SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

The following is an excerpt from the Recharge Ponds Monitoring Method [MM-02]

SGM Grant Program Requirements for Post-Performance Monitoring and Reporting

Recharge Ponds Monitoring Method

Project / Action Type	Recharge Ponds are an effective means of storing water in aquifers via constructed infiltration basins. The recharge pond facility would be designed (pond size, depth, and layout) to accommodate surface and sub-surface site conditions.
Similar / Related Project Types	Infiltration galleries comprise another managed aquifer recharge (MAR) method/project that has similar or overlapping implementation approaches, requirements, and monitoring methods to recharge ponds. Infiltration galleries are in the subsurface. Indirect potable reuse (IPR) and stormwater capture projects can be implemented using recharge ponds.
Metrics	Groundwater levels. Groundwater storage. Applicable water quality constituents Change in ground levels (situationally). Surface water flow rates (situationally). Surface water stage (situationally). Groundwater dependent ecosystems (situationally).
Measurement Units	Groundwater levels measured in feet in a consistent vertical datum. Recharge/demand volumes in acre-feet. Concentration or measurement of applicable groundwater quality constituents (typically mg/L).
Beneficial Users	Municipal and domestic water supply (MUN) Industrial service supply (IND) Industrial process supply (PROC) Agricultural water supply (AGR) Groundwater recharge (GWR) Freshwater replenishment to surface waters (FRSH) (situationally)

Approach to Implementing Recharge Pond Monitoring

Recharge ponds can be used to increase groundwater recharge and benefit sustainability indicators. The recommended monitoring methods for measurement and tracking of project benefits and impacts include groundwater levels, groundwater and source water quality, water flow (delivery) rates, and infiltration rates. These data comprise the relevant parameters for assessing performance of MAR using recharge ponds. If the project falls under a GSP, performance standards and recharge goals for each GSP project can be developed based on relevant conditions and criteria for the recharge site.

Justification

These recommended monitoring methods for recharge ponds can provide monitoring data of sufficient accuracy and quantity to assess whether the recharge project providing benefits to the groundwater users and if applicable if the project is meeting goals established by the GSP (sustainability criteria). Monitoring actual recharge performance using the appropriate methods can evaluate groundwater level responses, groundwater quality benefits and impacts, recharge rates, volumes, and aquifer storage capacity. Monitoring these properties during recharge pond operations helps the project proponent develop aquifer management strategies to achieve sustainability. The monitoring description below is divided into the primary monitoring that can be conducted to assess whether the project is providing groundwater sustainability benefits; secondary monitoring that would be beneficial to track the overall project benefits both groundwater, social, and economic; additional useful monitoring that could help track overall project performance and help establish useful metrics for future project implementation.

Primary Monitoring

Groundwater level and groundwater quality monitoring are the primary monitoring for assessing benefits and impacts of recharge pond projects. The monitoring approaches for these parameters are discussed in detail in the step-by-step guide to applying methods below.

Secondary Monitoring

Monitoring the volume and rate of water applied and recharged is an important consideration to assess project operation. The volume of applied water could be measured at the project diversion point. After the water is diverted, there are system losses that could be accounted for and calculated as part of the groundwater recharge volume.

Other Useful Monitoring

A water budget may be useful to assess the project benefits. A calibrated groundwater model can be used to estimate the total volume of groundwater recharged and how much water was lost to evapotranspiration, lateral flow to other areas, discharge to streams, etc. Quantifying the water budget for recharge pond projects with field monitoring is possible; however, this can be challenging and costly with the technology that is currently available.

In some cases, other sustainability indicators might benefit from recharge pond projects. Monitoring for the depletion of Groundwater and Surface Water Interactions (MM-07), Seawater Intrusion Management (MM-08), and Subsidence Management (MM-09) sustainability indicators are discussed in their respective Monitoring Methods.

A Step-by-Step Guide to Applying the Recharge Pond Method

Implementation of an appropriate and effective monitoring for a recharge pond project includes the following strategies and steps:

Safety plan: All projects with fieldwork related activities should produce a Safety Plan. Planning for fieldwork and availability of access to the site, such as monitoring wells, is necessary to maintain project safety. Recharge pond projects may require a Safety Plan to address these and other potential safety concerns.

