Minnesota Water Resources Conference

October 20-21, 2020

Book of Abstracts

ccaps.umn.edu/water

Sponsored by:
Water Resources Center
University of Minnesota

College of Continuing & Professional Studies
University of Minnesota

Cosponsored by:
Department of Civil Engineering, University of Minnesota
Minnesota Section, American Society of Civil Engineers
Minnesota Sea Grant College Program, University of Minnesota
Natural Resources Research Institute, University of Minnesota

Tuesday October 20, 2020

Concurrent Session I, Track A

Unregulated Contaminants in Source and Treated Drinking Water: PFAS
Jane de Lambert, Minnesota Department of Health; *Sarah Elliott,* US. Geological Survey; *Steve Robertson,* Minnesota Department of Health

Unregulated contaminants are one of the 21st century threats to drinking water for which existing monitoring resources and regulatory protections may be insufficient. The Minnesota Department of Health (MDH) monitors all public water systems (approximately 7000 statewide) for conformance with federal monitoring requirements and water quality standards. For thousands of chemicals in use in modern society, little or no monitoring of drinking water is done because there is neither a federal regulatory mandate nor resources to test for them in drinking water sources. One such group of chemicals is per- and polyfluoroalkyl substances (PFAS). During 2019, the MDH sampled source and treated drinking water from 47 facilities across Minnesota in order to characterize the presence of 32 PFAS compounds, among other contaminants. Fifteen of the drinking water facilities were sampled twice. A total of thirteen PFAS compounds were detected in at least one sample. The most widely detected compounds were PFOA and PFBS (30 detections), PFOS (31 detections), PFHxS (32 detections), and PFBA (76 detections). Average concentrations ranged from 0.8 (EtFOSAA) to 34.5 ng/L (6:2 FTS). The highest single concentration in a sample was 190 ng/L (PFBA). We assessed the potential hazard to human health by comparing detected concentrations in treated water samples to MDH drinking water guidance. Health risk for PFAS compounds is calculated via a Health Risk Index (HRI). The HRI is an additive risk assessment of co-contaminants that have similar health effects. Results from one drinking water system in the study exceeded the HRI for PFAS. Results from this study provide foundational data of the presence of PFAS compounds in Minnesota municipal drinking water.

Unregulated Contaminants in Source and Treated Drinking Water: Pharmaceuticals
Sarah Elliott, US Geological Survey; *Jane deLambert, Steve Robertson,* Minnesota Department of Health

The ubiquitous presence of unregulated contaminants in aquatic environments has been well documented. Consequently, it is plausible that drinking water sources can contain unregulated contaminants. Because federal regulatory mandates and resources do not exist for unregulated contaminants, such as pharmaceuticals, they are not routinely monitored in source and treated drinking waters. During 2019, the Minnesota Department of Health sampled source and treated drinking water from 47 facilities across Minnesota suspected to be vulnerable to wastewater influences. Samples were analyzed for 110 pharmaceuticals. Fifteen of the drinking water facilities were sampled twice. Preliminary results show that a total of 19 pharmaceuticals were detected in at least one sample. Most pharmaceuticals were detected in &lt10 samples metformin was an exception, which was detected in 15 samples. Similarly, &lt10 pharmaceuticals were detected in most individual samples. Concentrations ranged from 1.3 (carbamazepine antiseizure) to 2,040 ng/L (gabapentin nerve pain/antiseizure). Total concentrations of all pharmaceuticals detected in a given sample ranged from 2.2 to 2,169 ng/L. Generally, more pharmaceuticals were detected, and at higher concentrations, in source water compared to treated drinking water, indicating that some pharmaceuticals may be removed during the treatment process. We assessed the potential hazard to human health by comparing detected concentrations in treated water samples to MN Department of Health drinking water guidance or screening values and toxicity information available in the US Environmental Protection Agency’s ToxCast database. Preliminary results indicate that the hazard to human health may be low. Results from this study provide foundational data of the presence of pharmaceuticals in Minnesota municipal drinking water.

Management Approach to Safe and Sustainable Drinking Water Addressing PFAS Contamination across Fourteen Communities

Liz Kaufenberg, Andri Dahlmeier, Minnesota Pollution Control Agency; *Shalene Thomas,* Hannah Albertus-Benham, Wood PLC

On February 20, 2018, the State of Minnesota settled its Natural Resources Damage lawsuit against 3M for $850 million to address the approximately 150 square mile groundwater contamination plume affecting more than 140,000 residents in 14 communities within the East Metro.

The objective of this presentation is to discuss the approach used in the development of a Conceptual Drinking Water Supply Plan (CDWSP) for the East Metro area. The CDWSP is currently being developed and is intended to define the path to provide safe, sustainable drinking water in the East Metro Area while addressing each community's needs now and in the future. The plan considers both public water systems and private wells, using a region-wide approach. Several phases of the approach will be discussed including:

- Stakeholder communication and management
- Development of a new groundwater model
- Identification and evaluation of drinking water supply improvement options
- Development, screening and evaluation of concept-level projects and
- Development, evaluation and recommendation of scenarios.

Stakeholder communication and management will also be presented as well as how the drinking water system modeling, groundwater modeling, concept-level projects and scenarios were developed and integrated to drive the comprehensive regional approach.

