Understanding Multiple Benefits of Floodplain Restoration from Flood-Managed Aquifer Recharge in California's Central Valley

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OBJECTIVES

The objective of this project is to analyze and visualize the multiple benefits of Flood-Managed Aquifer Recharge (Flood-MAR) for floodplain restoration in California's San Joaquin Valley. To achieve this, students will:

1) Develop a geospatial representation of sites in San Joaquin Valley in which floodplains could receive benefits from Flood-MAR in each of the following areas:
   a) Flood risk mitigation for communities, infrastructure, or other human activity
   b) Groundwater levels for nearby drinking wells
   c) Surrogate wetland habitat for migratory birds and aquatic species
2) Estimate groundwater recharge and storage benefits using Hydrologic Engineering Center - River Analysis System (HEC-RAS) models by integrating with available GIS datasets
3) Create a Shiny application or other interactive web-based representation of potential benefits associated with Flood-MAR activities in the San Joaquin Valley.

SIGNIFICANCE

The future of California water and the strategies by which it is managed are expected to change according to future climate projections. Some of the expected effects of climate change on California water include earlier and increased mountain runoff, variance in drought persistence, and increased risk in flood frequency and severity (1). These factors are considerably consequential to the water challenge currently facing California - that is: ensuring plentiful supply from surface and groundwater in dry years, reducing flood risk in wet years, nurturing groundwater dependent ecosystems' (GDEs) health and resilience, and maintaining water quality and equitable distribution (2). These challenges can be addressed by floodplain restoration and recharge, which promotes healthy GDEs,

recharges groundwater levels and restores dry wells, and increases flood protection as climate change alters future flow regimes. The California Department of Water Resources (DWR) considers the mapping of floodplain habitats most suitable for Flood-MAR to be a priority action in their 2019 Research and Data Development plan (3). By creating a scalable framework that analyzes the feasibility of managed aquifer recharge in former floodplains and riparian habitats in the Central Valley, water management strategies can begin to integrate the multiple benefits of floodplain restoration into Flood-MAR research and implementation considerations.

Floodplain and riparian ecosystem restoration has been studied and carried out on a site-by-site basis in response to single driving forces specific to isolated projects (4). Important work in this area has been conducted by American Rivers and DWR on floodplains along the San Joaquin River to remove levees and restore natural floodplains (5). However, DWR and American Rivers acknowledge that a critical knowledge gap remains about the connection between floodplain restoration and groundwater recharge. The proposed Bren group project looks to develop an integrated water management analysis through which multiple benefits of floodplain restoration via managed aquifer recharge are considered. The goal is to provide a robust analysis that accurately presents the feasibility and multiple benefits of integrated water management by way of managed aquifer recharge in floodplains that are most suitable for replenishment, as determined by the Recharge for Resilience Project's suitability analysis framework. By expanding on an ongoing project with the Environmental Defense Fund (EDF) and including DWR, this project will provide a more in-depth understanding about the connection between floodplains and groundwater recharge to help inform future decisions regarding the implementation of Flood-MAR for multiple benefits.

BACKGROUND

Water resources management strategies in California must adapt to highly variable weather events, intensified by climate change, that are projected to result in more extreme precipitation events and longer, more severe droughts. The California Water Resilience Portfolio draft released in early 2020 prioritizes integrated, multiple-benefit management approaches to ensure the resilience of the state's water system (6). The passage of the Sustainable Groundwater Management Act (SGMA) in 2014 requires local groundwater sustainability agencies to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge over the next 20 years (7). Flood-MAR, the strategy of using flood water from rainfall or snowmelt for managed aquifer recharge, provides an opportunity to simultaneously reduce flood risk during storm events and recharge underlying aquifers to increase the state's drought-resilient water supply, while enhancing natural ecosystems (8).

Healthy floodplain habitats provide flood protection, improve water quality, recharge aquifers, and improve wildlife habitat for spawning fish and migratory birds (9). The extent to which Flood-MAR can contribute to or enhance those benefits remains unknown, a knowledge gap identified by DWR, EDF, and American Rivers as a valuable area of research in their ongoing process to understand the benefits and applicability of Flood-MAR in California. The proposed project will build upon the findings of the Recharge for Resilience Bren project, which created a framework for identifying regions of California best-suited for multiple-benefit managed aquifer recharge. Sites were prioritized based on land and soil characteristics and water quality, with additional considerations for conveyance infrastructure, rehydrating dry wells, and groundwater-dependent ecosystems. The proposed project aims to add to the understanding of multiple-benefit managed aquifer recharge by integrating the findings from Recharge for Resilience with an analysis of the multiple benefits of floodplain restoration that can be achieved by Flood-MAR.

EQUITY

In the Central Valley, most disadvantaged communities (DACs) rely on groundwater for up to 100% of their domestic water supply, making them disproportionately vulnerable to climate change events like droughts (10). Flood protection for DACs in high-risk areas is prioritized by DWR's Central Valley Flood Protection Plan (11). Flood-MAR and floodplain restoration create valuable opportunities to improve the water resilience of DACs by restoring groundwater levels and providing flood protection benefits.

