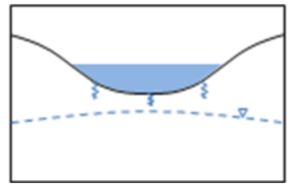
Recharge Lake/Wetland: Generalized Monitoring Strategy



General Hydrologic Characteristics of Recharge Lakes & Wetlands

The primary sources of water for recharge lakes and wetlands are direct precipitation and surface runoff. The lake stage of a recharge lake or wetland is higher than the surrounding (and underlying) water-table elevation. If the water-table elevation is several feet below the bottom of the lake bed, the lake will be perched and their will be no direct interaction between groundwater and lake. In the case of a perched system, pumping will not affect lake levels or leakage rates from the lake or wetland and monitoring of pumping effects is not necessary.

Where the water-table elevation is higher than the lake bed elevation (but lower than the lake stage elevation), hydraulic gradients will be from the lake to the water-table aquifer and the lake/wetland will leak (or recharge) water into the water-table aquifer. The rate of leakage is dependent on (1) the hydraulic head difference between the lake and the water table and (2) the permeability of the lake's bottom sediments.

Generally, recharge lakes are relatively deep compared to recharge wetlands. The water table is lower than the lake elevation but at or above the bottom elevation of the lake. Pumping in the area has the potential to lower the water-table elevation, causing an increase in the hydraulic head difference between lake/wetland and water table, and resulting in increased leakage from the lake to the water table. Increased leakage can result in a lowering of the water surface of the lake until it finds a new equilibrium.

Because recharge lakes and wetlands depend on surface inflows for a large portion of the overall water balance, it is important to try to quantify the surface-water inflows. If there are streams entering or exiting the lake or wetland, their contribution to the water balance of the lake can be estimated through some form of gauging. Depending on the setting, the gauging may be seasonal or more continuous. Stilling wells in the lake, equipped with automated stage recorders, are helpful for recording the fluctuations in lake stage and correlating these fluctuations with surface hydrology and climatological processes.

Generalized Monitoring Plan

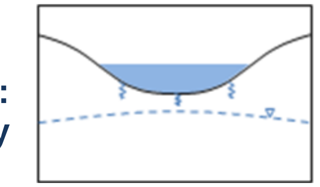
Although every setting is unique – monitoring plans must take into account local conditions, existing monitoring programs, and coordination among overlapping governmental units – all monitoring should incorporate the following elements:

- Lake-stage monitoring
- Groundwater withdrawal rate monitoring
- Potentiometric level monitoring
- Monitoring of other parameters, as a local need is identified

Coordination and Reporting

Monitoring related to Recharge lakes/wetlands will require coordination with DNR, nearby water appropriators, WMO's (if applicable), lake associations, and Metropolitan Council (if applicable).

Data should be compiled annually in a report to coordinating agencies. All monitoring data should be compiled in electronic form. Alternatives to annual reporting could be a dedicated web site where data can be downloaded.



Typical Monitoring Costs

The following are approximate costs for a generalized monitoring program, as described above. It is important to recognize that local settings may differ from the generalized assumptions. For example, drilling costs for piezometers will vary, depending on the depth to the pumped aquifer (or if there is more than one pumped aquifer) and the need for well screens (instead of open hole intervals). There may be some cost savings realized if existing monitoring installations are already present (e.g., there is an established gauging station or a piezometer). These cost estimates should only be used as a starting point for estimating the actual cost of a particular monitoring program.

	Justification	Frequency	Equipment	Capitol Cost[1]	Variables	Annual Cost[1]	Variables
Lake Stage	Pumping may affect lake stage. Lake stage is crucial to habitat and recreational use	Hourly or less	A piezometer, pressure transducer, and data logger in a stilling well	$100 to $3,000	Assumes dedicated pressure transducers and data loggers. Remote telemetry estimated to cost additional $3,000 per piezometer.	$100- $1,000	Assumes that downloading of data would occur along with piezometer transducer downloading)
Groundwater Withdrawal ▫ All pumped wells	Accurate and precise data are crucial to understand the relationship between pumping, changes in water level (i.e. drawdown).	5 minutes or less	SCADA-controlled data loggers in all pumped wells	$ 0 to $40,000 (assumes existing SCADA)	Electronic tabulation of flow rates for each well at 5-minute intervals may require modifications to existing system	$0 - $2,000	Cost dependent on SCADA system and requirements for manual formatting of tabulated data
Potentiometric Levels ▫ Near lake, in direct line with pumped wells	Change in aquifer water level is a key indicator of potential effect on lake stage.	15 minutes or less	A piezometer, pressure transducer, and data logger at each site	$ 15,000 to $30,000	Depth of piezometers; need for well screens (assumes 2-inch diameter piezometers)	$1,500	Well maintenance fee to MDH,
Other Parameters	These data provide indicators of the overall health of the stream and its capability to support trout habitat	Hourly or less		$ 3,000 to $4,500	Assumes dedicated pressure transducers and data loggers. Remote telemetry estimated to cost additional $3,000 per piezometer.	$2,000	Assumes quarterly downloading of data by well-owner staff. Add $150 per piezometer for annual data from telemetry (if used)

[1]The above costs do not include costs for conducting aquifer testing (which may be a Water Appropriation Permit requirement for a new pumping well). Annual costs include an estimate of staff costs to the well owner for data handling and maintenance.

