assessment techniques.

A previous version of this document was provided to consultants for comments. This revision reflects their comments. It draws on both current practice in Maine, and on standards and regulations in other New England states. Comments and suggestions for further improvement are encouraged. We expect that this guidance will be revised periodically, as our experience base grows.

Process Overview:

The applicant and their geologist will contact the DWP and schedule a pre-exploration meeting before expending significant resources on land acquisition, exploration, and/or testing. Potential sites will be reviewed, and preliminary approval for an exploration plan will be provided.

Once exploration has identified a likely development site, a certified geologist will develop a conceptual hydrogeologic model of the source of water for the proposed site. This model provides the basis for developing the pump test and delineation plan. Elements of a **conceptual hydrogeologic model** include:

1) Provide a description of the geology and geologic history of the area.
2) Generalized geologic cross-sections through the aquifer based on available information such as well logs, geologic reports, maps, and subsurface data.
3) A description of:
   a) Aquifer flow;
   b) Hydraulic boundaries;
   c) Recharge conditions;
   d) The interaction of the source of the withdrawal with surrounding water resources;
   e) The estimated zone of contribution;
   f) And any potential sources of contamination within the zone of contribution.
4) A conceptual groundwater flow net map for the aquifer and its recharge areas based on available data, which shows:
   a) Hydraulic head contours; and
   b) Groundwater flow directions in both horizontal and vertical planes under average, ambient, non-pumping conditions for the aquifer being considered and its recharge areas.

The conceptual hydrogeologic model will be refined based on results of the pumping test performed in accordance with the pump test plan and presented in the final report.

The pump test plan should contain location, construction, and purpose of at least three (and usually five or more) monitoring wells. It shall also include the planned pumping rate, duration, and frequency of monitoring. Pump tests should not be scheduled during the late winter/early spring season, as significant recharge events are likely to make data interpretation difficult. A minimum test shall include:

1) Confirm the adequacy of any existing Monitoring Wells (MWs).
2) Establish additional MWs so that a near field (2-10 ft from the pumping well) and at least two far field (~100 ft from a pumping well) MWs in the primary direction of ground water flow. MWs should be installed to monitor the flow system that feeds the well. MWs should be screened within 10 ft of the observed water table for shallow gravel wells. In some cases, driven points may be successful. Wells must have an adequate diameter (2 inch minimum) to allow installation of transducers for water level measurement.
3) Locate or establish a monitoring well to document background water levels in an area of the aquifer (or adjacent aquifer) that will not be influenced by pumping the well.
4) Ground water near surface waters that may represent sources of induced recharge should be monitored.
5) If significant potential contamination sources are identified, monitoring wells shall be installed to assess the potential for interaction between the source and the proposed well.
6) Survey the location and elevation of the MWs relative to the existing well(s) to the nearest 1 ft horizontal and 0.01 ft vertical. Where applicable, survey distance and elevation of all adjacent streams/lakes/rivers/wetlands.
7) For sites with potential surface water connection, establish a staff gage or transducer in nearby surface water bodies at the point of survey.
8) Monitor water levels in the MWs for two weeks on a daily basis to establish a level and trend. Read staff gage daily throughout this period, and at least twice daily during pumping.
9) Install transducers and data loggers capable of collecting water level data within the expected range of variation to a precision of 0.01 ft, unless the expected variation requires a lesser precision. Loggers must be capable of collecting data in log-cycle intervals for pump test analysis. (See time list below)
10) Conduct a step test, as required, to assess the hydraulic characteristics of the well itself. Allow the well to recover completely from the step test.
11) For all surficial wells the pump test shall be run for at least 48 hours and continue until stabilization has been reached or for 5 days, whichever is less. Stabilization is considered to be reached when the drawdown reading at an observation well near the production well or the production well has not varied by more than 1/2 inch (0.04 feet) during the preceding 24 hour period. An alternative definition of stabilization may be proposed by the applicant and must be reviewed and approved by the Department prior to implementation. The proposal must be prepared by an appropriately qualified person or firm. (*Note: this is an excerpt from the regulations, inserted here for clarity)*

12) Measure and record flow from well to the nearest gallon per minute. Also note operation times and flows of any other nearby wells, gravel mining dewatering operations, or other withdrawals (e.g. spring flows) from the aquifer during the entire period of observation.
13) The well should then be shut down for a period equivalent to the length of the pump test to observe recovery of water levels.
14) Observe precipitation during the period of monitoring. Either use a nearby National Weather Service station or establish an informal rain gage at the site and note timing and amount of precipitation during the pump test.
15) During the background, pumping, and recovery periods, collect water level data from the MW's and, if possible, from the pumping well, using the guidelines below.
16) Based on the conceptual hydrogeologic model, the DWP may require additional testing and evaluation or otherwise modify these parameters.

