Environment and Natural Resources Trust Fund
2016 Request for Proposals (RFP)

Project Title: **ENRTF ID: 018-A**

Minnesota: How Much Water? How is it Changing?

Category: A. Foundational Natural Resource Data and Information

Total Project Budget: $ 702,231

Proposed Project Time Period for the Funding Requested: 3 years, July 2016 to June 2019

Summary:

Accurate water storage estimates (groundwater, soil moisture, streams, lakes, wetlands) are essential to sustainable water management. We will integrate satellite monitoring with traditional ground-based measurements to improve water storage estimates.

Name: John Nieber

Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Water problems at two extremes, flooding over a road and low lake levels due to water deficits. The amount of stored in the landscape affects these issues. Images of types of technologies that will be used to address the estimation of water storage are shown, including satellite technologies, and traditional ground-based measurement systems like monitoring wells, stream gages and weather stations. An image is shown of Minnesota with estimates of water storage change using the GRACE satellite; the central portion of the state is shown to have decreasing storage.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Minnesota: How Much Water? How is it Changing?

I. PROJECT STATEMENT

Minnesota is known as a land of plentiful water – but nobody can tell us how much water there is. **This project will answer the question 'How much water is there?'** It will improve our ability to monitor and quantify the amount of water stored in groundwater aquifers, soils, lakes, wetlands, and streams throughout Minnesota. Knowledge of total water storage is essential to sustainable management and wise use of water resources throughout the state. For purposes of this proposal, water storage is defined as the total water volume at a single point in time in the groundwater aquifers, soil, and surface waters. This differs from water availability, which is a smaller volume, because the total volume stored cannot fully be extracted or used.

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 ecosystems throughout the state. Currently water storage in aquifers can be estimated using the network of MNDNR observation wells, and water storage in lakes and wetlands can be estimated from water level measurements at MNDNR/citizen monitoring sites. To date, none of these available data have been used to make estimates of total water storage throughout the state. In fact, to this day, we do not have an estimate of the total water present within Minnesota's borders.

We will improve the ability to monitor water storage by developing a methodology that joins data from remote sensing and ground-based measurements. Vast amounts of data are available from NASA satellites, but these are underutilized for Minnesota. For our project there are three satellites of particular interest. One is the GRACE satellite which provides data that can be used to quantify the change in storage of all water sources over large, multi-state size areas. A second is the SMAP satellite that provides data on the moisture stored in the soil over intermediate size areas. The third is the World-View3 satellite that provides high resolution images for outlining water levels in lakes and wetlands. Of course, ground-truth data are needed for proper interpretation of satellite-based data, and this is where the network of ground-based monitoring data is essential. The ground-based data sources include observation wells, meteorological stations, lake water levels, stream gages, surface topography, soil maps, and geological maps.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Acquire archived data and select hydrologic models. **Budget: $105,008**

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 all regions of the state for the period 2002-2015 (the GRACE satellite was launched in 2002). Satellite data will be acquired for the same time period. A number of available hydrologic models will be evaluated and tested and the most appropriate model will be selected for use with the project.

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.	03/31/2017
2. Model selected. Documentation of selection procedures and details of tests completed.	6/30/2017

Activity 2: Develop estimates of baseline water storage for each region. **Budget: $252,012**

Our methodology will not provide an estimate of the absolute storage of water but instead is intended to quantify the temporal change in water storage relative to a baseline. Therefore, a baseline of the water storage will be determined using available point ground-based measurements. This will involve 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. Estimates of water storage within the unsaturated zone overlying the surficial aquifers will be derived from soil property information, and quaternary map information. The point estimates will be extended with statistical methods to provide and maps of water storage across the state.

Outcome	Completion Date
1. Point estimates of baseline water storage for 2015 and 2002.	9/30/2017
2. Maps showing distribution of estimates of water storage by surface water and groundwater across the state of Minnesota for 2015 and 2002.	12/31/2017

Activity 3: Estimate the changes in water storage over the period 2002 to 2015. **Budget: $345,211**

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 water balance model selected in Activity 1 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 from the period 2002 to 2015. The baseline estimates of storage at these two endpoints will provide the basis for the test for accuracy of the methodology.

Outcome	Completion Date
1. Completed methodology for estimating the change in water storage across the state. User documentation on the methodology and associated software.	6/30/2018
2. Validation of water storage change estimation methodology.	03/31/2019
3. Final completion report.	06/30/2019

III. PROJECT STRATEGY

A. Project Team/Partners

No ENRTF funding required:

John L. Nieber, Professor, Department of Bioproducts and Biosystems Engineeering, will serve as project principal investigator.

Bruce Wilson, Professor, Department of Bioproducts and Biosystems Engineering, will work on the uncertainty of water storage estimates.

John Baker, Professor and Research Leader, USDA-ARS, Department of Soil, Water and Climate, will work alongside Dr. Griffis on the application of the land surface/atmosphere interaction model.

