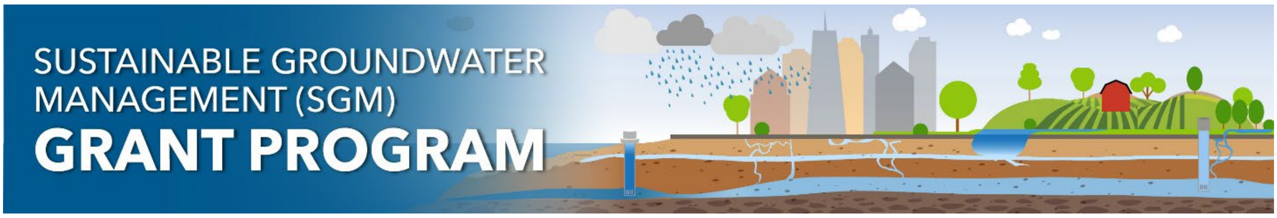


# California Groundwater Projects Tool Project

## Monitoring Methods

CALIFORNIA DEPARTMENT OF WATER RESOURCES

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# Notes and Acknowldgments

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# Scope and Limitations

These Monitoring Method (MM) has been prepared by GHD for the California Department of Water Resources (DWR) in an effort funded under Proposition 68 and may only be used and relied upon by DWR for the purpose agreed between GHD and DWR for their intended purpose.

The groundwater sustainability plan (GSP) Regulations specify that components of GSPs prepared pursuant to the Sustainable Groundwater Management Act (SGMA) require groundwater sustainability agencies (GSAs) to provide explanations of project and management actions (23 California Code of Regulations § 354.44). Nothing in these MM supersedes the GSP requirements as related to the development and implementation of GSPs, alternatives to a GSP, coordination agreements, and annual reporting requirements under SGMA. These MM were prepared under the SGMA Grant Program, which provides grant funding to support local agencies in implementing projects and actions that support efforts to reach groundwater sustainability goals.

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Data and information collected as part of this project was current as of June 2022. The California Groundwater Projects Tool Project was completed in August 2022. Since then, project specifics may have changed, and specific facts related to economic statistics as well as laws and regulations under development may have changed, and the information provided is based on the best available information to date.

SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

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SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

# Abbreviations and Acronyms

ACE – Areas of Conservation Emphasis

Ag-MAR – Agricultural or on-farm managed aquifer recharge

ASR – Aquifer Storage and Recovery

BCA – Benefit-Cost Analysis

BMP – Best Management Practice

B/C – Benefit-Cost Ratio

CASGEM – California Statewide Groundwater Elevation Monitoring

CGPS – Continuous Global Position Systems

CNDDB – California National Diversity Database

CWC – California Water Code or California Water Commission

DMS – Data Management System

DWR – California Department of Water Resources

ET – Evapotranspiration

Flood-MAR – Flood Managed Aquifer Recharge

GDE -- Groundwater Dependent Ecosystem

GIS – Geographic Information Systems

GIPP – Groundwater Implementation Projects Protocol

GPS – Global Position Systems

GRRP – Groundwater Reuse Replenishment Projects

GSA – Groundwater Sustainability Agency

GSP – Groundwater Sustainability Plan

GWRS – Groundwater Replenishment System

InSAR – Interferometric Synthetic Aperture Radar

IPR – Indirect Potable Reuse

ISW – Interconnected Surface Water

LID – Low Impact Development

MAMP – Monitoring and Adaptive Management Plan

MAR – Managed Aquifer Recharge

MCL – Maximum Contaminant Level

MGD – Million Gallons Per Day

MS4 – Stormwater from municipal separate storm sewers

NAVD88 - North American Vertical Datum of 1988

NPDES – National Pollution Discharge Elimination System

OCWD – Orange County Water District

PFAS – Per- And Poly-Fluoroalkyl Substances

QA – Quality Assurance

QA/QC – Quality Assurance and Quality Control

QC – Quality Control

Redox – Oxidation-Reduction Potential

RMP – Representative Monitoring Points

RWQCB – Regional Water Quality Control Board

SGMA – Sustainable Groundwater Management Act

SQL – Structured Query Language

SWRCB – California State Water Resources Control Board

TNC – The Nature Conservancy

USGS – United States Geological Survey

# Key Terms

**85th percentile (first flush) storm event** – Treatment and infiltration of the volume of runoff from the 85th percentile storm event. Flow-through systems are not part of the stormwater groundwater recharge projects.

