**PROJECT TITLE: Minnesota; How much water? How is it changing?**

**I. PROJECT STATEMENT**

Minnesota is known as a land of plentiful water – but up until now nobody has been able to determine how much water there is. This proposed project would complete an ongoing LCCMR-funded project to answer the questions **“How much water is in Minnesota?” and “how is it changing over time?”** In phase 1 (presently underway), we are completing an analysis for 17 of major watersheds in the central part of Minnesota. In this proposed phase 2, we will complete the same analysis for the remaining 63 of 81 major Minnesota watersheds, resulting in a consistent statewide assessment of current water storage and development of methods for tracking how that storage is changing with time.

This project will improve our ability to monitor and quantify changes in the amount of water stored in groundwater aquifers, soils, lakes, wetlands, and streams throughout Minnesota. Knowledge of total water storage and how it changes through time is essential for sustainable management and wise use of water resources throughout the state. Water storage affects the availability of the water for human use (industry, irrigation, power production, domestic), and the availability of the water needed to support aquatic ecosystems (streams, lakes, wetlands, springs, etc.) throughout the state.

Currently water storage in aquifers can be estimated using networks of observation wells (MNDNR, MDA, USGS, and other entities), and water storage in lakes and wetlands can be estimated from water level measurements at MNDNR/citizen monitoring sites. The combined phase 1 and phase 2 results will leverage these extensive monitoring data sets to produce the first statewide estimate of total water storage and changes through time. Adding to this capability we will utilize the vast amount of available satellite data for use in remote monitoring of water storage. In the current project we have been using satellite data to estimate storage of groundwater, soil moisture, and water in lakes in the central part of Minnesota. Putting the ground-based data together with the satellite data provides a reliable basis for tracking water storage, and also provide estimates of water storage in locations where ground-based measurements are sparse or missing entirely.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1 Title:** **Acquire archived data and calibration data for HSPF (Hydrologic Simulation Program Fortran) models.****Description:*****Monitoring data:*** *Used to ground-truth satellite data and models. Available data will be acquired for streamflows, river and lake water levels, wetland water levels, soil moisture, groundwater levels, and meteorological variables. The data will be acquired for the period 2002-2019.* ***Satellite data:*** *Used to observe large-scale changes in water storage and thereby extend ground-based monitoring data. Available data will be acquired from NASA and associated database sources.* ***Models:*** *Used to conduct water balances to explain storage changes observed by satellites and ground-based data. Through contract the MPCA has calibrated HSPF models for most of the major watersheds in the state.* **ENRTF BUDGET: $60,000** |
| **Outcome** | **Completion Date** |
| *1.* Complete set of hydrologic, soil, geologic, groundwater level, meteorological, and topographic data, prepared for our use. All data will be archived and available on DVD as well as on our current project website and on the USGS website. | *3/31/21* |

**Activity 2 Title:** **Develop estimates of groundwater, soil moisture and surface water storage for each of the 81 major watersheds for each year, 2002-2019.**

**Description:** *In our current study we have developed estimates of water storage in groundwater, soil moisture and surface water for the 17 major watersheds for each year of the period 2002-2015. We will use the same methodologies for estimating water storages of the remaining 81 major watersheds of the state, and for each year 2002-2019. The methodology involves the use of groundwater level data from the MNDNR monitoring well network along with aquifer property information (e.g., available Minnesota County Geologic Maps), river stage data, and lake/wetland water level data along with lake/wetland bathymetry data. Pointwise estimates of water storage are extended with statistical methods to provide areal estimates across whole watersheds.*

**ENRTF BUDGET: $172,000**

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| **Outcome** | **Completion Date** |
| 1. Point estimates of annual baseline water storage for 2002 through 2019. | 9/30/2021 |
| 2. Maps showing distribution of estimates of annual water storage by surface water and groundwater across the state of Minnesota for 2002 through 2019. | 12/31/2021 |

**Activity 3 Title:** **Estimate the changes in water storage over the period 2002 through 2019.**

**Description:** *The methodology for tracking the change of water storage across Minnesota will use satellite remote sensing data along with ground-based measurements. The methodology will use the HSPF model to combine and provide consistency among the various satellite and ground-based data. The method will use the data and the model to track changes in water storage for the period 2002 through 2019.*

**ENRTF BUDGET: $297,139**

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| **Outcome**  | **Completion Date** |
| 1. Completed methodology for estimating the change in water storage across the state. User documentation on the methodology and associated software. | 6/30/2022 |
| *2.* Validation of water storage change estimation methodology.  | 03/31/2022 |
| *3.* Final completion report. | 06/30/2023 |
| *4.* Publication of reports, data and models | 06/30/2023 |

**III. PROJECT PARTNERS AND COLLABORATORS:**

Jared Trost, USGS hydrologist for estimation of groundwater storage and publication of results; Francisco Lahoud, research associate, University of Minnesota for satellite data analysis; Zhenong Jin, Assistant Professor, University of Minnesota for estimation of evapotranspiration; graduate research assistants, University of Minnesota for data acquisition, analysis, and HSPF modeling; Dr. Bruce Wilson, professor, University of Minnesota for uncertainty analysis.

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:**

A permanent, publicly available, interactive map-based web page will be produced to make the results broadly available to state, national, and international users. Processed data for 2002 through 2019 will be available through the website, and procedures for acquiring data beyond 2019 will be outlined. The methodology will be presented to the Minnesota water community, including resource managers at state and local agencies and scientists at academic institutions, through a workshop and occasional seminars held at the University of Minnesota. Due to the potential of the methods for assisting with flood and drought forecasting we will meet with the National Weather Service, Weather Forecast Office located in Chanhassen. We would like to propose that through this project activity we will be able to assist the MnDNR to develop strategies for placement of additional observation wells that will be beneficial to the interpretation of satellite data.