Recommended minimum data collection pattern

Time since pumping started/stopped	**Minimum frequency of measurement**
0-10 minutes	Once per minute
10-100 minutes	Every five minutes
100-1000 minutes	Every 30 minutes
1000 + minutes	Every 60 minutes

Additional data may be collected beyond these minimums if the particular data logger program, or local site conditions require different steps. For more complex sites, additional monitoring locations may be required to gain an adequate understanding of the flow system. Data analysis and reduction should be guided by methods outlined in Lohman (USGS PP 761) and Driscoll (Groundwater and Wells), or other standard hydrogeologic references. The plan should include the proposed methods of pump test analysis.

Safe Yield Evaluation

Data analysis should include an analysis of safe yield of the aquifer and well based upon some or all of the following:

- Analysis of recharge to the site under normal and drought conditions.
- Potential for contamination by existing contaminant sources.
- Potential for salt water intrusion.
- Potential for full zone of groundwater contribution to extend into areas where land uses cannot reasonably be controlled.
- Extrapolation of drawdown to 180 days without significant recharge.
- Significant adverse impacts (quality or quantity) on neighboring wells.

Delineation of contributing areas to a community water supply well requires the application of appropriate geologic information and methods to assess ground water flow and the influence of boundary conditions. Unless the aquifer is homogeneous and isotropic and no near-field boundary conditions are present, analytical methods (e.g., WHPA, stagnation point calculations) will not provide realistic results. For most sand and gravel wells, surface water bodies provide positive (recharge) boundaries, and the edges of the deposit provide negative (barrier)

boundaries. These conditions influence the contributing area significantly, and cannot be adequately simulated by common analytical methods.

A Maine Certified Geologist who is familiar with the conditions at the well site shall perform the delineation. The Department encourages the Geologist to consult with Source Protection staff in the selection of an appropriate delineation method. The goal of wellhead delineation is to provide the public water supplier with an area that is most likely to provide recharge to the well. This area must be reasonably sized, and appropriate to the anticipated yield of the well.

Department policy requires the use of delineation methods that allow for the calculation of travel time boundaries at 200 and 2,500 days, as a minimum for all wells located in surficial deposits that supply community systems with populations serving greater than 250 people. Evaluation of pump test data, well logs, surficial mapping, and hydrogeologic evaluation all should be inputs to the delineation. Methods must be at least as rigorous as those used in the Maine Geological Survey delineation project. Such methods may include both semi-analytical models like WHAEM and fully discrete models like MODFLOW-MODPATH. Delineations derived from WHPA code models are not acceptable, unless the responsible geologist can explicitly demonstrate that there are no boundary conditions that will influence the contributing area to the well.

For new large community supplies in bedrock, the method applied shall be at least as rigorous as that used in the MGS bedrock delineation project. This method does not attempt to calculate travel times, but does perform a structured sensitivity analysis that yields a series of probability zones for contributing areas.

MGS Delineation Protocol

This protocol is intended to be descriptive of a method shown to be effective in a number of settings. There are other methods that will also produce time-of-travel zones for community water supplies. Use of this or other delineation protocols should be reviewed with DWP staff during the pump test design stage of well development.

The MGS used MODFLOW and MODPATH, well-documented USGS models, with the Groundwater Modeling System, developed by the US Army Corps and Brigham Young University, as a pre- and post-processor. Regional aquifer, well and surficial coverages from MGS mapping along with USGS digital elevation models provided starting points for discretization. All locations were geo-referenced to UTM coordinates to match the DWP GIS database.

Developing a digital (numerical) model of the aquifer allows for the simulation of boundary conditions as well as heterogeneity within the aquifer. Digital modeling is appropriate for projects with sites where there are clear indications of near-field boundary conditions or large aquifer heterogeneity. Modeling offers a more precise delineation of travel times, which may also be more accurate if the aquifer and boundary condition types are well defined.

In order to make digital modeling feasible, the MGS used a standard set of GIS coverages, aquifer characteristics, and hydrologic parameters to develop simulations for each site. Details of these assumptions are shown in the attached samples of surficial and bedrock delineations.

Reporting

Key reports in this process are the Pump Test/Delineation Plan and the Hydrogeologic Report documenting the results of the pump test and delineation. The Plan is required to obtain preliminary approval for well development. The Report is required for final approval of the well. The submission also must fulfill all other requirements of the Drinking Water Regulations for New Source Approval.

The water quality data submission should be bound separately from the Hydrogeologic-Delineation Report, as they are filed separately at the DWP.

The DWP encourages PWSs and their consultants to meet with DWP staff early in the exploration process in order to minimize the potential for expending resources inappropriately. During exploration and development, conditions are often encountered that lead to a change in approach. This is also a good time to meet with DWP staff.