Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Work Plan

Date of Report: January 9, 2014

Date of Next Status Update Report: January 31, 2015

Date of Work Plan Approval:

Project Completion Date: June 30, 2016

Does this submission include an amendment request? _No_

PROJECT TITLE: Rain Water Reuse and Valuation Investigation

Project Manager: Scott Alexander

Organization: University of Minnesota

Mailing Address: Dept. of Earth Sciences, 310 Pillsbury Dr SE

City/State/Zip Code: Minneapolis, MN 55455

Telephone Number: (612) 626-4164

Email Address: alexa017@umn.edu

Web Address: https://sites.google.com/a/umn.edu/um-chillers/

Location: Hennepin and Ramsey Counties

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$300,000**
	Amount Spent:	**$0**
	Balance:	**$300,000**

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 03l

Appropriation Language:
$300,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to design, install, and monitor a rainwater reuse system for use in evaporative chiller systems and identify other potential applications for rainwater reuse systems.

I. PROJECT TITLE: Rain Water Reuse and Valuation Investigation

II. PROJECT STATEMENT:

This project aims to convert a liability, in the form of excess storm water runoff in urban environments, into a valued resource for chilled water production. Rain water reuse for evaporative chiller feed directly replaces potable drinking water typically supplied by ground water wells. Rain water has the advantage very low dissolved solids as it is naturally distilled by atmospheric processes.

Currently, most urban areas, and particularly commercial districts, produce large amounts of rainfall runoff creating localized flooding while washing nutrients and contaminants downstream. Conventional storm water systems to mitigate these problems are difficult to implement in densely urban areas with many pre-existing structures and dense underground utilities. Additionally, most urban properties, especially shopping centers, put a premium on maximizing parking area.

Coincidentally, evaporative chiller systems are widely used in commercial, retail, and educational settings. On the U of M Twin Cities campuses about 1/3 of the summer-time potable water usage goes to evaporative chiller systems (100 million gallons/year). Chilled water systems fed by ground water can only cycle water 3 to 4 times before it has to be replaced to prevent mineral build up. By its very dilute, naturally distilled character, rain water can by cycled many more times before disposal. Additionally, this distilled water should reduce chemicals and acids used in "blow-down" cycles where accumulated minerals are removed reducing waste discharge and extending equipment life.

The discharge from roofs is nearly pure distilled water, relatively free of contaminants, and requires only modest cleanup for reuse. In Minnesota, the annual average rainfall on a typical building can easily supply feed water to evaporative chillers cooling the same building and perhaps several surrounding buildings.

Calculations of storage volumes and treatment requirements, based on rainfall rates, urban roof water quality, and seasonal chiller demand, are needed to estimate project costs and space requirements. Once these baseline parameters and engineering/operational issues are defined, design and implementation of rain water reuse in an operational chiller system can commence. The cost of cistern systems compared to traditional storm water management can be offset by savings on potable water supply.

Supplemental work would include evaluation of rain water reuse compared to applications that have been traditionally supplied by treated, municipal potable water supplies. Current reuse programs are focused on lawn and turf grass irrigation where low cost treated city water is difficult to displace. New areas of reuse include water supply for toilet flushing, laundry, industrial process water, and anywhere the naturally dilute nature of rain water would be an advantage. Additionally, this study would investigate scaling up from individual chillers to district areas, identify policy issues, and analyze cost benefits associated with a high quality, non-potable water supply distinct from gray water and treated waste water.

III. PROJECT STATUS UPDATES:

Project Status as of December 31, 2014:

Project Status as of June 30, 2015:

Project Status as of December 31, 2015:

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Rain water quality and evaporative concentration

Description: We will collect representative samples of rain water from typical roof types representing seasonal, storm-to-storm, and single-storm variation. A variety of roof types will be utilized on the St. Paul and Minneapolis Campuses including red clay tile typical of historic buildings, flat tar roofs and galvanized steel common on commercial buildings, and asphalt shingles representative of residential roofs. Rain water itself varies in composition between individual storms and even with in single storms. In particular, the earliest parts of rain storms concentrate dust and particulates in the air while later rainfall has a much lower load of solids. Systems that bypass the first flush of rain water could be used to reduce sediment and contaminant load in the cistern water.

