Enhancing Groundwater Recharge with Stormwater

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California’s GW Supplies Face a Triple Threat

- Increasing demand
- Shifting land use
- More intense rainfall

Less GW Recharge
The Recharge Initiative

- Map locations where enhanced recharge might be best accomplished
- Model availability of stormwater from hill slopes
- Design/create field projects and measure/validate:
  - benefits to water supply
  - improvements to water quality
- Monetize activities and polities that incentivize stakeholders and strengthen partnerships

Central Coast: heavily reliant on groundwater

GW = 83% of demand

Simultaneously a challenge and an opportunity for this region... ...template for CA?

DWR Water Plan Update 160-98
Central Coast: Virtually "off the grid" in terms of large-scale water transfers

Central Coast hydrologic region

modified from Mount (1995)

Different Scales of Managed Recharge

Low-impact development (LID)  Regional spreading grounds
### Different Scales of Managed Recharge

<table>
<thead>
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<td>1-10 af/yr per site</td>
<td>$10^4$-$10^5$ af/yr per site</td>
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### Stormwater as a Source for Managed Aquifer Recharge (MAR)

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<td><strong>Distributed Stormwater Collection → MAR (DSC-MAR)</strong></td>
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**Pajaro River and Pajaro Valley Groundwater basins**

PVGB, lower PR basin, mostly Santa Cruz and northern Monterey Counties

Primary fresh water resource is groundwater

PVWMA: Special Act district (1984)

PVWMA serves 70,000 acres, 30,000 irrigated

Major crops: Strawberries, cane berries, table crops, organic (30%)

→$1B farm revenue

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**Overdraft is a regional challenge**

Pumping:

~55k ac-ft/yr

City of Watsonville:

~7k ac-ft/yr

Sustainable yield:

40k–45k (?) ac-ft/yr

(depending on pumping distribution, time horizon, natural variability)

Overdraft:

10k–15k (?) ac-ft/yr

(depending on definition, annual conditions, definitely large, 200 to 350 ft/yr)

*map from PVWMA, 2012*
**Distributed Stormwater Collection – Managed Aquifer Recharge (DSC-MAR)**

Bokariza Ranch, **Project goal:** ~100 ac-ft/yr

modified from Beganskas and Fisher (2017)

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**Stormwater as a Source for DSC-MAR: Example**

**Instrumented 2011-present**
- Precipitation
- Water level (culvert, basin)
- Infiltration rate
- Sediment accumulation

Real-time sensor network
**Stormwater as a Source for DSC-MAR: Example**

**WY12-15 = drought**  
**WY16 = El Niño**  
**WY17 = ...?**

**WY15: most rain fell in a single long storm, >100 ac-ft of runoff/infiltration!**

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**Many forms of groundwater recharge (natural, managed)**

Each form of recharge requires specific conditions, properties, design, operations – "all recharge is local"
Where to Place DSC-MAR Projects?

Two main project components:
1. Spatial (GIS) analysis for MAR suitability
2. Runoff (PRMS) analysis for stormwater generation from hillslopes

Combining spatial data to assess MAR Suitability

- Compile, patch, reconcile, regrid, reproject datasets
- For each dataset, categorize for conditions that are more/less favorable for DSC-MAR
- Combine datasets to create maps showing composite suitability

Schematic example:

![Schematic example diagram showing combined suitability](image-url)

Fisher, Lozano et al. (2017)
**Regional Soils: data extraction/processing**

- Extract shape files and Access database from SSURGO (USDA)
- Merge shapes with properties, process to assess infiltration capacity

>5000 polygons, 211 soil types

Teo et al. (2017) – in prep

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**Regional Soils: Categorical Assignment**

- Combine data from multiple soil layers
- Assign IC index on a log₂ scale (distributes wide range of values)

Teo et al. (2017) – in prep
Regional Bedrock: Unit Classification

- Combine regional data from multiple reports/maps
- Evaluate unit by unit to determine which bedrock units are/might be/are not aquifers
- Assign classification as an index

Teo et al. (2017) – in prep
Suitability for Managed Aquifer Recharge based on Surface Conditions

- Combine soils, bedrock info
- Additional considerations include: slope, land use, veg (discussed below)

Subsurface Unit Geometry and Properties

- Combine regional data from multiple reports/maps
- Evaluate unit by unit to determine which bedrock units are/might be/ are not aquifers
- Assign classification as an index
One county, three (+?) groundwater basins, all in overdraft...