Primary Monitoring Method

1. **Design a monitoring well network, if applicable the network should be consistent with GSP Regulations and guidelines specified in DWR's Best Management Practice (BMP) 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016):** The monitoring network may be capable of capturing data on a sufficient temporal frequency and spatial distribution to demonstrate short-term, seasonal, and long-term trends in basin conditions for each of the relevant sustainability indicators and provide enough information to evaluate project performance. The location of the monitoring network should be easily accessible such that gaining access to the site does not inhibit gathering and downloading data. The following steps may be taken to design the monitoring network:
   - Determine the number and appropriate locations for monitoring wells and vadose zone piezometers based on site-specific and nearby hydrogeologic conditions (see example in Figure 1) and on non-hydrogeologic aspects such as land ownership, proximity to other beneficial water uses, contaminant sources, and subsurface structures. Useful considerations, guidelines, and applications for locating monitoring wells at recharge project sites are provided *in Standard guidelines for managed aquifer recharge, ASCE/EWRI 69-19 / American Society of Civil Engineers* (American Society of Civil Engineers, 2020).

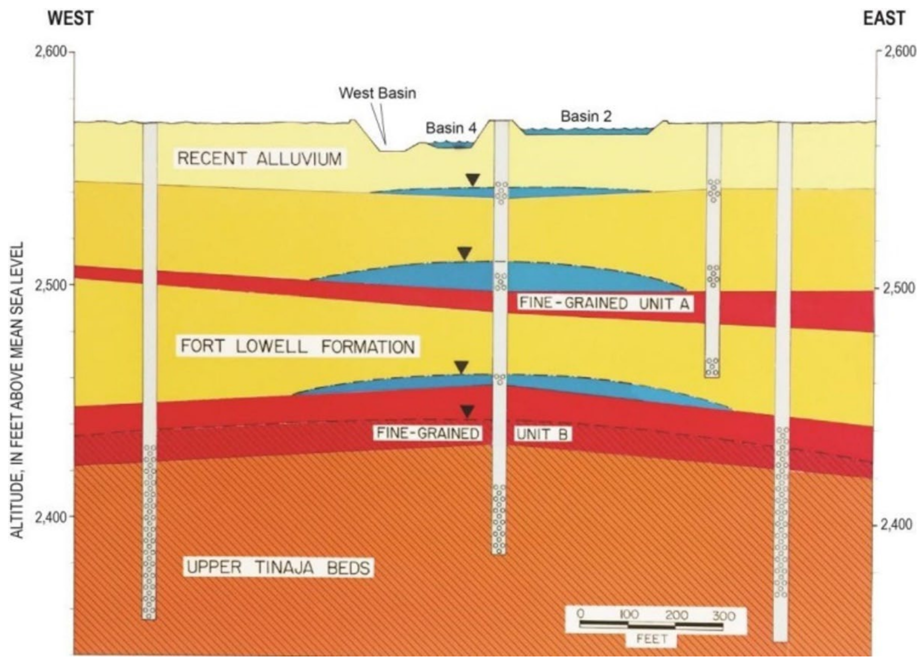

***Figure 1*. Example recharge pond facility showing the localized hydrogeology with location and depth of monitoring wells for monitoring and measuring the project benefits to groundwater sustainability.**

   - At a minimum, one monitoring well may be located up hydraulic gradient from the recharge pond and one monitoring well may be located down hydraulic gradient from the recharge pond to provide data for evaluating effects of recharge on groundwater levels and groundwater quality. However, three or more monitoring points would be needed to determine the magnitude and direction of the local hydraulic gradient in a given aquifer or aquifer zone, or to monitor more than one aquifer or aquifer zone. Projects using recycled water as the source are required by California Title 22 to have two downgradient monitoring locations between the recharge pond and downgradient drinking water wells. For further information on this subject, refer to the Indirect Potable Reuse Monitoring Method (MM-05).
   - The spatial extent and frequency of monitoring for groundwater levels and groundwater quality will depend on background conditions and size of the recharge pond. In general, more spatially extensive monitoring can be needed for larger recharge ponds, projects with multiple ponds, and for sites with larger recharge rates. Monitoring may be more frequent for areas that are subject to larger fluctuations in groundwater conditions (for example, fluctuations in pumping or natural recharge in the surrounding area).