Woodbury PFAS Planning and Expedited Treatment Project

Aaron Vollmer, Jacob Strombeck, AE2S; *Jim Westerman,* City of Woodbury

The City of Woodbury has seven per – and polyfluoralkyl substances (PFAS) impaired wells. Without these wells, Woodbury has only 12 non-impaired wells that are limited in ability to meet the City's existing and growing summer and peak water needs leaving the City without necessary water supply capacity and redundancy. The City, with guidance from the Minnesota Department of Health, was intending to use some of the impaired wells and allow for mixing within the distribution system to dilute the PFAS concentration to acceptable limits. However, through extensive hydraulic modeling, Woodbury's distribution system would not provide for this mixing if the impaired wells were operated in the future and portions of the City could be supplied with water containing levels of PFAS above current state and federal standards. Since mixing is insufficient, Woodbury is left with only 12 working wells limiting capacity, redundancy, and its ability to meet demand. Near-term treatment of some of the impaired wells is needed to meet interim peak water demand projections until a larger long-term solution is developed in conjunction with the State of Minnesota. The near-term treatment solution, using granular activated carbon (GAC) for PFAS treatment, has been designed and constructed on an

expedited emergency basis to ensure operability in summer 2020. Authorization was given to the City by the State in January 2020 with the goal to have the plant operational by summer of 2020. The expedited nature of the near-term project provided some very unique and challenging issues that needed to be addressed. The City utilized the design-build process to expedite the project because traditional methods would not allow for operation within such a short window of time. This presentation will provide an overview on PFAS and the contamination in Woodbury groundwater, discuss the hydraulic mixing modeling, and provide insight into the rapidly deployed near-term treatment solution.

Tuesday October 20, 2020

Concurrent Session I, Track B

Building Community Resiliency Leveraging City-Wide 2D Storm Sewer Modeling
Justin Klabo, AE2S; *Jen Desrude,* City of Burnsville

Communities have extensive GIS & Storm Sewer Modeling Data available to them. This presentation will walk through how communities can utilize this data to help plan, predict and mitigate flooding within their communities. The overall goal of the presentation is to better educate individuals how to build resiliency to urban flooding. The City of Burnsville, like many communities throughout the Metro, had a 1D City-Wide XPSWMM model developed as part of their MS4 program to better understand how their storm sewer system functions. The City wanted to upgrade their 1D model into a 2D model to create a model with the highest level of accuracy for their complex storm sewer network (Burnsville is the first community within the Metro to develop a City-Wide 2D model). The 2D model allowed the City to have a better understanding of current conditions a traditional 1D model wouldn't be able to identify (i.e. surface flow velocities, erosion susceptibility of overland flow areas, EOF capacity issues in residential areas, and showing where overland flow conveyance points are most critical). These items are in addition to the main component of the model which is the flood inundation rasters developed for the various storm events. This modeling output data was then taken and integrated into a custom built Resiliency Model evaluating the Consequence of Failure versus the Likelihood of Failure criteria. The various parameters were then weighted based on input from City staff to determine the most critical aspects of their system such that the resiliency model would take these factors (weights) into account to determine which areas are the most "critical". This approach removed any "bias" from the evaluation process allowing the City to develop a guiding document/living model the City can use for future planning & mitigation projects. All of the processes are fully dynamic allowing the 2D model and Resiliency Analysis to be rerun to re-prioritize the zones annually.

Edina's Flood Risk Reduction Strategy
Jessica Wilson, Ross Bintner, City of Edina; *Sarah Stratton,* Barr Engineering Company

Urban flooding is increasingly demanding the attention of water resources managers. Over a ten-month period, a task force of staff and community members worked to come to a shared understanding of what flooding is, what is valuable, and what matters, where, and to whom.

The effort to put flooding into focus has resulted in the creation of a framework for understanding factors that define flood risk, climate, exposure, and vulnerability. Our definition of flood risk is adapted from the 2012 IPCC special report, "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation."

We explored the factors that are driving increasing flood risk. The primary and secondary drivers are climate change and aging infrastructure. Well-drained landscapes and imperviousness also matter, but are more historical drivers of flood risk.

Conventional flood risk management focuses primarily on reducing exposure to flooding or transferring risk, although sometimes in unknown or unexpected ways. This often means public capital infrastructure projects to modify the flood or regulatory standards applied when properties develop or redevelop. Through this framework we recognize that the public realm is a large opportunity space to reduce risk, but not the only one. Some of the simplest and most cost-effective ways to reduce risk are for people to reduce the vulnerability of their structures and property. This framework calls for public and private actions to reduce community flood risk. Additionally, the framework recognizes climate as a factor.

We defined the sectors of municipal work within which we work to connect on the promise to comprehensively reduce the risk of flooding throughout the community infrastructure, regulation, outreach and engagement, and emergency services.
This work to develop a strategy for reducing flood risk has resulted in a shift from a problem-solving paradigm to one of risk management.

Preserve Boulevard Lift Station: Solving Persistent Urban Flooding Problems with Innovative Solutions

Joe Seidl, Bob Leba, SRF Consulting Group; *Carter Schulze,* City of Eden Prairie; *Joe Seidl,* SRF Consulting Group

Eden Lake located in Eden Prairie has experienced regular and prolonged high-water levels for decades resulting in increased erosion, reduced water quality, and a system that is more susceptible to flooding from large rain events. The high water levels are caused by urban development and limited flows through the existing storm sewer. Eden Lake drains directly to a wetland that ultimately outlets to Purgatory Creek. Traditional flood management practices, such as increasing discharge rates or adding storage volume could not be implemented without adversely impacting downstream properties and water resources.