ENRTF funding required:

Timothy Griffis, Professor, Department of Soil, Water and Climate, will conduct the research related to the water balance model.

Jared Trost, Hydrologist, USGS, Mounds View, will work on the estimation of water storage in the aquifers of the state.

Roman Kanivestsky, Adjunct Professor, Department of Bioproducts and Biosystems Engineering, will assist with the interpretation of geologic data for the various geologic provinces throughout Minnesota.

Francisco Lahoud, Research Associate, will work on the satellite data and combining with ground-based data.

Graduate Research Assistants, will be involved in data collection, data processing, modeling, data analysis, etc.

Undergraduate Research Assistant, will assist with data collection, data processing, and results presentation.

B. Project Impact and Long-Term Strategy

Quantification of water storage on the surface and in the subsurface across Minnesota is essential for sustainable management of water use and improvement of the quality of Minnesota water resources. The developed methodology, which will be data intensive and modeling intensive, will be installed on a server computer at the University of Minnesota, and will be available to state agencies for installation on agency computers and free use by state agency staff. The methodology will be taught to water resource managers within the agencies. The methodology will also be taught in hydrology and water management courses at the University. The methodology and associated software will be disseminated to interested persons at other universities and agencies outside the State of Minnesota.

C. Timeline Requirements

The schedule (or timeline) for the project activities and completion deadlines were set based on the assessment of how long it is expected that the individual activities will require to complete. The total time for the project is estimated to be 36 months.

2016 Detailed Project Budget

Project Title: Minnesota: How Much Water? How is it Changing?

IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Personnel:	
John Nieber, Professor, BBE -Will serve as project principal investigator. Will oversee all project activities and manage the project to meet proposed deadlines. Will directly conduct the activities related to the compilation of the data and processing of the data for input to the selected water balance model. Will work directly on the estimation of the baseline water storage distribution in Minnesota. Will work directly with the co-PIs on the application of the water balance model for the calculation and validation of the change in water storage over the period from 2002 to 2015. Period: 7/2016 - 6/2019. 1.5 months/year	$ 0
Bruce Wilson, Professor, BBE - Will work on the uncertainty of estimates of water storage. Period: 7/2016 - 6/2019. 0.5 month/year	$ 0
Timothy Griffis, Associate Professor, SWC - Will conduct the research related to the water balance model. His expertise is in land surface/atmosphere interaction and conducts research on measurement of modeling of evapotranspiration processes. He will advise one of the two graduate students supported on this project. 75% salary/25% benefits. Period: 7/2016 - 6/2019. 1 month/year	$ 39,999
John Baker, Professor and Research Leader, USDA-ARS, SWC - Will work alongside Dr. Griffis on the application of the land surface/atmosphere interation model. He has expertise in soil moisture monitoring and micrometerology and evapotranspiration processed. He will work with the quantification of soil moisture storage and also storage of surface waters in lakes and wetlands. Period: 7/2016 - 6/2019. 0.5 month/year	$ $0
Roman Kanivesty, Adjunct Professor, BBE - Will work with the interpretation of geologic data for the various geologic provinces throughout Minnesota. This is essential to quantify the water storage characteristics of those aquifers. 75% salary/25% benefits. Period: 7/2016 - 6/2019. 1.5 month/year	$ 50,083
Francisco Lahoud - Research Associate. He will work with the satellite remote sensing data and Dr. Griffis on combining the satellite data results with the meteorological and hydrologic data analysis. He is currently working on his Ph.D. using remote sensing data using GRACE satellite data for quantifying the storage within the Minnesota River Basin. He also has practical experience working with other remote sensing platforms such as Landsat and is familiar with satellites that have soil moisture monitoring sensors. 75% salary/25% benefits. Period: 7/2016 - 6/2019. 12 months/year	$ 187,811
Graduate research assistants (2 - one in BBE and one in SWC). They will assist with the research and be involved in data collection, data processing, modeling, data analysis, etc. 57% salary/43% benefits. Period: 7/2016 - 6/2019. 6 months/year	$ 260,353
Undergraduate research assistant to assist with data collection, data processing, and results presentation 100% salary. Period: 7/2016 - 6/2019. 4.5 months/year	$ 28,385
Contracts:	
USGS; 25% support for Jared Trost. Will be work with Dr. Nieber on the estimation of water storage in the aquifers of the state. Period: 7/2016 - 6/2019. 3 months/year	$ 129,600
Equipment/Tools/Supplies:	
None.	$
Travel:	
To facilitate the ability to travel to different parts of the state to check on monitoring wells, geological data, streamflow data, meteorological data, etc, and to travel to meetings associated with the project.	$ 6,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 702,231

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	N/A	
Other State $ To Be Applied To Project During Project Period:	N/A	
In-kind Services To Be Applied To Project During Project Period:		
Indirect Costs/Facilities and Administration (52%)	$ 242,646	secured
Funding History:		
Remaining $ From Current ENRTF Appropriation:	N/A	

How much water is there?