A representative selection of the collected rain waters and roof run off will be analyzed for constituents susceptible to concentration and mineralization in evaporative chiller systems. A laboratory scale concentration of sampled rainwater can be done with a bench top rotary evaporator. Some minerals, especially calcite, can easily precipitate clogging plumbing systems. Metals commonly found in roofing materials like copper and zinc can prevent, or poison, mineral precipitation. By conducting laboratory-scale evaporative concentration studies using pure rain water and roof run off water we can define the limits of rain water recycling in evaporative chiller systems. The results of the lab scale rotary evaporator will be used to define the initial operation of a full scale evaporative chiller in Activity 2.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 143,000
Amount Spent: $ 0
Balance: $143,000

Activity Completion Date: July 31, 2015

Outcome	Completion Date	Budget
1. Journal article on properties and quality of rain water from urban roof top environments.	June 30, 2015	$ 100,000
2. Journal article on potential impacts and improvements to chiller operation from rainwater reuse.	July 31, 2015	$ 43,000

Activity Status as of: **December 31, 2014**

Activity Status as of June 30, 2015:

Activity Status as of December 31, 2015:

Final Report Summary:

ACTIVITY 2: Design, installation, and monitoring of rain water reuse system.

Description: A specific site will be found on campus for the cistern system that is favorably located near an existing evaporative chiller system. A specific design will be produced that meets the needs of the site and takes advantage of current construction projects on campus. The cistern and treatment system will be connected to an existing evaporative chiller system.

Real time monitoring of water quality within the chiller system will allow adjustment, adaption, and optimization of operation. Direct determination of the number of operational cycles rain water can be reused through and the reduction in periodic descaling requirements are a key result. This real world experience can be applied to additional rain water reuse systems on campus and all around the state of Minnesota.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 125,500

Amount Spent: $ 0
Balance: $125,500

Activity Completion Date: June 30, 2016

Outcome	Completion Date	Budget
1. Design rain water storage and reuse system.	July 31, 2015	$ 15,000
2. Install rain water reuse in evaporative chiller system.	March 1, 2016	$ 100,000
3. Journal article on monitoring and operation of rain water fed chiller system.	June 30, 2016	$ 10,500

Activity Status as of June 30, 2015:

Activity Status as of December 31, 2015:

Final Report Summary:

ACTIVITY 3: Public Education and Outreach.
Description: Results will be provided in an addendum to the Minnesota Storm Water Manual in coordination with UM Extension Service. Journal articles covering the potential for rain water reuse in commercial evaporative chiller systems will be produced. Additional opportunities that take advantage of rain water properties for irrigation, non-potable supply to toilets, laundry, etc. will similarly be written up in for peer reviewed journals.

We are also already working with local engineers and architects to develop rain water reuse systems in the commercial market. Of particular interest are retail settings, like large shopping centers, that produce detrimental amounts of storm runoff but are resistant to giving up parking space for storm water management. These same retail areas use large evaporative chillers systems that consume significant ground water resources. Having an operational system on campus would allow open house tours demonstrating their operational requirements.

Results of this study will be combined with existing storm water quality monitoring on campus. We will explore additional opportunities for reuse of storm water runoff on campus as at the 17th Ave Residence Hall where roof runoff is stored for reuse in toilet flushing and at the Landcare Building where a cistern stores storm water for irrigation. While rain water quality declines from pure rain water to roof runoff to street level runoff finding ways to reuse this water instead of simply dumping it to the river at critical. New options for rain water reuse are particularly important where underground conditions limit infiltration of storm water and dense urban areas where there is no room for conventional storm water management systems.

Summary Budget Information for Activity 3:
ENRTF Budget: $ 31,500
Amount Spent: $ 0
Balance: $31,500

Activity Completion Date: June 30, 2016

Outcome	Completion Date	Budget
1. Addendum for Storm Water Manual.	June 30, 2016	$ 16,000
2. Peer reviewed journal articles on policy implications for storm water reuse.	June 30, 2016	$ 8,250
3. Peer reviewed journal articles on additional reuse opportunities.	June 30, 2016	$ 8,250

Activity Status as of December 31, 2015

Activity Status as of June 30, 2015:

Activity Status as of December 31, 2015:

Final Report Summary:

V. DISSEMINATION:

Description: Project results will be reported in an addendum to the Minnesota Storm Water Manual, several peer reviewed journal articles, and in semi-annual reports to the LCCMR.

Status as of December 31, 2014:

Status as of June 30, 2015:

Status as of December 31, 2015:

Final Report Summary: July 31, 2016

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Explanation
Personnel:	$ 131,726	Research Scientist (S. Alexander) 72% salary, 28% benefits, 2 years, 40% time position; Graduate Students in Earth Sciences and Mechanical/Civil Engineering 52% salary, 48% benefits (includes tuition), 2 years, 2 - 1/4 time positions
Equipment/Tools/Supplies:	$ 60,274	Water chemistry and stable isotope analysis of rain water and evaporative concentrates 300 analyses at $110 per analysis and water treatment and monitoring supplies for pilot cistern system.
Capital Expenditures over $5,000:	$ 100,000	Pilot scale cistern components and installation.
Capital Expenditures over $5,000:	$ 8,000	Roto-Evaporator for evaporation of rain water research.
TOTAL ENRTF BUDGET:	**$ 300,000**	

Explanation of Use of Classified Staff:
N/A

Explanation of Capital Expenditures Greater Than $5,000:
Roto-evaporator will be used to simulate evaporation of rain water in the laboratory allowing investigation of geochemical processes and mineral equilibria as they will evolve in the full scale evaporative chiller. The roto-evaporator will continue to be used in follow-on rain water reuse studies at the University of Minnesota.