   - Development of the monitoring well network may consider both unconfined and confined aquifers, and screened intervals and annular seals for monitoring wells should be carefully designed to target the specific aquifer or aquifer zone being monitored.

2. **Refine the specific "monitoring plan" if significant data gaps are identified based on results of initial monitoring:** The monitoring network should be dependent upon the initial hydrologic conceptual model and available data and will likely undergo refinement both temporally and spatially as recharge operations proceed and data are obtained that improve understanding of the monitoring needs so that necessary information can be efficiently integrated to demonstrate sustainability.
3. **Evaluate construction considerations for the monitoring wells and vadose zone piezometers:**
   - Wells that are part of the monitoring program may be dedicated groundwater monitoring wells with known construction information. The selection of wells may be aquifer-specific and wells that are screened across more than one aquifer may be avoided where possible.
   - If existing wells are used, the screened intervals may be known to interpret and utilize the water level or water quality data collected from those wells.
   - Monitoring wells and vadose zone piezometers may be drilled and installed in accordance with DWR Bulletin 74-81 and 74-90, or as updated.
   - When possible or feasible, use of a casing advancement drilling method may be advantageous because it uses no drilling fluids and seals off the borehole wall, which provides better lithologic information (representative cuttings of the depth interval being drilled) than rotary drilling methods. For vadose zone piezometers, either the hollow-stem auger method or a casing advancement method may be used because the piezometers cannot be developed to remove drilling fluids.
   - New monitoring wells in an unconfined aquifer may be constructed in the upper part of the pre-recharge saturated zone with the screened interval extending above the water table to accommodate water level rise from recharge operations. The length of screen below and above the pre-recharge water table will depend on the range of seasonal fluctuation of background water levels and the anticipated amount of water level rise from recharge.
   - Vadose zone piezometers may be installed to the tops of potential impeding layers that may cause development of perched groundwater conditions and lateral flow. Vadose zone piezometers may also be installed to provide monitoring points between the recharge ponds and locations of sensitive subsurface structures, contaminated sites, and other features that could potentially be affected by shallow groundwater.
4. **Implement monitoring well and vadose zone piezometer monitoring:** Protocols for monitoring of groundwater levels and groundwater quality are addressed in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016). Selected notable considerations for implementation of monitoring include the following:
   - All monitoring should be conducted in such a manner to produce reliable, consistent, high-quality, defendable data (see example in Figure 2).

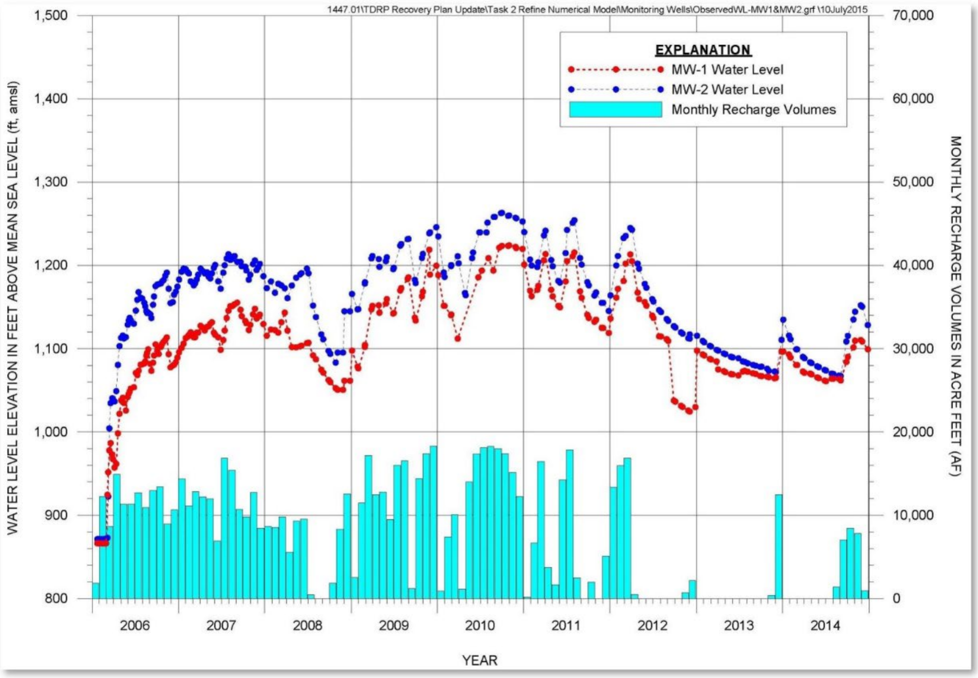

Figure 2. **Example groundwater level and recharge volume monitoring results provided in a high quality, reliable, consistent, and defendable manor.**