## A

**Active (or direct) groundwater recharge** – Occurs through designed and constructed systems like injection wells or surface infiltration galleries such as ponds.

**Ag-MAR / On-farm recharge** – Flood-MAR in an agricultural setting.

**Allocation –** See groundwater allocation.

**Applied recharge** – Occurs from infiltration of agricultural and landscape irrigation.

**Avoided cost** – Costs that would otherwise be incurred in the absence of a project or activity but could be avoided by the project or activity.

**Aquifer** – A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant quantities of groundwater to wells and springs.

**Aquitard** – A confining bed or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but stores groundwater.

## B

**Benefit Cost Analysis (BCA)** – The overall process of calculating monetized benefits and costs of a project or activity and comparing them using standard metrics such as Net Benefit or Benefit Cost Ratio. The BCA process includes the physical quantification of all benefits, estimating the monetary value of all benefits and costs, when they occur over the project's life, converting the monetized benefits and costs to a consistent point in time using discounting, and then calculating one or more metrics.

**Benefit Cost Ratio (B/C)** – Present value of total quantified benefits divided by present value of total quantified costs (lifecycle costs).

**Bioswale** – A narrow strip of a vegetated area that redirects and filters stormwater. Bioswales are stormwater runoff conveyance systems that can absorb low flows or carry runoff from heavy rains to storm sewer inlets or directly to surface waters. Bioswales improve water quality by infiltrating the first flush of storm water runoff and filtering the large storm flows they convey.

**Borehole extensometer** – A measuring device designed to measure changes in length. Used in measuring displacement (movement) with a high degree of accuracy.

## C

**Casing advancement drilling method** – Drilling method for well and piezometer installation that uses solid casing to hold a borehole open while a separate stem with a drill bit is advanced for removing cuttings within the casing. This method can be used without introduction of drilling fluids for installation of vadose zone piezometers.

**Chemical oxidation injections** – In situ remediation technology for groundwater or soil where strong oxidants are injected or mechanically mixed into the treatment zone to promote destructive abiotic degradation reactions.

**Confined aquifer** – An aquifer that is bounded above and below by aquitards, or formations of distinctly lower permeability than that of the aquifer itself.

**Conjunctive management (use) of surface and groundwater —** Coordinated and planned management of both surface and groundwater resources to maximize the efficient use of the resource; that is, the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average surface water supply. Surface water and groundwater resources typically differ significantly in their availability, quality, management needs, and development and use costs. Managing both resources together, rather than in isolation from one another, allows water managers to use the advantages of both resources for maximum benefit

**Constituents of concern** – Any substance defined as a hazardous substance, hazardous waste, hazardous material, toxic substance, solid waste, pollutant or contaminant by an Environmental Law.

**Continuous Global Positioning System** – Continuously measures the three-dimensional (3D) position of a point on near the earth's surface.

**Cost benefit ratio** – see Benefit Cost Ratio.

**Cost effectiveness** – The lifecycle cost per unit of physical benefit achieved. A project is cost effective if it achieves a desired level of physical benefits (e.g., annual recharge volume) at the lowest cost per unit among feasible alternatives.

## D

**Data management system** – A platform capable of storing and reporting information relevant to the development and implementation of a monitoring plan.

**Demand reduction –** The management actions can reduce water use through water efficiency and water conservation measures

**Discounting** – Converting a monetized amount, either a cost or a benefit, to an equivalent amount at a different point in time (technically called compounding if the different point in time is in future). A discount rate is used to express the fact that human society prefers receiving benefits sooner and paying costs later, and the annual expression of this time preference is called the discount rate. The appropriate discount rate should be justified. The time preference exists even if no inflation is anticipated - the discount rate is not the same as expected inflation or expected cost escalation.

**Disconnected losing stream** – The groundwater is so far below the surface water that recharge occurs through an unsaturated zone (the vadose zone) to the water table.