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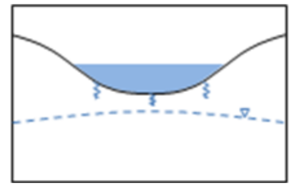
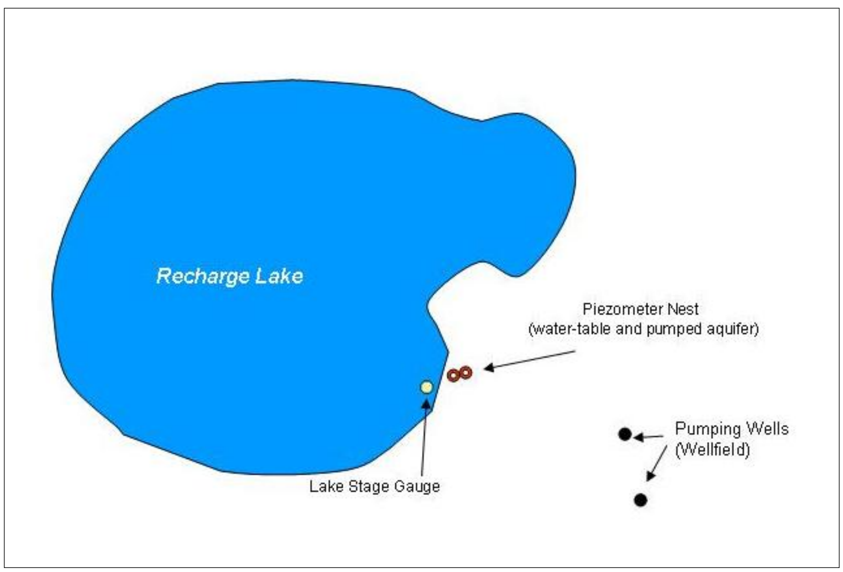
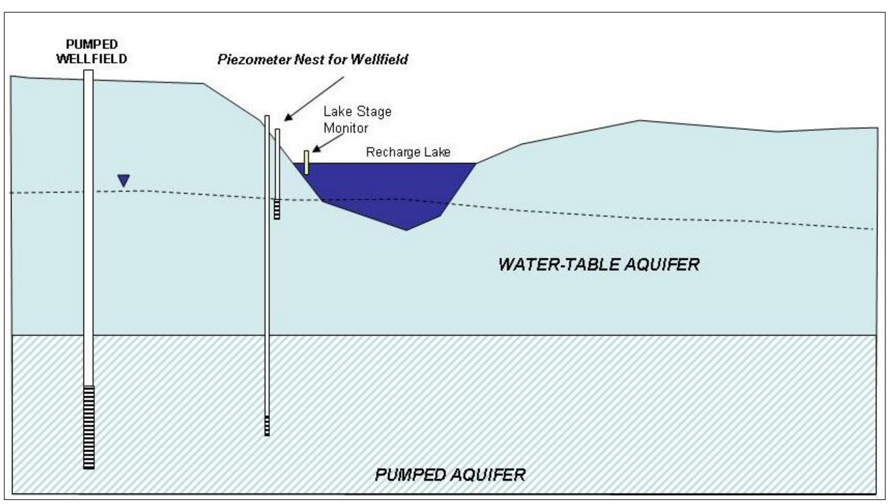


To facilitate the discussion of monitoring programs, a generalized hydrologic setting for a Recharge lake is presented.

The Recharge lake is assumed to:

(1) no surface-water outlet;
(2) groundwater inflows that are less than groundwater outflows;
(3) have high-capacity groundwater pumping in the region near the lake; and
(4) pumping is from an aquifer deeper than the surficial water-table aquifer..





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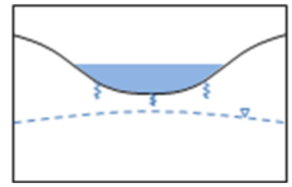

A generalized monitoring system and program consists of the following:

Groundwater Withdrawal Rates

Purpose

Accurate and precise pumping rate measurements for individual wells are crucial to understanding the relationship between pumping, changes in potentiometric levels in the aquifer (i.e. drawdown), and lake-wetlands stage. Before a causal link can be established, correlations need to be developed between pumping and responses in the aquifer and lake. These correlations cannot be relied upon unless the data are accurate, precise, and frequent. These types of data are important not only in establishing a potential causal effect but also to refute the existence of a hypothesized effect.