- Conduct "baseline monitoring" in the monitoring wells prior to commencement of recharge operations to document groundwater levels and trends, and to characterize ambient groundwater quality and trends. While baseline monitoring for groundwater levels and quality may be conducted at a minimum prior to commencement of recharge operations, collecting baseline monitoring for at least one (1) year before recharge operations during prior seasonal low and seasonal high groundwater level periods would provide a more robust dataset to compare to project implementation data should groundwater level or quality impacts occur.
- Following commencement of recharge operations, implement "operational monitoring" as required to evaluate changing groundwater conditions and associated risk (e.g., unreasonable harm to beneficial uses), and to better manage recharge operations; the monitoring frequency for groundwater levels and the sampling frequency and chemical constituents to be analyzed for groundwater quality monitoring will be determined by the project proponent and regulating agencies.
- While semi-annual monitoring is required for groundwater levels at the basin-scale, more frequent monitoring (such as quarterly, monthly, or weekly) can be necessary for some projects to provide a more robust understanding of groundwater dynamics within the system. More frequent monitoring of groundwater levels (regional aquifer and perched groundwater) becomes critical for recharge operations management if/when water levels rise close to land surface or to sensitive subsurface structures or affect beneficial uses.

Secondary Monitoring Method

1. **Implement monitoring of water deliveries starting at commencement of recharge operations:** Monitoring for instantaneous flow rates should be as frequent as practicable if conducted manually and are recommended to be hourly (or more often) if measured electronically (data stored in a datalogger or SCADA-type system). Measurements of total cumulative volume can be obtained commensurate with instantaneous flow rate measurements.
2. **Implement monitoring of infiltration rates:** Use either the wetting cycle calculation method (volume infiltrated during a wetting cycle) or falling-head method (rate of water level decline in a pond) described previously. For both methods, the water volume lost to evapotranspiration can be factored in, also described previously. The frequency of monitoring can depend on the rotation cycle for the ponds or the operator's discretion for managing recharge operations and planning rehabilitation, with the goal of maximizing infiltration rates and recharge volumes.

Data and Protocols - Fundamentals

Recharge pond monitoring typically consists of 1) measuring changes in groundwater levels; 2) monitoring groundwater quality impacts, and 3) monitoring recharge rates/volumes. Table 1 provides an example summary table of monitoring metrics that could be used for reporting on the benefits of recharge pond projects. **The fundamental monitoring metrics** for recharge ponds include the following:

– **Aquifer groundwater level monitoring** using wells or piezometers installed in the saturated zone for evaluating changes in groundwater levels and gradients due to recharge operations.

– **Vadose zone water level monitoring** in piezometers installed above perching layers (if present). Perched layers may cause water level rise close to land surface that could adversely impact infiltration rates and adjacent land and beneficial water uses.

– **Groundwater sampling of monitoring wells or piezometers** to evaluate water quality changes due to recharge. Recharge may result in blending of source water with ambient groundwater and/or mobilization and flushing of chemical constituents in the vadose zone as the water infiltrates.

Figure 3. Example collection of well data.

– **Volumes and flow rates of water delivered to the recharge ponds using flow meters** installed at the diversion points. Diversion points can be pipelines or canals that provide a variety of water sources including surface water, recycled water, and storm water.

– **Recharge pond infiltration rate** for evaluating project performance, determining management strategies (e.g., wetting and drying cycles, rotation or filling of multiple pond systems), and the need for pond rehabilitation. Recharge ponds are typically managed to maintain or maximize infiltration rates.

– **Water lost to evaporation** can be monitored as needed to accurately determine infiltration and/or loading rates and associated recharge volumes. Evaporation can be measured using standard evaporation pans installed at the recharge site or estimated using meteorological data that are available from relatively nearby meteorological stations and associated databases.