**Disinfection by-product (also called trihalomethanes)** – Chemicals that are formed when chlorine disinfectant and bromine interact with natural organic materials in water.

**Distributed projects / Distributed stormwater projects** – Projects that retain rainfall and stormwater runoff on site (at end user locations) to infiltrate and replenish local groundwater basins. Examples of distributed recharge projects include green streets, park retrofits, permeable pavement, and bio-swales.

**Dormant crops** – see Flood-MAR dormant crops.

## E

**Ecological significance** – Supporting an ecological community that is identified as significant under legal terns, could be local, regional, statewide, or national significance.

**Enhanced in situ biodegradation** – The use of microorganisms to degrade contaminants in place with the goal of producing harmless chemicals as end products.

**Ex situ remediation (or excavation of contaminant sources)** – Refers to the removal of a substance from its natural or original position, such as the extraction and treatment of contaminated groundwater above ground.

## F

**Fallowed land** – Agricultural land that is maintained in good agricultural and environmental conditions but will not be harvested for the duration of a crop year.

**Fallowed fields** – see fallowed land

**Flood-MAR** – An integrated resource management strategy that uses flood water resulting from, or in anticipation of, rainfall or snow melt for managed aquifer recharge (MAR) on agricultural lands and working landscapes, including but not limited to refuges, floodplains, and flood bypasses.

**Flood-MAR dormant crops** – A field of perennial plants in a state of temporary metabolic inactivity or minimal activity. Plants generally go dormant during the cold winter months.

## G

**Gaining stream** – If groundwater elevations are higher than the water level in the stream, the stream is said to be a gaining stream because it gains water from adjacent groundwater.

**Green Infrastructure (GI) / Low Impact Development (LID)** – Interchangeable terms used in the broader stormwater nomenclature. Stormwater management systems that mimic and/or are designed to incorporate natural media and processes. For example, rain gardens, bioretention cells, bioswales, green roofs, rain barrels/cisterns, permeable pavements, and engineered wetlands.

**Groundwater allocation –** An amount of groundwater use that has been defined and quantified over a period, usually one year, and can be assigned or distributed to specific users within a basin

**Groundwater Dependent Ecosystems (GDE)** – Ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface, which generally includes plant and animal communities that rely on shallow groundwater levels or interconnected surface water to meet all or some of their needs.

**Groundwater gradient (also known as hydraulic gradient)** – The slope of the water table or potentiometric surface. The driving force that causes groundwater to move in the direction of maximum decreasing total head (or pressure).

**Groundwater overdraft** – Occurs where the average annual amount of groundwater extraction exceeds the long-term average annual supply of water to the basin.

**Groundwater trading/market –** An institution that allows individuals to voluntarily buy, trade, exchange, or sell some aspect of the right to pump and use groundwater (e.g., an allocation).

## H

**Historical flows** – Daily streamflow measurements in the historical record.

**Hollow-stem auger method** – Drilling method for well and piezometer installation that utilizes a hollow, steel stem with continuous spiral steel flights welded to the exterior. A drill bit on the lead auger disturbs soil material when rotated, whereupon the spiral flights transport the cuttings to the surface. A monitoring well can be installed inside of the stem.

**Hydraulic gradient** – see Groundwater gradient

**Hydrostratigraphy** - A geologic framework consisting of a body of rock having considerable lateral extent and composing a reasonably distinct hydrologic system.

**Hydrostratigraphic zone** – Refers to a geologic area consisting of a body of rock having considerable lateral extent and composing a reasonably distinct hydrologic system.

## I

**Incidental recharge** – Occurs through unlined irrigation canals or leaky conveyance pipes.

**Indirect potable reuse** – An engineered approach to store advanced treated water in the ground for later recovery and use or to increase water stored in aquifers.

**Infiltration gallery (recharge trench gallery)** – Subsurface perforated pipe or block drain, which is used to infiltrate water. Also known as a reverse tile drain in the agricultural setting.

**Injection front** – The interface where the injected water mixes with the aquifer. Water quality degradation can occur at the injection front due to changes in water geochemistry.

