Annual Report Summary

Period Covered by the Report: September 1, 2017 through August 31, 2018
Date of Report: November 31, 2018
EPA Agreement Number: 83582401
Title: Assessment of Stormwater Harvesting via Manage Aquifer Recharge (MAR) to Develop New Water Supplies in the Arid West: The Salt Lake Valley Example
Investigators: R.R. Dupont,
Institution: Utah State University
Research Category: Human and Ecological Health Impacts Associated with Water Reuse and Conservation Practices
Project Period: September 1, 2015 through August 31, 2018; no-cost extension to August 31, 2019.

Objective(s) of the Research: The project is designed to test the hypothesis that Managed Aquifer Recharge (MAR) via Green Infrastructure (GI) systems for stormwater harvesting is a technically feasible, socially and environmentally acceptable, economically viable, and regulatorily achievable option for developing new water supplies for arid Western urban ecosystems experiencing increasing population, and climate change pressures on existing water resources

Progress Summary/Accomplishments (Outputs/Outcomes):
Research Component 1, Monitoring of Existing MAR/GI Stormwater Management Systems –
Based on existing MAR/GI system monitoring that has taken place during Years 1 to 3, a wide range of pollutant concentrations result when data from a range of rainfall events are combined even at a specific site. Based on Year 3 data, for the two sites treating primarily pavement runoff (300 East and the Early Childhood Education Building, USU, in Logan), overlapping 95% Confidence Intervals of measured runoff pollutant concentrations showed differences between sites for only for TP and Pb (higher at the 300 E site) under similar rainfall events. Many of the MAR/GI systems being monitored appear to be releasing contaminants to underlying soils. The 300 East bioswale continues to release dissolved solids as indicated by elevated EC values, and continues to be a net producer of low concentrations of dissolved Zn, As, and Pb. A vegetated parking strip showed low but increasing concentrations of TDN, NO_3-N, Cr, Fe, As, and Cd. Field testing of the impact of plant type, Antecedent Dry Days between storms, and pollutant loading rates on pollutant removal in bioretention systems is complete and preliminary analyses have indicated the facilitated removal of NH_4-N, Cu and Zn from pore water by plants at the Green Meadow site. All plants tested were more effective at removing NH_4-N from pore water than the unplanted plots, with sedge/bulrush, cattail, and baltic rush being the most effective. Sunflowers did not remove more Cu from the pore water than the unplanted plots but all other tested plants were equally effective in reducing Cu concentration in the pore water. Only the sedge/bulrush mix removed more Zn from the pore water than the unplanted plot
Although As is not a constituent of stormwater, conditions within bioretention systems appear to be conducive to the solubilization of native As-bearing minerals. All treatments had As concentrations greater than 100 µg/L in the pore water. Plant type, in particular sunflowers,

sedge, and mixed grasses, influenced the extent of dissolution and the potential release of As to underlying groundwater.

Research Component 2, Integrated Modeling – To support precipitation-runoff modeling, an Artificial Neural Network (ANN) based methodology was developed for imputing missing weather data values. By achieving approximately 26% of the root mean square error (RMSE) of a standard imputation method, the ANN-based technique provided over 300% improvement in accuracy of imputing net radiation. Precipitation-runoff simulation of the Red Butte Creek (RBC) Watershed above Red Butte Reservoir (RBR) using HEC-HMS indicates that most precipitation infiltrates and contributes to groundwater flow. Simulations also reaffirm that most Red Butte Creek streamflow is hyporheic and comes from groundwater. For Water Years 2016 and 2017 and for four Climate Scenarios (CSs), simulations showed minor differences in the proportions of precipitation that would become surface water and groundwater leaving the Red Butte Creek study area above the Red Butte Reservoir. Simulations predict that all GI designs would substantially reduce the runoff volume and increase the infiltration volume within the existing developed area. For example, if runoff from roofs and sidewalks drain to a pervious area, the runoff volume is predicted to decrease by 57.5% and infiltration to increase by 17.5%. A swale density of 170 ft/ac (128.0 m/ha) would be required to achieve the same runoff decrease, but that would increase infiltration by 72.6%. A combination of GI techniques could more effectively reduce runoff and increase infiltration than using only one of the GI practices. Analysis of the impact of GI implementation scenarios on reducing pollutant loading to surface water suggested similar trends. When implementing GI for a small portion (10%) of the connected impervious areas, the greatest volume reduction is produced when roof runoff is treated, while the best solid loadings reduction is produced when the system is treating street runoff. For a 50% GI implementation scenario, runoff reduction was similar no matter the surface treated. However, there was a large difference in TSS reduction with varying surfaces. Implementing GI for streets produced larger particulate solids reduction compared to roofs. The benefits of GI for both the 10% and 50% implementation options vary depending on the surface treated, and the decision of what GI technique to implement depends on the reduction objectives, i.e., whether a priority is placed on volume or pollutant load reduction.