Table 1. **Example Data Monitoring Report (Generally Annually)**

Annual Monitoring Report	
Total Volume Entering Recharge Basin	XXX AF
Infiltration Rate	XXX in/hr
Evaporative Losses	XXX AF
Total Volume Entering Groundwater	XXX AF
Average Groundwater Level Change (Recharge Area / Background)	+/- XXX ft / +/- XXX ft
Average Groundwater Quality Constituent Change (list all identified, Recharge Area / Background)	+/- XXX mg/L / +/- XXX mg/L
Groundwater Basin Recharged	XX Basin
Incurred Costs	$XXX

The **fundamental monitoring tools** for recharge ponds include the following:

- Groundwater levels are measured manually using electronic sounders and automatically using pressure transducers lowered into and/or installed in the monitoring wells and piezometers. Groundwater level monitoring protocols are provided in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016). The use of dataloggers in association with pressure transducers allows automated collection and storage of water level measurements at frequent intervals.
- Primary tools for monitoring groundwater quality include dedicated or temporary pumps installed in the monitoring wells to purge the wells and obtain groundwater samples for laboratory analyses using protocols provided in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016). Passive sampling systems or bailers can also be used to sample, but it should be recognized that the method of sample collection could affect the constituent concentrations detected.
- Water deliveries are measured using flow meters installed in the delivery pipeline to measure instantaneous flow rate and total cumulative volume. For canal conveyance, instantaneous flow rates using flumes or weirs can also be used. Pressure transducers and dataloggers can be used to collect water pressure or head, that can be converted to flow rate using a discharge curve (see Flood-MAR Monitoring Method [MM-03]). Dataloggers allow for automated collection and storage of measurements at frequent intervals.
- Primary tools for measuring infiltration rates depend on the method used and can include 1) the flow meters described above to measure the volume of water added during a wetting cycle (then subtract evaporation losses and divide the remaining water volume by the pond area and by the wetting cycle time interval), or 2) a staff gauge (with pressure transducer and datalogger) to measure water level decline in a recharge pond during a falling-head cycle during which no water is added to the ponds.

Specific details for implementation of monitoring for a given recharge pond facility may be refined based on site conditions but should be commensurate with the complexity, risk, and sources of unreasonable harm for the proposed recharge pond operations.

Data Analysis and Reporting

1. **Analyze monitoring data:** Monitoring data can be used to evaluate the effectiveness and performance of the recharge pond, determine any limiting factors on performance, and identify options for improving performance if needed. This assessment also includes evaluating possible increasing concerns, as recharge continues, for causing unreasonable harm to nearby land or beneficial water uses and if/how recharge operations can be better managed to avoid significant risks.
2. **Prepare reports and manage data:** Includes compliance with regulatory and grant requirements and providing data to DWR, which is addressed in the Data Management and Monitoring Method (MM-12). Generally, data can be uploaded to the DWR system annually and progress on project implementation and monitoring can be provided in Annual Reports. In addition, a full assessment of the project performance can be provided in a 5-Year Assessment Report and may be required if the project falls under the direction of a GSP.

Data Standards

Groundwater, surface water, and water quality monitoring data should conform to the technical and reporting standards of the California Water Code (CWC) §352 *et seq*.

Groundwater levels - Groundwater elevation measurements should be recorded relative to a consistent vertical datum. A general rule of thumb for recharge pond projects is that groundwater levels shall not rise to within 10 feet of land surface due to recharge operations.

Groundwater quality - Concentrations of groundwater quality constituents of concern should be compared to maximum contaminant levels (MCLs) available from the SWRCB.

Key Protocols

The following protocols should be followed for required monitoring:

- Standard groundwater level and groundwater quality monitoring protocols as described in DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).
- Guidelines for establishing monitoring networks and resolving data gaps to reduce uncertainty are provided in DWR's BMP 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016).
- Technical and reporting standards included in CWC §352 *et seq*.

Additional guidance or references include:

- Standard guidelines for managed aquifer recharge, ASCE/EWRI 69-19 / American Society of Civil Engineers. (American Society of Civil Engineers, 2020)
- Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) Managed Aquifer Recharge. (National Resource Management Ministerial Council, 2009)