SRF Consulting Group worked with the City of Eden Prairie, Riley Purgatory Bluff Creek Watershed District, and local property owners to design a system that would help mitigate the flooding problems of Eden Lake while minimizing adverse impacts. The 2019-2020 Preserve Boulevard Reconstruction Project included storm sewer upgrades and the construction of a lift station capable of pumping 8,000 GPM. The design diverts water into neighboring Neil Lake to utilize existing storage and reduce impacts downstream. Detailed hydraulic modeling was critical in evaluating potential designs, securing permits, and sizing stormwater infrastructure.

The focus of the presentation will be on the design process, hydraulic modeling, and coordination required to advance this project from conceptual design through construction. We will outline the alternatives evaluated in the preliminary design and summarize the benefits of the selected lift station design over traditional solutions.

Northern Columbia Golf Course BMPs: Advancing Urban Flooding and Water Quality Solutions by Partnering Across Jurisdictional Lines

Lisa Breu, SRF Consulting; *Nancy Stowe,* Mississippi Watershed Management Organization; *Erin Hunker,* SRF Consulting

The 1NE Watershed drains 2,000-acres of northeast Minneapolis and southern Columbia Heights into the Mississippi River. The watershed comprises typical mixed urban development, with a large park, golf course and rail yard lying in its center. The 1NE Watershed faces numerous urban stormwater challenges, with multiple residential flooding locations, combined sewer overflow connections and a lack of water quality treatment.

The Mississippi Watershed Management Organization (MWMO), City of Minneapolis (City), and Minneapolis Park and Recreation Board (MPRB), in conjunction with SRF, have been working to plan, prioritize and develop preliminary and final designs for capital projects that improve stormwater management, increase flood resiliency, reduce pollutant loading to the Mississippi River and improve ecological function with the 1NE Watershed.

The focus of this presentation will be on the planning and final design of three new BMPs and a new storm sewer trunk system within Columbia Park and Golf Course. The project reduces flood inundation extents and duration and significantly reduces phosphorus and total suspended solids loading from a 600-plus acre watershed to the Mississippi River. The presentation will include a summary of the ‘lessons-learned’ from working with multiple stakeholders who are committed to working together to find a solution but may have diverging priorities along the way. We will also discuss the unique nature of this multi-agency partnership and its role in overcoming historic hurdles to improving stormwater management and ecological function in the 1NE Watershed. This project was a recipient of a BWSR Clean Water Planning and Practices grant.

Concurrent Session I, Track C

A Tale of Two Filters: Amending Filtration Media with Biochar to Remove Bacteria from Urban Stormwater

Justine Dauphinais, Jon Janke, Chase Vanderbilt, Coon Creek Watershed District; *Erik Megow, Ed Matthiesen,* Wenck Associates

There are numerous Best Management Practices designed to remove conventional pollutants from stormwater, but very few that target bacteria. Biochar, a charcoal-like substance made via pyrolysis of organic material, has recently been gaining attention as a potential filter media amendment for removing bacteria. Following a series of successful small-scale field trials that reduced E. coli concentrations in urban stormwater by 49-97%, the Coon Creek Watershed District, Wenck Associates, and the Cities of Blaine and Coon Rapids teamed up to construct two full-scale biochar- and iron-enhanced sand filters that treat a combined 1.5 square miles of suburban land use. Each filter is split into two identical cells, one with 30% biochar by volume added and one without. This design allows for head-to-head performance monitoring, testing the ability of biochar to remove E. coli while reducing nutrient and bacteria loading to two impaired creeks. We will present project design considerations and specifications, preliminary performance results since June 2020, and lessons learned along the way. This work was supported by MN Clean Water Fund grants administered by the MN Board of Water & Soil Resources.

Parkview Center School Filtration BMP: A Case Study for Coordination and Cost Savings

Nate Zwonitzer, Capitol Region Watershed District; *Todd Lieser,* Roseville Area Schools

Capitol Region Watershed District (CRWD) partnered with Roseville Area Schools to design and install an underground filtration system at Parkview Center School that captures and treats 12.5 million gallons of polluted runoff from the school and surrounding neighborhoods each year. The site was identified in subwatershed studies as an ideal location to make additional progress towards phosphorus loading goals of the Lake McCarrons Management Plan by installing a regional BMP. A Targeted Watershed Program grant from BWSR and the Clean Water Fund was secured to support design and construction. Multiple site constraints were identified that made typical stormwater infiltration impossible including poor draining soils, high groundwater and limited surface space due to regular use of athletic fields. Through persistent and comprehensive site investigations, a proprietary filtration system consisting of 53 cartridges that specifically target dissolved phosphorus was determined to be the best approach. The system is estimated to remove over 45 pounds of phosphorus per year.

The partnership with the school district was critical to the success of the project. It not only provided needed space but also resulted in cost savings for both parties through construction coordination between the BMP at Parkview and planned construction activities at other School District sites. Importing soil to Parkview from active construction at the nearby high school

reduced the school district's soil hauling and disposal costs by approximately $30,000, and saved CRWD over $200,000 on soil import costs. The soil was required to conduct a surcharge to support the BMP as well as provide cover. The raised grade also benefited the school district by reducing the cost of a future parking lot expansion. To address questions about long-term effectiveness of the filtration system, CRWD established a monitoring plan that will also inform pretreatment and filter maintenance needs.