The prototype cistern is required to store several thousand gallons of rain water for reuse in a nearby existing evaporative chiller system. The cistern system will be permanently installed in an underground vault or basement area and will continue to be used for feed water to an evaporative chiller system.

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 1.3 FTE

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
In-kind salary	$ 20,000	$ 0	Time for UMN Facilities Co-PIs to work on project.
State			
TOTAL OTHER FUNDS:	**$ 20,000**	**$ 0**	

VII. PROJECT STRATEGY:

A. Project Partners: UMN Facilities

B. Project Impact and Long-term Strategy: This project aims to reduce the demands on municipal water supplies and the aquifers by chiller systems while reducing storm water runoff. Storage cisterns can help cities meet increasingly stringent MS-4 storm water rules while reducing the load on existing storm water conveyances. The reduction in ground water demand can help preserve this precious resource for human consumption. The cisterns can be placed underground at commercial sites and then paved over to retain parking.

By realizing the value of rain water compared to potable drinking water we can reduce the need for additional wells and water treatment systems in a given municipality. A direct by-product is the more efficient operation of evaporative chiller systems. Current evaporative chiller systems are fed by municipal drinking water which has a significant load of dissolved minerals. These minerals concentrate in the chiller waters and must be disposed to the municipal waste water treatment system after 3 to 8 cycles in the chiller. In addition, harsh chemicals are used remove any built up mineral scale on a semi-annual basis. The discharge of these chemical de-scalers requires additional permits and fees. This is better than the old, now illegal, systems that used ground water in a once through process but is not a lot better. The low concentration of dissolved solids in rain water may allow more than 20 operational cycles of use before disposal.

Rain water reuse in chiller systems will reduce demands on storm water systems, municipal water supplies, and chiller operation. The costs of cistern installation and operation can be offset reduced costs for storm water management and drinking water supply allowing wide-spread adoption.

Chiller systems actually mimic the natural system where evapo-transpiration of rain water dominates the hydrologic cycle in Minnesota. The chiller reuse systems will never replace prairies and woodlands but do preserve their function in the hydrologic cycle.

C. Spending History:

Funding Source	M.L. 2008 or FY09	M.L. 2009 or FY10	M.L. 2010 or FY11	M.L. 2011 or FY12-13	M.L. 2013 or FY14
UM Facilities – for rain water cisterns at Landcare Building for irrigation water.		$25,000			
UM CPPM – for rain water cisterns at 17th Ave Residence Hall to flush toilets.				$100,000	
UM DEHS – storm water quality	$7,000	$5,000	$5,000	$10,000	

monitoring on campus.					

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S): See attached visual element.

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM: N/A

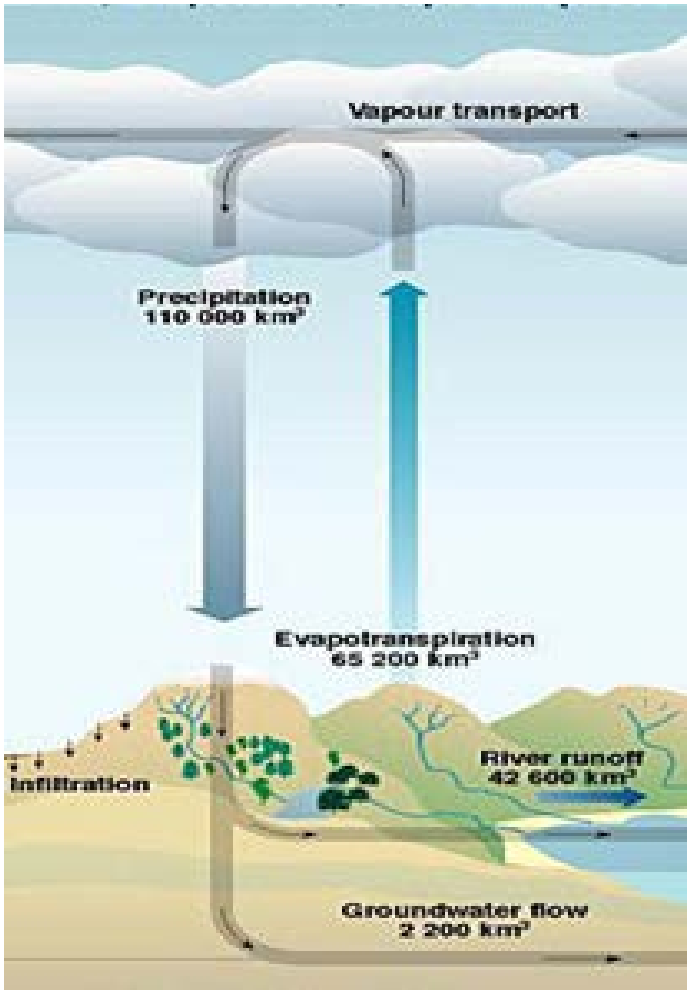
XII. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than January 31, 2015; July 31, 2015; and January 31, 2016. A final report and associated products will be submitted between June 30 and August 15, 2016.