San Lorenzo River Basin
- Mountainous, rural/urban
- GW levels down by 100 m
- Inland, no SW intrusion

Pajaro Valley GW Basin
- Agricultural, urban, rural
- Considerable SW intrusion
- Special Act District

Soquel/Aptos GW Basin
- Mountainous, rural/urban
- First hints of SW intrusion
- Models say: critical overdraft (so does DWR!!)

M. Cloud, pers. comm.

Suitability for Managed Aquifer Recharge based on Surface+Subsurface Conditions

PVGB

Pajaro Valley Groundwater Basin

Subsurface analysis:
- Transmissivity (K x b)
- Vadose zone thickness
- Available storage
- Change in storage

Composite analysis:
- Covers a fraction of the subregion – where there are subsurface datasets

Teo et al. (2017) – in prep
Where to Collect Stormwater Runoff?

Precipitation Runoff Modeling System (PRMS)
- USGS, open source, widely used
- Watershed-scale hydrologic model
- Water is added by precipitation, routed through four main reservoirs (no snow for us)
- Apply future climate scenarios (normal, dry, wet)

modified from Markstrom et al. (2015)

Where to Collect Stormwater Runoff?
- Hydrologic response units (HRUs) defined by topography
- HRUs = 0.1 to 1.0 km² (25 – 250 acres)

Beganskas et al. (2017) – in prep
Example model parameters for PRMS

- Vegetation density (%)
- Percent sand (%)
- Percent impervious area (%)

Historical climate data at high spatial resolution

- Daily records, 1981-2014
- 800 m grid
- $P$, $T_{\text{min}}$, $T_{\text{max}}$
- Weighted PRISM values for each HRU

*Example: Day 101 (Jan 10, 2003)*

Beganskas et al. (2017) – in prep
Why not Use Climate Model Output?

Climate Change Projections for California
2070-2099 relative to 1951-1980

Projected minimum air temperature change (degrees C)

18 models, 18 predictions
from Flint and Flint (2014)

Why not Use Climate Model Output?

Regional climate models can’t replicate **spatial** distribution...
Regional climate models can’t replicate **temporal** distribution (#, length, gap, intensity)...

Example: Day 101
(Jan 10, 2003)

Precip (cm)

UC WATER
Sustainability and Water Policy Initiative

Regional climate model

20 x 20 km grid
**Model Climate Scenarios**

Historic record: Water years 1982 to 2014

Non-exceedance probability vs. Total annual precipitation (in)

- **Dry**
- **Normal**
- **Wet**

**Model Results**

*Basin-wide precipitation*

- **Dry**
  - Precipitation: 16 in/yr
- **Normal**
  - Precipitation: 20 in/yr
- **Wet**
  - Precipitation: 32 in/yr

All climate scenarios have months with significant rainfall

*Beganskas et al. (2017) – in prep*
Model Results
Basin-wide precipitation and runoff

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Precipitation</th>
<th>Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td></td>
<td>2.3 in/yr (14%)</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td>3.3 in/yr (16%)</td>
</tr>
<tr>
<td>Wet</td>
<td></td>
<td>8.6 in/yr (27%)</td>
</tr>
</tbody>
</table>

1 inch of runoff = 11,300 acre-feet
There is ample runoff available for collection

Beganskas et al. (2017) – in prep
Example PRMS parameters

Dry

Normal

Wet

Runoff

Mean annual runoff
14 in
0 in

Next steps: combine mapping & modeling

MAR suitability + Runoff availability

• Assess existing and planned sites
• Help to identify and assess new sites
**Planned Project Site**

- Working ranch and rangeland
- >1300 acres draining into 15 acres
- Interest in improvement to water supply and water quality

**Conceptual project design**

- Secured land-owner agreement
- Survey to estimate costs - needed for grant applications
- System engineering design - landowner to cover this cost
- Grant applications submitted with RCD, PVWMA, local stakeholders - Funded!
- Field experiments Summer 2016 to test infiltration properties, rates of reaction during infiltration, variations in microbial populations and activity
- Construction in 2017

*Demonstrated improvements to water quality...*
How to Improve Water Quality during DSC-MAR?