Understanding the Role of Dissolved Phosphorus in Managing Stormwater
Michael Trojan, Minnesota Pollution Control Agency; *Jacques Finlay,* University of Minnesota

Phosphorus goals, such as those in Total Maximum Daily Loads, are typically expressed as total phosphorus. Stormwater management has largely focused on managing particulate phosphorus. Dissolved phosphorus, however, is considerably more bioavailable than particulate phosphorus. Treating dissolved phosphorus is also more challenging, but without addressing it in our stormwater management efforts, it is unlikely many impaired waters will be restored. In this presentation we discuss the occurrence and distribution of dissolved phosphorus in urban stormwater runoff, focusing on seasonal and spatial differences in phosphorus source mobilization in urban areas, and present strategies for effectively managing it.

Hydrodynamics of Urban Ponds and Impacts on Phosphorus Retention
Ben Janke, Jacques Finlay, Vini Taguchi, John Gulliver, Heinz Stefan, University of Minnesota

Ponds are a potentially vital aspect of water quality in urban watersheds due to widespread abundance and use for purposes of stormwater management. This management has focused mainly on the role of ponds for storage and attenuation of high flows water quality benefits (e.g., phosphorus reduction) are assumed to arise from settling of particulates, with relatively little consideration to interactions between hydrologic and biogeochemical processes. To inform improved management of ponds for phosphorus (P) retention, we studied three urban detention ponds in Roseville, MN to quantify a complete annual budget of water and P fluxes in the ponds. We continuously monitored inflows, outflows, and water quality (nutrients, dissolved oxygen), along with temperature profile time series at 30-minute resolution. Across the ponds, annual retention of total P was high (&gt50%) despite expecting ponds to be net sources of P due to old age, high outflow P concentrations, and frequently-observed hypolimnetic hypoxia that could cause soluble P release from sediments. Event-scale analyses suggest strong hydrologic controls on P: retention of P increased roughly with antecedent pond storage capacity, and outflow soluble P tended to decrease as inflow-induced mixing depth increased, indicating dilution or exposure of inflows to oxic sediments. By contrast, wind-mixing events were rare due to high sheltering by trees. Together these results suggest that understanding hydrologic and wind-sheltering effects are crucial to improving pond performance for meeting downstream water quality goals

Concurrent Session I, Track D

Chloride Trend Analysis in an Urban Shallow Lake
Chris Kucek, Capitol Region Watershed District; *John Manske,* Ramsey County Public Works; *Mark Houle,* Capitol Region Watershed District

Como Lake is a popular 70.5 acre shallow lake in St. Paul, Minnesota that is heavily impacted by stormwater runoff from the surrounding urban watershed. In 2014, Como Lake was listed as impaired for excessive chloride by the Minnesota Pollution Control Agency (MPCA) for exceeding the chronic state standard of 230 mg/L. Chronically elevated levels of chloride can directly harm native freshwater organisms by disrupting osmoregulation, and there is currently no practical method to remove chloride from fresh water bodies. Depth and surface chloride concentrations were sampled from 1984-2020 by Ramsey County Public Works (RCPW) in partnership with Capitol Region Watershed District (CRWD). Samples were analyzed by year, season, and depth to understand chloride trends within Como Lake. Continuous conductivity readings measured in the hypolimnion by a sonde from April to October in 2017-2019 were correlated with sampled chloride concentrations. Regression analysis found a strong correlation between chloride concentrations and conductivity (R-squared = 0.88). This relationship was used to model chloride concentrations during this time and showed that conductivity measurements can be used as a surrogate for chloride sampling in Como Lake. Average chloride concentrations in Como Lake are increasing in the entire water column, with especially high readings found in the hypolimnion during winter and spring. Continued monitoring year-round will be needed to document future changes to chloride concentrations in the lake as statewide deicing best management practices and regulations are adopted and as impacts to the aquatic ecosystem are observed.

Lake Management Strategies for Harmful Algal Bloom Management
Elizabeth Crafton, Hazen and Sawyer

There is an overall increasing trend in harmful algal blooms (HABs), most notably cyanobacteria dominated HABs. Many water supply systems are plagued by such blooms, which places an added burden on the local economy and impacts recreation and public relations. More frequent HABs in recreational waters increases the risk of human exposure to cyanotoxins. Managing HABs requires a holistic multi-barrier approach that encompasses monitoring, and both short- and long-term management practices. This presentation will outline short- and long-term management practices and review key components of a monitoring program. Short-term management is used to proactively respond to the immediate issue and is an important aspect as it can either maintain water quality or contribute to its decline. Algaecide is the most commonly used short-term management technique, therefore it is important to understand the relationship between application, the release of intracellular cyanotoxins and the risk of human exposure to reactional waters. Whereas long-term management focuses on preventing the occurrence of HABs by addressing the driving forces (eutrophication and ecosystem

imbalance). Both short and long-term management are driven by the monitoring program used to characterize the system and track changes. The monitoring program can also determine the potential for cyanotoxin presence and risk of human exposure. Additionally, the monitoring programs provide key biological information that determines which management techniques (short- and long-term) are applicable for the system. Recommended strategies for systems with different characteristics will be reviewed as well as monitoring programs to evaluate risk of HAB and cyanotoxin occurrence.

A Holistic Adaptive Management Plan for Improving Como Lake over the Next 20 Years
Britta Belden, Bob Fossum, Capitol Region Watershed District

Como Lake is a beloved natural resource in St. Paul, Minnesota that has been highly impacted over time by urban development as evidenced by frequent algal blooms and a curly-leaf pondweed infestation. Como Lake has been listed as impaired for nutrients since 2002 with annual average phosphorus concentrations measuring three-times greater than the State standard (60 µg/L). Excess phosphorus is due to decades of stormwater runoff as well as significant internal loading.