Environment and Natural Resources Trust Fund
M.L. 2014 Project Budget
Project Title: *Rain Water Reuse and Valuation Investigation*
Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 03l
Project Manager: *Scott Alexander*
Organization: *University of Minnesota*
M.L. 2014 ENRTF Appropriation: $ *300,000*
Project Length and Completion Date: *2 Years, June 30, 2016*
Date of Report: *01/07/2014*

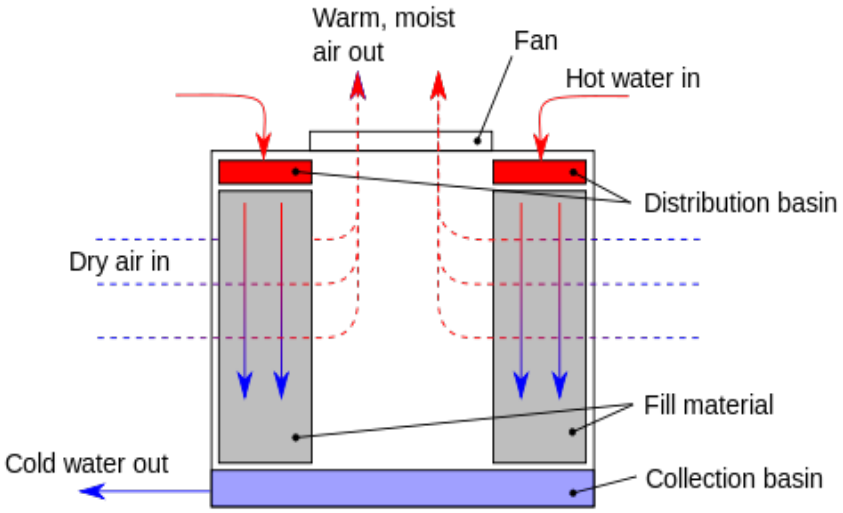
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Rainwater analysis***			***Cistern installation and monitoring***			***Public education & outreach***				
Personnel (Wages and Benefits)	**$92,000**	**$0**	**$92,000**	**$8,226**	**$0**	**$8,226**	**$31,500**	**$0**	**$31,500**	**$131,726**	**$131,726**
Research Scientist 72% salary, 28% benefits, 2 years, 40% time position ($55,388);											
Graduate Students in Earth Sciences and Mechanical/Civil Engineering 52% salary, 48% benefits (includes tuition), 2 years, two - 1/4 time positions academic yr, 1/8 summer ($76,328).											
Equipment/Tools/Supplies											
Supplies: Water chemistry and stable isotope analysis of rain water and evaporative concentrates 300 analyses at $110 per analysis.	**$33,000**	**$0**	**$33,000**							**$33,000**	**$33,000**
Supplies: Water treatment and monitoring supplies for pilot cistern system	**$10,000**	**$0**	**$10,000**	**$17,274**	**$0**	**$17,274**				**$27,274**	**$27,274**
Capital Expenditures Over $5,000											
Equipment: Roto-Evaporator for evaporation of rain water research	**$8,000**	**$0**	**$8,000**							**$8,000**	**$8,000**
Equipment: Pilot scale cistern components and installation				**$100,000**	**$0**	**$100,000**				**$100,000**	**$100,000**
COLUMN TOTAL	**$143,000**	**$0**	**$143,000**	**$125,500**	**$0**	**$125,500**	**$31,500**	**$0**	**$31,500**	**$300,000**	**$300,000**

Rain Water Reuse and Valuation Investigation Visual

Rain water is naturally distilled from the oceans.



UNESCO 1999



Evaporative chillers that recycle rain water mimic the natural hydrologic cycle replacing plant transpiration with evaporation.

About 60% of Minnesota rain water is transpired back to the atmosphere under natural conditions.

Sanford and Selnick 2013 JAWRA 49:217-230.