Research Component 3, Social Science Research – Results of the on-line survey confirmed that there are serious social, political, and legal obstacles to using deep dry wells as a means to recover stormwater through managed recharge to deep aquifers. There is more receptiveness (and fewer concerns) about approaches that rely on infiltration and recharge of shallow (non-culinary) aquifers, with some preference for subsurface storage/infiltration systems as being more acceptable to local residents, developers, and politicians. Results from the household surveys demonstrated that individual residents are largely unaware of how stormwater is handled in their neighborhoods. In cases where GI has been deployed, subsurface storage/infiltration was well regarded, while surface storage/infiltration systems had a more uneven track record.

Publications/Presentations During Reporting Period:
Dupont, R.R. 2018. *The Grey to Green Infrastructure Transition - An Historical Shift In the Modern Infrastructure Paradigm*. Presented to the Intermountain Sustainability Summit, Weber State University, Ogden, UT. March 1.

Dupont, R.R., J. Richardson, D. Willey, R. Fernandez. 2017. *Stormwater contribution to organic loading to the Lower Jordan River, Who Would have Known?* Presented to the Salt Lake County Watershed Symposium, West Valley City, UT. November 15-16.

Dupont, R.R., J. Richardson, D. Willey. 2018. *Stormwater Impacts to an Urban River in the Intermountain West: the Use of Continuous Monitoring Datasets*. 2018. Presented at the 111th Air and Waste Management Association Annual Conference and Exhibit, June 25 to 28, Hartford, CT. Paper #410122, Sustainability Metrics, Initiatives, and Analytics session.

Dupont, R.R., J. Richardson, D. Willey. 2018. *Demonstrating the Pollutant Loading from Stormwater Discharge to an Urban River in the Intermountain West Using High-Frequency Data*. Manuscript of platform presentation at the 2018 StormCon Conference, Denver, CO, August 14, 2018.

Fernandez, R. 2017. *Green versus Grey Infrastructure Costs*. Presented to the Utah Section of the American Public Works Association, Sandy, UT. October 3.

Fernandez-Valesquez, R.A. 2018. *Application of WinSLAMM to Evaluate the Effect of Green Infrastructure Implementation in Northern Utah*. A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Environmental Engineering, Utah State University, Logan, UT.

Fernandez-Velasquez, R., R.R. Dupont. 2018. Modeling the Effect of GI Implementation In the Red Butte Creek Area, The Case for "Not All GI is Created Equal." Presented to the Salt Lake County Watershed Symposium, West Valley City, UT. November 14-15.

Jackson-Smith, D. and E. Fairchild. 2018. *Greening Cities in the Semi-Arid West: Social, Institutional, and Political Drivers of Stormwater Green Infrastructure in Utah.* Presented to the International Symposium on Society and Resource Management, Snowbird, Utah, June 20.

Limbu, S.B., and R.C. Peralta. 2017. *Estimating Canyon Contribution to Salt Lake Valley Surface Water Flow and Groundwater Flow: Red Butte Watershed Case Study*. Presented to the Utah Section of the American Public Works Association, Sandy, UT. October 3.

Masoudiashtiani, S. and R.C. Peralta. 2017. *Befitting location of an injection well recharging Salt Lake Valley Groundwater in the Red Butte Creek watershed*. Presented to the Utah Section of the American Public Works Association, Sandy, UT. October 3.

Prudencio, L., S.E. Null. 2017. *Calling All Collaborators: Robust Decision-Making & Climate Adaptation*. Presented to the Salt Lake County Watershed Symposium, West Valley City, UT. November 15-16.