Capitol Region Watershed District (CRWD) and its many partners updated the Como Lake Management Plan (CLMP) in 2019 to define goals and management actions to improve water quality over the next 20 years. The CLMP takes a holistic approach to addressing water quality issues by identifying actions that work toward the goals of the plan under three categories: in-lake, watershed, and community actions. The identified actions are organized into a short-term implementation plan that operates on a 3-year adaptive management cycle. Actions from the short-term implementation plan will be completed and the lake's response will be evaluated. Based on how the lake responds, actions will be planned for the following 3-years to continue working toward water quality goals. This adaptive management strategy acknowledges that Como Lake is a living natural system and is designed to work with the lake as it changes.

In 2020, CRWD began implementing several management actions for the first implementation cycle including two major projects: an herbicide application and an alum treatment. Monitoring will determine the effectiveness of these actions and help plan for future management.

Satellite Remote Sensing for Water Quality Spatial/Temporal Trend Analysis in 10,000+ Minnesota Lakes Using an Automated High-Performance Computing Environment
Leif Olmanson, Benjamin Page, David Porter, Jeffrey Peterson, Marvin Bauer, Patrick Brezonik, University of Minnesota

Using Landsat imagery, we have been assessing lake water clarity in Minnesota, USA for over 20 years. For early assessments we used empirical methods and in situ Secchi calibration data. Recent advances in satellite technology (improved spectral, spatial, radiometric and temporal resolution) and atmospheric correction, along with cloud and supercomputing capabilities, have enabled development of automated regional-scale measurements of water quality. These new capabilities provide opportunities to improve lake and fisheries management by measuring more

variables (chlorophyll, colored dissolved organic matter (CDOM) and total suspended matter, the main determinants of water clarity) more often. Using these new capabilities we created a 30-year (1985-2015) Landsat-derived water clarity database and 2015 and 2016 CDOM maps for 10,000+ lakes. These maps along with auxiliary data were used for spatial/temporal analysis to explain regional differences in water quality. Areas dominated by forest/wetland had higher water clarity than agricultural/developed areas. Decreases in water clarity throughout the state were attributed to land use intensification and increasing late summer temperatures. Differences in CDOM were related to predominant land cover/use with wetland/forested areas associated with higher CDOM than agricultural areas. CDOM temporal changes were attributed to wetter conditions in 2016: decreases in agricultural areas due to dilution by rainfall and increases in forest/wetlands areas, due to enhanced CDOM transport from forested wetlands.

Concurrent Session I, Track E

Temporal Dynamics of Pathogens and Antibiotic Resistance in Raw and Treated Stormwater

Tamara Walsky, Satoshi Ishii, University of Minnesota; *Anita Anderson, Nancy Rice,* Minnesota Department of Health

Stormwater is considered as an alternative water source for both potable and non-potable uses. However, stormwater has not been widely used as an alternative water source, most likely due to a lack of knowledge about the presence and risks associated with pathogens and antibiotic resistance genes present in raw and treated stormwater and how these populations change with environmental conditions. Five different stormwater reuse systems in the Twin Cities metro area were sampled from every three weeks from June to October 2019 to build a comprehensive data set for analysis of temporal dynamics of pathogens and antibiotic resistance genes (ARG) in raw and treated stormwater samples. Microfluidic qPCR, a high-throughput quantification tool provided microbial data for 12 bacterial pathogens, 11 viral pathogens and 48 ARGs along with physiochemical testing such as turbidity, free and total chlorine, and water temperature to evaluate environmental conditions. The calculated pathogen and ARG removal efficiencies for each stormwater reclamation process compare how well these contaminants can be removed by different stormwater reclamation systems. Correlations between pathogen and ARG levels and environmental parameters such as temperature and precipitation assess the impact of precipitation and other environmental variables on pathogen and ARG concentrations in stormwater.

Determination of Fecal Contamination in the Skunk Creek and Agate Bay Watershed

Lisa DeGuire, University of Minnesota, Duluth; *Derrick Passe, Emily Nelson,* Lake County SWCD; *Chan Lan Chun,* University of Minnesota Duluth

Fecal contamination of Minnesota beaches and waterways continues to be a widespread and pervasive problem. Skunk Creek, Burlington Bay and Agate Bay Beach in Two Harbors, MN are listed as “impaired” for the fecal indicator Escherichia coli, and recreational advisories are an issue of concern for both residents and tourists alike. This project aims to differentiate between sources of fecal contamination within the Skunk Creek and Agate Bay watersheds in Two Harbors, using culture-independent microbial source tracking methods, and to explore the relationships between elevated levels of E. coli and the ancillary water quality parameters along a watershed gradient. Water samples were collected from eight sites along the impaired waterways during base flow and storm events. Water chemistry, namely major ion compositions and the levels of E. coli, were measured along with physicochemical water quality parameters. Potential fecal sources were determined using quantitative polymerase chain reaction (qPCR) analysis with human (HB and Lachno3) and avian biomarkers (GFD). Our results identify hotspots and potential sources of fecal contamination, showing greater levels of human biomarkers at downstream sites and increased levels of the avian biomarker, iron

concentrations, water temperature and turbidity in upstream sites. Additionally, levels of E. coli were correlated with stormwater events, while human fecal sources appear to be site-specific and independent from storm events. These findings are essential in developing mitigation and management strategies to E. coli impairments and applicable to other Minnesota streams experiencing similar stressors.