**In-lieu recharge** – Occurs when surface water is used instead of groundwater to purposefully allow for natural and applied recharge to occur.

**Interconnected Surface Water** – Surface water that is hydraulically connected by a continuous saturated zone to the underlying aquifer.

**Interferometric Synthetic Aperture Radar (InSAR)** – A technique for mapping ground deformation using radar images of the Earth's surface that are collected from orbiting satellites.

**Intrinsic tracers** – Non-reactive constituents that can be used to track water fate and transport. Constituents should be notably different concentrations or values in either the aquifer or injected water source to be used as a tracer. Common tracers are salts, temperature, and non-reactive minerals or metals.

**In situ remediation** – Term meaning “in place” or in the natural or original position, such as the treatment of groundwater in the subsurface.

**Isocontour** – The geographic line where chloride in groundwater is estimated to be a specified concentration.

## J, K -none

## L

**Legacy contaminants** – Contaminants or chemicals, often used or produced by industry, which remain in the environment long after they were first introduced.

**Lifecycle cost** – All costs required to produce benefits over the useful life of the project, including planning, design, construction, operation, maintenance, and replacement costs. Generally, they are shown on a yearly basis over the project life and also expressed as a single, present value amount.

**Lithologic** – The description of rocks, especially in hand specimens and in outcrops, on the basis of such characteristics as color, mineralogic composition, and grain size.

**Losing Stream** – If the groundwater elevation is lower than the water level in the stream, it is said to be a losing stream because it loses water to adjacent groundwater.

**Low Impact Development (LID)**– refer to Green Infrastructure.

**Lysimeter** – A measuring device that can be used to measure the amount of actual evapotranspiration released by plants.

## M

**Managed aquifer recharge (MAR)** – The purposeful recharge of water to aquifers for subsequent recovery or for environmental benefit.

**Microsoft Access database** – A database platform through Microsoft. The platform allows the user to access and manipulate database, such as insert, update, delete, create and create records and run queries against a dataset also able to generate figures and tables from the results of the query.

**Minimum Thresholds** – A concept defined in the Sustainable Groundwater Management Act (SGMA) statute and regulations. It is the quantitative value that represents the groundwater condition in each representative monitoring well site that, when exceeded, may cause an undesirable result. Groundwater Sustainability Plans (GSP) must develop and support the specific minimum thresholds for their coverage area.

**Mixing zone** – The portion of the aquifer where injected water and groundwater interact.

## N

**Net benefit** – The present value of monetized benefits minus the present value of costs. This metric uses the same information as the Benefit Cost Ratio, except expressed as a difference (benefits minus costs) rather than a ratio.

**North American Vertical Datum of 1988 (NAVD88)** – The vertical control datum established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-United States leveling observations.

**National Geodetic Vertical Datum of 1929 (NGVD29)** - The Sea Level Datum of 1929 was enacted in 1973. The datum is a vertical control datum in the United States by the general adjustment of 1929.

## O

**On-farm recharge / Ag-MAR** – Flood-MAR in the agricultural setting.

**Oxidation state** – (also known as oxidation-reduction, or redox state) Redox processes require one chemical species that donates electrons and another chemical species that accepts those electrons. As a chemical species donates electrons it is “oxidized,” and as the other species accepts electrons it is “reduced.” The redox state of groundwater—whether the groundwater is oxic (oxidized) or anoxic (reduced)—has profound implications for groundwater quality.

## P

**Piezometer** – A device used to measure groundwater pressure head at a point in the subsurface.

**Perched groundwater** – Groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater.

**Permeable reactive barriers** – A permeable wall or vertical zone containing reactive media, oriented to intercept and remediate a contaminant plume as groundwater migrates the zone.

**Present value** – The use of discounting to convert benefits or costs occurring at different times to a consistent point in time. Although “present value” is the common term, the point in time for comparison could be a future time, such as at the start of project operations. Therefore, the reference year should be stated for any present value calculation.

**Pressure transducer** – A sensor that collects and records water pressure in a well. Water pressure is used to calculate water levels.

**Primary productivity** – The rate at which energy is converted to organic substances by photosynthetic producers and the overall health of vegetation.