Location(s)

Each high-capacity pumped well

Measurement Frequency

Groundwater withdrawal rates must be accurately measured and recorded on a continuous basis for each high-capacity pumped well. At a minimum, measurements should be made every 5 minutes or less.

Equipment/Method(s)

SCADA systems should be capable of measuring and tabulating flow measurements on an interval of approximately 1 minute or less. Electronic tabulation (such as spreadsheets) should be developed and maintained for each well that provides a continuous record of pumping rate at the above interval. Each flow measurement should correspond with an accurate date and time.

Potentiometric Levels

Purpose

In general, high-capacity pumping will affect surface water bodies only if the pumping also affects potentiometric levels in the aquifer that is being pumped and the water-table aquifer. In other words, in order to affect stage elevation of surfacewater bodies, pumping must induce drawdown. But, it is important to understand that the absence of observed drawdown effects near surfacewater features is not, by itself, an indicator that pumping is not affecting the gaining feature. It is possible that pumping even far away from a gaining feature can capture groundwater that would otherwise flow into the feature without ever inducing measurable drawdown in the groundwater system at the gaining feature.

Data from piezometers located between pumping centers and the lake will provide an indication of how extensive the pumping center's cone of depression is and how it changes over the course of a year. The purpose of the well nests adjacent to the trout stream is to correlate changes in the potentiometric surface of both the pumped aquifer and the water table aquifer with stream flows. These data are useful in developing a causal relationship between pumping, potentiometric heads, and lake stage They are also useful in determining if changes in lake stage are in response to local pumping or to regional effects, such as regional pumping (many miles away) or climatic/meteorological conditions.

Location(s)
It is recommended that a nest piezometer be installed approximately next to the lake/wetland, in direct line with each pumping center (i.e. well field) and the lake/wetland and completed in the pumped aquifer. The piezometer nest should consist of one piezometer screened at approximately the same interval as pumping wells in the area and one piezometer screened across or just below the water table.

Measurement Frequency
Such systems are capable of recording head measurements at intervals of 15 minutes or less – a frequency level that is recommended. At a minimum, measurements should be made every 15 minutes or less.

Equipment/Method(s)
Piezometers in bedrock units (i.e. pumped aquifers) should have screens or open-hole intervals that span at least one transmissive zone (e.g., significant horizontal fracture) but should not span the entire aquifer. A screen or open hole interval of less than 20 feet would be preferred. The screen or open hole should preferably be at approximately the same stratigraphic horizon as the mid-point of the open hole portion of the pumped well(s). Water-table piezometers should have screens no longer than 10 feet. In all cases, piezometers should be equipped with pressure transducers and automated data logging systems. They are typically much more cost effective and precise than manual measurements. A system for a single piezometer is usually less than $2,000 and requires download of data on a quarterly basis. Remote telemetry and/or interface with SCADA systems is also possible.

Lake Stage Monitoring

Purpose
To a great extent, concerns over the effects of pumping will relate to lake/wetland stage because lake/wetland stage is a parameter that many users of the lake or wetland will be most keenly aware. Many lakes have a record of lake stage levels, collected usually by volunteers. Most wetlands do not. Some of these records are good and some are of uncertain quality. Most are not collected frequently enough. For lakes and wetlands near high-capacity pumping areas, reliably establishing the natural fluctuation of lake stage is very important..

Location(s)
The location for lake stage monitoring should be at a readily accessible but protected location (to minimize disturbance, accidental damage, and vandalism).

Measurement Frequency
Ideally, hourly measurements would be ideal. Daily measurement should be a minimum frequency.

Equipment/Method(s)
Lake stage should be recorded using stilling wells (to protect from wave action and other interferences) and automated pressure transducers (or other automated stage recorders). Manual staff gauge measurements could augment automated measurements on a bi-weekly to monthly schedule. If there is the capability to manual measure on a regular basis (e.g., there are volunteers from a lake association), manual measurements with a staff gauge could substitute for a stilling well with automated measurements.

Other Parameters
Purpose
Temperature, dissolved oxygen, and specific conductance data provide indicators of the overall health of the lake/wetland.

Aquifer test pumping of new wells can allow for quantification of aquifer parameters and regional drawdown effects.

Groundwater flow modeling is useful in evaluating the vast amount of data that will be collected over time.

Location(s)
Temperature, dissolved oxygen, and specific conductance data may be collected at stream gauging stations or lake stage monitoring locations.

Aquifer testing may be done on existing or new pumped wells.

Measurement Frequency
Temperature, dissolved oxygen, and specific conductance data may be collected using automated measuring equipment for relatively low cost.

Equipment/Method(s)
New wells should have some sort of aquifer (pumping) test performed to quantify aquifer parameters and regional drawdown effects.