Stormwater Reuse for Irrigation Assessment Methodology: Four Years Later, Three Case Studies on Targeting Water Reuse for Irrigation to Meet Specific Partner Goals
Charlie Sawdey, Alex Schmidt, Houston Engineering, Inc.

Across the metro, there has been growing interest in implementing stormwater reuse irrigation projects as a means to tackle multiple local goals: reducing reliance on groundwater supplies, improving water quality, and alleviating surface runoff flood events. Using a 2016 Clean Water Fund grant from the Board of Water & Soil Resources, the Rice Creek Watershed District developed a GIS based watershed-scale assessment methodology (Stormwater Reuse for Irrigation Assessment Methodology) to identify and prioritize potential locations suitable for stormwater reuse irrigation projects throughout their District. Since then, the RCWD, along with the City of Eagan and Washington County have employed this methodology to determine technically feasible sites for reuse irrigation projects and apply different criteria to identify the best local projects based on each entity's unique goals, including: reducing impact of high groundwater users, identifying cost-effective implementation solutions, implementing projects in infiltration restricted or priority watershed areas, and engaging partners that are more likely to be willing to implement. Use of the methodology has resulted in successful engagement of local decision makers to pursue stormwater reuse irrigation projects at sites prioritized by this methodology.

Report on Stormwater Issues: National, State, and Local Perspectives
Randy Neprash, Stantec, Minnesota Cities Stormwater Coalition, National Municipal Stormwater Alliance

This presentation will be an up-to-date report on various stormwater issues of interest and concern. Because of the presenter's unique roles in local, state, and national stormwater contexts, this report will include information about all these levels of practice and how they may be interrelated.

This presentation will include information about:

- Stormwater portions of the 2020 AWIA Bill in Congress
- Stormwater reuse – in the contexts of the EPA Water Reuse Action Plan and the MN Dept. of Health
- Stormwater research – in the contexts of national initiatives and organizations
- MN MS4 General Permit reissuance
- PAH and coal tar sealant lawsuits
- Lake Pepin TMDL and related MS4 concerns
- Other TMDL issues related to MS4 permits

- Street sweeping and “crediting” under the MS4 permits
- Other issues and areas of interest/concern

The author recognizes that this abstract does not comply with typical submittals or the Conference’s submittal standards. There has been significant interest in many of these issues and the author is able to provide a unique and very current perspective on this wide range of items. Having a well-informed perspective on these national stormwater items is unusual.

Concurrent Session II, Track A

Impacts of Stormwater Infiltration on Chloride in Minnesota Groundwater
Michael Trojan, Sharon Kroening, David Fairbairn, Minnesota Pollution Control Agency; *Alycia Overbo, Tracy Lund,* Minnesota Department of Health

Chloride concentrations are increasing in shallow groundwater in urban areas. Deicing salt is the primary source of this chloride. During winter, when deicing salt is heavily used, chloride concentrations in urban runoff typically exceed 1000 mg/L and often exceed 10,000 mg/L. Infiltration is a preferred practice for managing stormwater runoff but can impact shallow groundwater quality. We estimated chloride loading for several different scenarios to identify potential impacts of infiltration on shallow groundwater. In this presentation, we present these results and provide recommendations to minimize groundwater impacts from stormwater infiltration.

The Sentinel Lakes Groundwater Network: A Paired Groundwater/Surface Water Study of the Movement of Phosphorus and Chloride
Andrew Streitz, Minnesota Pollution Control Agency

Since 2013, a network of shallow monitoring well nests have operated on the shores of selected lakes enrolled in the MN Department of Natural Resources Sentinel Lakes program. Taking advantage of the robust surface water datasets collected for this program, paired monthly groundwater and surface water samples have been collected and analyzed from the wells and four lakes for the last seven years. Continuous monitoring is performed through downhole instruments placed in wells to collect ambient air temperature and barometric pressure, groundwater elevation and water temperature, and conductivity. This dataset of groundwater and surface water information is unusual in its breadth and length of sampling in the state, and provides insights into the movement of compounds of interest between groundwater and surface water in counties dominated by agriculture.

An analysis of the data has revealed surprising trends in the interaction between groundwater and surface water, including the strong control groundwater exerts over surface water chloride levels at Lake Shaokatan. The relation between chloride concentrations in groundwater and the lake exhibit an R Squared regression value of 0.94. Phosphorus concentrations in both groundwater and the lake tracked the steady improvement in density of lake aquatic vegetation through 2017, as well as its decline as Phosphorus levels once again rose. At Madison lake where a downward gradient carries surface water through groundwater and into the Minnesota River valley, rising levels of Phosphorus in the lake are matched by similarly rising concentrations in both the shallow and deep groundwater wells.

Phosphorus and chloride are growing concerns in the state as both threaten the quality of the state's water resources. Tracking their transport from land use into groundwater and surface water resources will become critical in understanding the source of the threat, and the environmental conditions that allow its spread

The Effects of Iron Mining on Hydrology in the Saint Louis River Basin
Tim Cowdery, Anna Baker, US Geological Survey

The St. Louis River Basin (SLRB) in northern Minnesota contains not only part of the Mesabi Iron Range, but also territory ceded by the Tribes of this region, who maintain rights to hunt, fish, and gather on this land. Mining has the potential to alter groundwater flows that feed rivers, wetlands, and lakes. However, the flows between groundwater and surface-waters across the basin are not well understood. In cooperation with Tribal representatives from five bands of Minnesota Chippewa and Ojibwe, the U.S. Geological Survey compared two new groundwater-flow models to explore how groundwater flows and surface-water interactions may have changed as a result of iron mining.