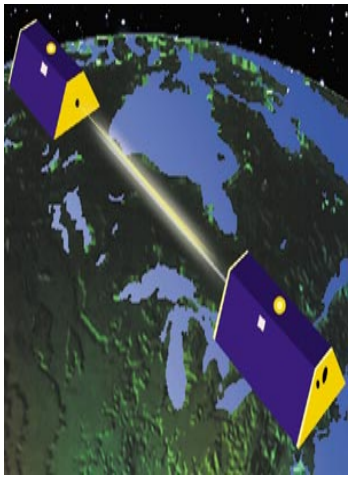
The issues:

Too much water

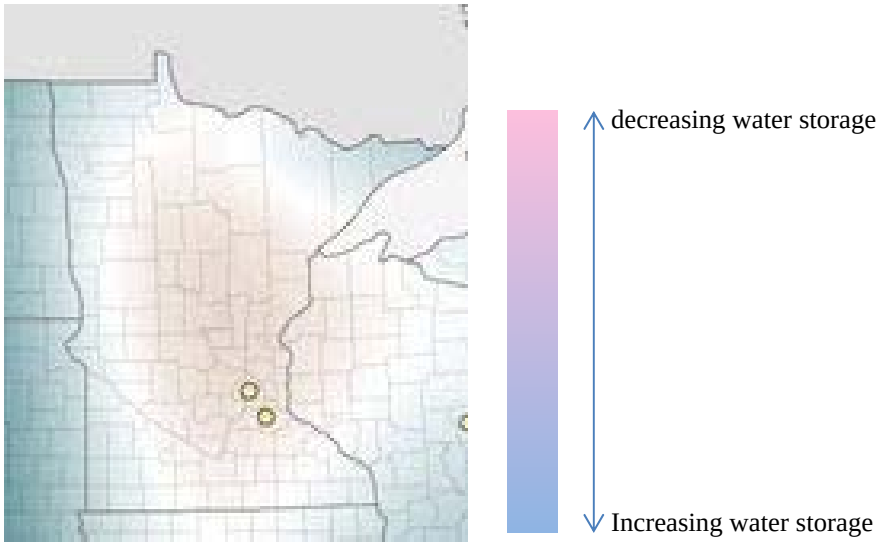
Too little water

How much water is there? We can quantify this by combining multiple data sources, including data from satellites, observation wells, stream gauges, weather stations, soil maps, geology maps, and land surface topography.

Satellites:

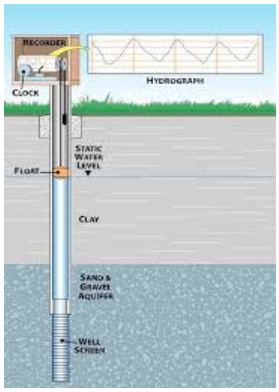


GRACE



GRACE satellite results, 2003-2012. Large parts of Minnesota show decreasing water storage (Source: NOAA)

Ground-based measurements:



Observation wells

Streamflow

Weather

Project Manager Qualifications & Organization Description

PI:

Name: John L. Nieber
Title: Professor
Degrees: 1972, B.S., Forest Engineering, Syracuse University
1974, M.S., Civil and Environmental Engineering, Cornell University
1979, Ph.D., Agricultural Engineering, Cornell University
Licensed Professional Engineer: Minnesota
Certified Professional Hydrologist: American Institute of Hydrology
Affiliation: Department of Bioproducts and Biosystems Engineering, University of Minnesota
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John Nieber has over 35 years of experience working as a professional hydrologist in conducting teaching and research activities related to hydrology and water quality. In the 1980's he collaborated on research involving remote sensing of soil moisture and is currently advising a graduate student on a self-funded project using GRACE satellite data, and meteorological and hydrologic data to characterize changes in water storage within the Minnesota River Basin. He managed a LCCMR project on freshwater sustainability from 2007-2009, from which maps of groundwater recharge were derived. The work resulting in three publications in the scientific literature and has influenced freshwater sustainability planning activities within Minnesota. One student, Dr. Heidi Peterson received her Ph.D. degree as a result of support from this project. John Nieber has managed numerous other projects as well, including being the manager of a five-year contract with the MPCA for the Impaired Waters Program. He is the author of over 60 refereed articles in the scientific literature.

Organization:

The University of Minnesota Twin Cities campus is one of the Big Ten universities. It ranks very highly in many of its programs including its College of Food, Agriculture and Natural Sciences, and it College of Sciences and Engineering. It has excellent library resources and its resources for supercomputing are exceptional. In addition to all of the high quality features at the University of Minnesota, faculty at the University of Minnesota have developed excellent working collaborative relationships with scientists and engineers at the state and federal agencies within Minnesota.