## Q – none

## R

**Recharge pond** – A surface facility constructed to infiltrate surface water into a groundwater basin. Water is spread over the surface of a basin or pond in order to increase the quantity of water infiltrating into the ground and then percolating to the water table.

**Recharge trench gallery** – refer to Infiltration Trench Gallery.

## S

**Saturated zone** – The zone in which all interconnected openings are filled with water, usually underlying the unsaturated zone.

**Screened interval** – Refers to length of the well that has a screen, which is a filtering device that serves as the groundwater intake portion of wells constructed in aquifers.

**Seawater intrusion** – Occurs when pumping results in lowered groundwater levels that pulls in saline water from surface water into the groundwater aquifers.

**Soil flushing (also known as leaching)** – The loss of water-soluble plant nutrients from the soil, due to rain and irrigation.

**Soil matrix** – An assemblage of mineral particles of various sizes, shapes, and chemical characteristics, together with organic materials, in various stages of decomposition and living soil populations.

**Soil vapor extraction** – A physical treatment process for in situ remediation of volatile contaminants in vadose zone (unsaturated) soils.

**SQL database** – A database platform that stands for Structured Query Language (SQL). The platform allows the user to access and manipulate database, such as insert, update, delete, create and create records and run queries against a dataset also able to generate figures and tables from the results of the query.

**Subsidence** – The settling or sinking of the ground surface / land. Defined by change in ground surface elevation, not absolute ground surface elevation. Subsidence can only be identified after multiple, successive ground surface elevation measurements.

**Subsidence (elastic)** – Elastic subsidence is reversible.

**Subsidence (inelastic)** – Inelastic subsidence is permanent.

**Sustainable yield** – The maximum quantity of water that can be withdrawn annually from a groundwater basin without causing undesirable results.

## T

**Tracer studies** – Tracer studies inject a harmless constituent of known concentration into the subsurface which is monitored at downgradient locations. Used in the field to obtain information on the direction and velocity of the flow of groundwater and associated contaminants, and the presence of preferential flow paths.

**Thalweg** – The center of a channels stream flow, a line drawn to join the lowest points along the entire length of a stream bed or valley in its downward slope, defining its deepest channel.

**Thermal remediation (or thermal reduction)** – In situ remediation technology for groundwater where energy is injected into the subsurface to mobilize and recover volatile and semi-volatile organic contaminants. This method commonly utilizes steam-enhanced extraction, electrical-resistance heating, or thermal-conductive heating to remediate contaminants from source zones.

**Title 22** – California's Code of Regulations refers to state guidelines for how treated and recycled water is discharged and used.

## U

**Unconfined aquifer** – An aquifer that is not bounded on top by an aquitard. The upper surface of an unconfined aquifer is the water table.

## V

**Vadose zone (also known as the unsaturated zone)** – The portion of the subsurface that lies between the bottom of the land surface and the water table that defines the upper boundary of the groundwater system.

**Vertical datum** – A surface of zero elevation to which heights of various points are referenced.

## W

**Water budget** – Accounting of the total groundwater and surface water entering and leaving a basin including the changes in the amount of water stored.

**Waterlogging of roots** – Excess water in the root zone accompanied by anaerobic conditions. The excess water inhibits gaseous exchange with the atmosphere, and biological activity uses up available oxygen in the soil air and water – also called anaerobiosis, anoxia or oxygen deficiency.

**Water supply augmentation –** Includes projects that bring in additional water supplies or capture water that would have otherwise left the basin, such as floodwater capture and recycled water use.

**Watermaster Program –** A state program established in 1924, to ensures that water is allocated according to established water rights as determined by court adjudications or agreements by an unbiased, qualified person, thereby reducing water rights court litigation, civil lawsuits, and law enforcement workload. It also helps prevent the waste or unreasonable use of water.

**Willingness to pay** – A fundamental economic concept that describes how people value increases in a good or service, such as additional water supply or improved water quality or environmental quality. It is the amount of value (money or other goods or services) that an individual or group would be willing to give up to obtain the good or service. Actual payment (exchange of money) need not take place, although observed prices and transactions (i.e., actual payments) are often used as the best way to estimate WTP for some goods.

## X, Y, Z **- none**

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