Field and laboratory studies:
• What are relations between infiltration rate, microbial activity, and nitrogen cycling?
• How can the use of a permeable reactive barrier (PRB) impact these relations?
• How can development and use of a low-cost PRB improve water quality during MAR?

Experimental configuration
Beganskas et al. (2017) – in prep
A woodchip PRB can expand the range of infiltration rates during which nitrate removal occurs!

The PRB may also stimulate more consistent nitrate removal than native soil

*data from Schmidt et al. (2011), Beganskas et al. (2017) – in prep*

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**Applying results at field scale:**

Harkins Slough (WY08)

*data from Schmidt et al. (2011), Beganskas et al. (2017) – in prep*
Infiltration through the PRB was associated with statistically significant shifts in microbial populations. Particular increases in communities that fix N, degrade organic compounds, reduce N, and denitrify. RNA work in progress...

Beganskas et al. (2017) – in prep

Costs to Growers/Landowners for DSC-MAR

- Land taken from production/reduced access
- Maintenance of infiltration structures (basins, dry wells)

How can participation be incentivized?
**There is a Workable Example: Net Energy Metering**

- generate energy locally
- account for net usage
- excess power goes on the grid for sale (and eventual use)

**Net Energy Metering**

Net energy metering is a type of Distributed Generation that allows customers with an eligible power generator to offset the cost of their electric usage with energy they export to the grid. A specially programmed “net meter” will be installed to measure the difference between electricity the customer purchases and exports to the grid. The methods of applying credit for exported energy vary with the program.

- Requires
  - reliable measurement and accounting
  - formula to calculate benefit/rebate
  - stakeholder and Agency trust

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**Example: Net Recharge Calculations**

Irrigated area: 75 irrigated acres
Applied water: 2.5 ft
Annual precipitation: 1.5 ft (18 inches)
Runoff/precipitation = 0.4 (appropriate for intense events)

Options:

<table>
<thead>
<tr>
<th>Drainage:</th>
<th>200 acres</th>
<th>400 acres</th>
<th>600 acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infiltration:</td>
<td>2</td>
<td>4</td>
<td>6</td>
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Augmentation fee = $203/ac-ft
*(outside of Delivered Water Zone)*

Recharge Net Metering rebate: 50% of net infiltration
Recharge Net Metering (ReNeM) in the PVGB
(five-year pilot program, 10/2016-9/2021)

• Goal: 8-10 field projects, each ≥100 ac-ft/yr
• Third-party certifier (TPC) identifies sites, raises capital, develops engineering, plans/builds for measurement
• TPC works with landowners/tenants to validate
• TPC certifies performance, reports to agency
• Agency applies formula to calculate rebate (= credit )

Program status
• One site is operational, three more funded and in development for 2017…
• Multiple requests for site consideration…

Recharge Net Metering (ReNeM)…
…requires three kinds of support

• Capital costs
  site ID, design, engineering, installation

• Validation
  measurements, sampling, certification

• Rebates (Incentives)
  offset for operation and maintenance costs

In the PVGB:
Costs are competitive, program is revenue positive
Recharge Net Metering (ReNeM)...
...is not Groundwater Banking

ReNeM:
- Incentivizes **infiltration**, not recharge, not storage
- No water ownership/right is claimed, no recovery is promised
- Rebate is performance based, year by year
- Incentive based on a rebate of fees

*An aquifer is a bank like a colander is a bucket*

*Should CA incentivize other GW management activities?*

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**Summary and Ongoing Work**

- Stormwater can help to improve groundwater
- **Find the best locations** to enhance recharge
- Design systems to **measure performance**
- Improve water quality along with supply
- Groundwater recharge provides hydrologic system services, justifies incentives
- MAR with stormwater can be part of a successful portfolio for sustaining groundwater
Thank you! Questions?

Funding:

State of California Coastal Conservancy

UC WATER

Security and Sustainability Research Initiative

GORDON AND BETTY MOORE FOUNDATION

NSF