AVAILABLE DATA

This project will make use of the following publicly available data sources:

- Recharge for Resilience decision support tool
- Cal-Adapt California Climate Change Data - San Joaquin River/Merced River streamflow
- USGS Basin Characterization Model outputs - precipitation, recharge, soil storage, runoff
- The Nature Conservancy indicators of Groundwater-Dependent Ecosystems (iGDE) dataset
- DWR California dry groundwater well dataset
- Soil Agricultural Groundwater Banking Index (SAGBI)
- Hydrologic Engineering Center (HEC) - River Analysis System (RAS) Central Valley dataset
- State Water Resource Control Board Water System Source Data
- California Environmental Health Tracking Program's Drinking Water Systems Service Areas

APPROACH

1) Perform a spatial analysis to determine floodplains in California's San Joaquin Valley that would receive multiple benefits from Flood-MAR:
   a) Determine potential flood protection benefits from floodplain restoration by identifying future flood risk scenarios for the Central Valley using Cal-Adapt Climate projection data
   b) Identify dry groundwater wells in or near floodplains that could be restored with increased recharge from Flood-MAR
   c) Identify potential surrogate wetland habitat and groundwater-dependent ecosystems that could benefit from aquifer recharge
2) Apply the framework of recharge site suitability established by Recharge for Resilience to determine priority areas for utilizing Flood-MAR for floodplain restoration
3) Integrate HEC-RAS software with GIS databases to estimate groundwater recharge and storage benefits from inundated floodplains
4) Develop Shiny application or other interactive web-based representation of potential Flood-MAR benefits and/or priority recharge sites based on multiple benefit floodplain restoration

DELIVERABLES

In addition to the final written report, policy brief, poster, and oral presentation provided by the group as required by the Bren School of Environmental Science & Management, the final deliverables for the client(s) will include:

1.) Geospatial representation of floodplain habitats that would receive multiple benefits from managed aquifer recharge
2.) Quantification of ecosystem service restoration and recharge benefits
3.) A Shiny application or other web-based interactive tool to display project findings

INTERNSHIP

The Environmental Defense Fund commits to host and mentor one paid intern at their San Francisco office during the summer of 2020.

The Department of Water Resources will offer a volunteer summer internship under the supervision of Jennifer Marr in DWR's Division of Planning in Sacramento, CA.

REFERENCES

(1) Hanak, E. & Lund, J. R. (2011). *Adapting California's Water Management to Climate Change. Climatic Change.* 111: 17. https://doi.org/10.1007/s10584-011-0241-3

(2) California Department of Water Resources (2019). *California Water Plan Update 2018.* Sacramento (CA): California Department of Water Resources. California Natural Resources Agency. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Docs/Update2018/Final/California-Water-Plan-Update-2018.pdf

(3) California Department of Water Resources (2019). *Flood-MAR Research and Data Development Plan: Priority Actions to Expand Implementation of Effective and Efficient Flood-MAR Projects in California.* Sacramento (CA): California Department of Water Resources. California Natural Resources Agency. https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Flood-Management/Flood-MAR/Flood-MAR-RDD-Plan_a_y_19.pdf

(4) Rohde, S., Hostmann, M., Peter, A., & Ewald, K.C. (2006). "Room for rivers: An integrative search strategy for floodplain restoration." *Landscape and Urban Planning*. 78(1-2): 50. https://doi.org/10.1016/j.landurbplan.2005.05.006

(5) Nylen, D. (2018). "A Visual Journey: Restoring California's Floodplains." American Rivers. https://www.americanrivers.org/2018/01/visual-journey-restoring-californias-floodplains/

(6) California Natural Resources Agency, California Environmental Protection Agency, & California Department of Food & Agriculture (2020). *California Water Resilience Portfolio (draft).* Sacramento (CA): California Natural Resources Agency, California Environmental Protection Agency, California Department of Food & Agriculture. http://waterresilience.ca.gov/wp-content/uploads/2020/01/California-Water-Resilience-Portfolio-2019-Final2.pdf

(7) California Department of Water Resources (2014). "SGMA Groundwater Management." https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

(8) California Department of Water Resources (2018). Flood-MAR: Using Flood Water for Managed Aquifer Recharge to Support Sustainable Water Resources. White Paper. Sacramento (CA): California Department of Water Resources. California Natural Resources Agency. https://water.ca.gov/Programs/All-Programs/Flood-MAR

(9) The Nature Conservancy (2018). "Benefits of Healthy Floodplains." https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/benefits-of-healthy-floodplains/

(10) MacLeod, Clara, & Linda Estelí Méndez-Barrientos. "Groundwater Management in California's Central Valley: A Focus on Disadvantaged Communities." *Case Studies in the Environment*, January 1, 2019. https://doi.org/10.1525/cse.2018.001883

(11) California Department of Water Resources. "Small Communities Flood Risk Reduction." https://water.ca.gov/Work-With-Us/Grants-And-Loans/Small-Communities-Flood-Risk-Reduction