Each model is a three-dimensional (3-D) finite-difference (MODFLOW) groundwater flow model of the Iron Range part of the SLRB (3,207 square miles). One model represents and is calibrated to modern land uses (1995–2015), including current iron mining. The other model is a pre-mining scenario and was constructed from the modern model by removing all mining features and restoring the pre-mining landscape. Within the assumptions and simplifications of these models, we will present the differences between these model results as an estimate of how groundwater flows and surface-water interactions in the SLRB have changed with iron mining.

Fluxes across the horizontal boundaries of these models were determined from a regional SLRB-wide two-dimensional (2-D) analytic element model (10,032 square mile) also produced for this study. The basin-wide 2-D model and modern-conditions 3-D model are resources for boundary flows to site-specific models throughout the SLRB.

Does What We Don’t Know Matter? A Framework for Evaluating a Groundwater Model’s Ability to Predict Future Mining Impacts
Meg Haserodt, Michael Fienen, Randy Hunt, Anna Baker, Tim Cowdery, US Geological Survey; *John Coleman,* Great Lakes Indian Fish & Wildlife Commission

A MODFLOW model of groundwater/surface-water interactions under current mining conditions in the Partridge River basin in Minnesota was used to develop a framework to evaluate the potential impact of hypothetical, future mining scenarios for known mineral deposits on streamflow, wetland groundwater-elevation, and mine inflow. The MODFLOW model for this project is an inset model that was extracted from a larger MODFLOW model of the Mesabi Iron Range. The model inherits boundary fluxes and major hydrostratigraphic units from the Iron Range model while the discretization of groundwater recharge, the stream geometry, minor hydrostratigraphic units, and representation of mining features were refined for the inset. The use of Monte Carlo techniques to develop probabilistic capture zones for a given hypothetical mine pit demonstrates the importance of including uncertainty residing within the model. Data worth for a given forecast of interest is shown to help guide future data collection efforts with the goal of reducing the uncertainty in the model predictions.

Concurrent Session II, Track B

A Subwatershed Account of a Statewide Nitrate Problem
Mark Ryan, Travis Thiel, Vermillion River Watershed JPO

Nitrate concentrations are a significant concern in surface water and groundwater throughout Minnesota and in the Vermillion River Watershed in particular. This is a concerning trend despite education and outreach on nitrogen application rates, efforts to highlight the issue through newsletters and other media, numerous studies, and regulatory discussions. The Vermillion River Watershed Joint Powers Organization (VRWJPO) and partner organizations have worked to define the problem through long-term evaluation of nitrate sources and impacts to waters and have begun to develop projects and practices to respond to the issue.

The South Branch Vermillion River subwatershed provides an excellent study area to illustrate the nitrate issue and some approaches to mitigating the problem. At the subwatershed outlet monitoring station, nearly two decades of water quality monitoring have shown an alarming trend in nitrate concentration. Much of the land use is row crop agriculture, and a history of drainage alteration has permeated its water retention areas. Elevated nitrate is a potential stressor in downstream trout stream reaches and contributes to the need for advanced treatment of drinking water in places like the City of Hastings.

In recent years, the VRWJPO has worked with partners to design and construct nitrate treatment projects in the South Branch subwatershed, including a woodchip-enhanced wetland treating drainage ditch flows and a woodchip bioreactor to treat tile drainage. Development of these projects is full of challenges related to unreliable or unproven technologies, construction difficulties, and public perception and acceptance. In reviewing the cost-effectiveness of end-of-pipe treatment compared to source control for nitrate reduction, a more holistic approach to mitigating nitrate is needed for the watershed and the State to seriously address this issue.

River Nutrient Trends over the Past 20 Years
James Jahnz, Dave Wall, Lee Ganske, Minnesota Pollution Control Agency; *Hong Wang, Jack Barland,* Met Council; *Rochelle Nustad,* US Geological Survey

Analyzing river nitrogen and phosphorus trends is one way that Minnesota tracks long-term progress toward its nutrient reduction strategy goals. Reducing nutrient concentrations is important for local water health and drinking water. Reducing nutrient loads is important for downstream lakes, reservoirs and the Gulf of Mexico. Three organizations assessed river nutrient concentrations and loads from multiple river locations over the past one to four decades. Phosphorus concentrations have generally decreased and nitrate-nitrogen and total nitrogen concentrations have generally increased over the past 10, 20 and 40 years. However high year-to-year variability makes it difficult to confidently show trend directions at many of the monitoring locations. Phosphorus concentration trends over the past approximate 20 years

show mostly decreases (improvements) around the state, with reductions ranging from 15% to 55%. Over the past 10 years, phosphorus concentrations have decreased at nearly half of 57 monitoring sites evaluated, with all other sites showing no significant trend. However, increasing precipitation in southern Minnesota over the past two decades has been offsetting some of the benefits of our phosphorus-reducing activities. As a result, phosphorus load reductions are not statistically significant in most southern Minnesota rivers, unless statistical methods are used to adjust for flow variability. Nitrate concentration trends over the past approximate 20 years show increases of 20 to 60% in most major rivers. However several sites have no trend, and a couple sites showed decreases. Over the past 10 years, nitrate concentrations increased at over one-third of the sites and had no statistically significant trend at the other sites. This suggests that efforts to reduce nitrate thus far are either insufficient and/or not enough time has elapsed for the full effects of our efforts to be seen in rivers.