Prudencio, L., S.E. Null. 2018. *Simulating the effects of green stormwater infrastructure on surface water and ecosystem services in Salt Lake Valley (poster)*. Presented at the Utah State University Spring Runoff Conference. Logan, UT. March 27.

Prudencio, L., and S.E. Null. 2018. Stormwater Management and Ecosystem Services: A Review. Environmental Research Letters, 13(3): 033002. DOI: 10.1088/1748-9326/aaa81a.

Rife, T., RR. Dupont, Joan McLean. 2017. *Evaluation of Bioretention Media Performance at Salt Lake Public Utility Site (poster).* Presented to the Salt Lake County Watershed Symposium, West Valley City, UT. November 15-16.

Zhang J. and R.C. Peralta. 2018. Estimating infiltration increase and runoff reduction due to green infrastructure. *Journal of Water and Climate Change*. IWA Publishing. In press. 6 p.

Future Activities: Analysis of samples collected from field demonstration sites will be completed to explore comparisons of the performance of GI/MAR systems as a function of vegetation type across turf and a range of common GI plant species (cattail, sedge, sunflower, baltic rush, bulrush, and mixed wild rye and bunch grass species), as well as the impact of Antecedent Dry Days and pollutant loading on bioswale performance and groundwater protection. Sample collection from conventional and green roof and dry well samples will be completed in order to quantify water quality improvements provided by green roof treatment compared to conventional roofing materials. Disaggregation of pollutant loading data will be completed and relationships between pollutant concentrations and storm intensity and duration will be documented using rainfall data available from each of the field sites.

Using the HSPF model, additional alternative climate scenarios will be simulated to determine the sensitivity predicted groundwater resource impacts to a wide range of future climate conditions. In the groundwater modeling arena, the following activities are planned for Year 4 of the project: a) an update of the modified USGS Salt Lake Valley MODFLOW model to include appropriate boundary conditions for Years 2014 through 2017; b) refinement of the Salt Lake Valley MODFLOW model with a uniform 308 ft x 308 ft grid. c) removal of specified recharge cells existing in the SLV MODFLOW; d) transferring transient heads from the refined SLC MODFLOW model to the HypoRBC boundary cells; e) addition of the surface water routing, SFR, and lake, LAK, packages to the HypoRBC model; f) addition of the unsaturated zone flow, UZF, package to HypoRBC; g) and automation of the process of using SLV MODFLOW refined heads as HypoRBC boundary conditions. To complete the GUI as part of the MAR modeling software package, the following will take place during Year 4 of the project: a) revision of the main window for improved clarity and user friendliness; b) addition of windows to provide theoretical and procedural details of determining MAR well recovery effectiveness (REN); c) addition of the option to use both metric and US measurement units; d) addition of a button to allow MODFLOW and MT3DMS model computation of REN; and e) addition of the ability to estimate the equivalent turf area that could be irrigated with the evaluated MAR strategy.

Activities related to the Year 4 ecosystem services component of project integrated systems modeling includes: 1) finalizing integration of groundwater and surface water modeling efforts, 2) finalizing calibration and validation of models, 3) completing the stormwater management model runs described above, and 4) continued stakeholder engagement

A Stakeholder Advisory meeting is scheduled for December 10, 2018, and is designed to be a ½ day participatory modeling workshop retreat. This meeting will serve as a workshop opportunity where stakeholders will complete a tutorial exercise and receive a hands-on opportunity to explore the capabilities of the draft integrated systems models. The stormwater management model runs outlined in Table 2 will be described and discussed at this meeting and interaction with Advisory Committee members will aid in identifying a set of feasible and viable scenarios for simulations to be completed by the end of the project. A final workshop/presentation in the summer of 2019 will also be organized to share the final model simulations with the SAC as well

as a broader group of stormwater managers from Utah municipalities. Finally, analysis of the various social science data will be completed and a research manuscript for peer review will be prepared for publication.

Supplemental Keywords: vulnerability, TDS, habitat, indicators, sustainable development, public policy, cost-benefit, engineering, social science, ecology, hydrology, environmental chemistry, Great Basin, agriculture, industry, commercial, residential, stormwater, aquifer recharge, groundwater, green infrastructure, ecosystem services, modeling.

Relevant Web Sites: None to date.