ADDITIONAL RESOURCES

US Fish and Wildlife EcoAtlas datasets: https://www.ecoatlas.org/data/
US Fish and Wildlife Areas of Conservation Emphasis (ACE):
https://wildlife.ca.gov/Data/Analysis/Ace#523731773-climate-resilience
USGS Basin Characterization Model: https://ca.water.usgs.gov/projects/reg_hydro/basin-characterization-model.html
Water Supply Index Forecast: https://mavensnotebook.com/2020/01/09/water-supply-index-forecast-for-january-1-2020/
Map of CA groundwater-dependent ecosystems:
https://www.researchgate.net/publication/44807334_Mapping_Groundwater_Dependent_Ecosystems_in_California
Soil Agricultural Groundwater Banking Index (SAGBI) map of CA: https://casoilresource.lawr.ucdavis.edu/sagbi/
Cal-Adapt California climate change data: https://cal-adapt.org/
USGS National Elevation Database: https://catalog.data.gov/dataset/usgs-national-elevation-dataset-ned
US Census Bureau 2010 Census Data: https://www.census.gov/programs-surveys/decennial-census/data/datasets.2010.html
DWR Levee Flood Protection Zone (LFPZ) dataset: https://gis.lfpz.water.ca.gov/lfpz/
The Nature Conservancy case studies of multiple-benefit recharge: https://groundwaterresourcehub.org/case-studies/recharge-case-studies/
The Nature Conservancy and DWR Database of Groundwater Dependent Ecosystems:
https://groundwaterresourcehub.org/sgma-tools/mapping-indicators-of-gdes/
Scott Jasechko, Dry Groundwater Wells in the Western United States:
https://iopscience.iop.org/article/10.1088/1748-9326/aa8ac0/pdf
California Environmental Health Tracking Program's Drinking Water Systems Service Areas:
https://cehtp.org/water/
State Water Resources Control Board Water System Source Data: https://data.ca.gov/dataset/drinking-water-public-water-system-information

BUDGET & JUSTIFICATION

It is not anticipated that the proposed project would require additional funding beyond the $1,300 contributed by the Bren School.

CLIENT LETTER OF SUPPORT

(see attached)

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

January 23, 2020

Group Project Selection Committee
Bren School of Environmental Science and Management
2400 Bren Hall
UC Santa Barbara, California 93106-5131

Re: Master's Group Project Proposal – Understanding Multiple Benefits of Floodplain
     Restoration from Flood-Managed Aquifer Recharge in California's Central Valley

Dear Committee Members:

Through our Flood-MAR Program, the Department of Water Resources (DWR) has been
evaluating opportunities for achieving multiple benefits by using floodwater for managed
aquifer recharge. Flood-MAR is a promising resource management strategy for improving
water management sustainability and adapting to climate change. DWR enthusiastically
supports your proposal to extend the evaluation of Flood-MAR opportunities to provide
groundwater recharge and floodplain restoration benefits in the Central Valley.

Flood-MAR strategies have illustrated the ability to provide multiple benefits. This study will
help Madera County and the local water purveyors identify potential opportunities and
benefits of increasing groundwater recharge to support sustainable management of the
basin and restoring floodplain habitat. The information in the study can help identify
locations for future Flood-MAR project implementation.

To progress and continue this work, DWR can offer a volunteer internship, under the
supervision of Jennifer Marr in DWR's Division of Planning. Office space will be made
available in Sacramento, California.

If you need additional information, please contact Jenny Marr, Supervising Engineer of
DWR's Statewide Infrastructure Investigations Branch at (916) 651-9229 or email
Jennifer.Marr@water.ca.gov.

Sincerely,

for Kamyar Guivetchi, Manager
Division of Planning

January 24th 2020

Group Project Committee
Bren School of Environmental Science and Management
University of California, Santa Barbara

Environmental Defense Fund's Western Water Program is pleased to support Alex Ehrens and Alex Milward's proposal, "Understanding Multiple Benefits of Floodplain Restoration from Flood-Managed Aquifer Recharge in California's Central Valley".

As climate change continues to affect the water supply reliability across California, EDF is seeking solutions to build economic, social, and ecological resilience. A critical component of year to year supply security is storage. While historically states across the Western U.S. have relied on dammed rivers to provide above ground storage, more and more water managers are recognizing the value of aquifer recharge as a pragmatic storage option. With strategic implementation, groundwater recharge projects can also benefit community health, groundwater-dependent ecosystems, and migratory bird species. EDF seeks to a support a Bren student group in exploring opportunities for multi-benefit groundwater storage in the San Joaquin Valley, one of the most climate vulnerable regions in the state.

EDF's extensive experience, well-developed relationships, and strong reputation among water managers, consultants, and public agency staff will allow us to support an effective and timely Bren group project.

As a Bren alum, I am particularly excited to support EDF's engagement on this joint project. Having first-hand experience on the student side of the process, I am confident that I can help ensure a mutually beneficial project that both provides EDF with tangible results to help forward our objectives and offers a meaningful learning experience for the Bren students.

Sincerely,

Anna Schiller

Anna Schiller, MESM 2018
Water and Lands Project Manager