Watershed Fair-Share Nutrient Load Targets for Improving Downstream Waters
Derek Schlea, Hans Holmberg, LimnoTech; *Dave Wall,* Minnesota Pollution Control Agency

Minnesota's Nutrient Reduction Strategy (NRS) identifies Minnesota's goals to reduce nitrogen and phosphorus loads entering downstream waters such as the Gulf of Mexico, Lake Winnipeg and Lake Pepin. The NRS asks that each watershed consider a proportional reduction from anthropogenic sources to collectively achieve downstream load reduction goals. The NRS also provides a range of possible nutrient reduction targets based on modeled agricultural and total river nutrient loads from the early 2000's. LimnoTech, working in partnership with the Minnesota Pollution Control Agency, recently used updated modeling and monitoring information to develop improved equitable (fair-share) nutrient load targets for each HUC8 watershed in the state, that in aggregate would meet downstream goals. The newly developed watershed planning targets focus on reducible or anthropogenic nutrient loads, and they account for in-stream attenuation occurring between HUC8 watershed outlets and the state line. HSPF model results, supplemented with Minnesota's Watershed Pollutant Load Monitoring Network findings and recently updated SPARROW model results, were used to develop the HUC8 nitrogen and phosphorus load planning targets. One of the findings is that HUC8 phosphorus load reductions needed for Lake Pepin are very similar to what is needed for Minnesota's fair-share effort to reduce the Gulf of Mexico hypoxic zone. Meeting phosphorus load reduction needs for Lake Pepin will also result in Minnesota meeting its commitments for the Gulf of Mexico. As watershed strategies and plans are periodically revised and updated, the new planning targets can provide better guidance on the magnitude of needed change for reaching downstream water goals.

What Have We Learned from Testing for Nitrate in over 30,000 Private Wells in Minnesota?
Kimberly Kaiser, Nikol Ross, Brennon Schaefer, Minnesota Department of Agriculture

The Minnesota Department of Agriculture (MDA) determines current nitrate-nitrogen (nitrate) concentrations in private wells, on a township scale, through the Township Testing Program (TTP) which supports the Nitrogen Fertilizer Management Plan (NFMP). The MDA has identified

townships throughout the state that are vulnerable to groundwater contamination and have significant row crop production. More than 90,000 private well owners have been offered nitrate testing in over 344 townships by 2019.

Each selected township is offered testing in two steps: the “initial” sampling and the “follow-up” sampling. In the initial sampling, all township homeowners using private wells are sent a nitrate test kit in the mail. If nitrate is detected in their initial sample, the homeowner is offered a well site visit by a trained hydrologist for a follow-up nitrate test and pesticide sample.

As of January 2020, 344 vulnerable townships from 50 counties participated in the TTP from 2013 to 2019. In the 344 townships initially tested, 143 (41%) had 10% or more of the wells over the Health Risk Limit (HRL) for nitrate. Overall, 9.1% of the 32,217 wells exceeded the 10 mg/L HRL for nitrate.

The MDA has sampled approximately 6,100 wells in 42 counties for nitrate and pesticides as part of the Private Well Pesticide Sampling (PWPS) Project since 2014. Pesticides and/or pesticide degradates were detected in 75% of the approximately 5,000 wells tested since 2016. The data indicates the higher the nitrate concentration is in a water sample, the more likely it is that at least one pesticide is present in areas of vulnerable groundwater and row crop agriculture. Concentrations of pesticides in private wells sampled have tended to be low however, there have been some exceedances of health reference values, particularly for total cyanazine in 2019.

Private well owners and local partners are the cornerstone of this program. Follow-up testing is scheduled to be completed by the end of June 2021.

Concurrent Session II, Track C

Products and Evolving Reactivity of Natural Iron-Bearing Minerals Toward Sulfide
Nathan Johnson, Jacob Daire, University of Minnesota Duluth; *Jeanette Voelz, Chan Lan Chun, R. Lee Penn, Kamilah Amen,* University of Minnesota

Iron minerals play dynamic roles in sulfur cycling in natural and engineered environments. Sulfate enters surface waters through oxidation of sulfur-bearing minerals and wastewater effluents and can impact sensitive freshwater ecosystems. The reactivity of pure iron minerals with sulfide has been widely studied but the reactivity of heterogeneous iron-bearing materials is relatively unknown. Using lab-scale reactors, this research elucidated reaction kinetics and products of aqueous sulfide with two natural iron-bearing minerals derived from taconite. Siderite (SR)- and iron oxide (IO)-rich materials were selected based on mineralogical characteristics and iron quantity. Generally, the SR material reacted with more hydrogen sulfide per gram compared to the IO material. SR retained more solid phase sulfur, where IO produced more elemental sulfur and thiosulfate. Sulfate as an oxidation product was minimal for both materials in lab-scale batch and column reactors. Reaction kinetics were dependent on the molar ratio of the amount of sequestered sulfide to initial sulfide concentration (ΔHS/HSinital). SR maintained an appreciable reaction rate with sequential spikes, while the reaction rate of IO decreased with sequential sulfide spikes. The reactivity and products in the column reactors were comparable with those observed in the batch reactors. A reactive-transport model developed using kinetics from batch experiments was used to describe the evolution of sulfide reactivity through a column. The reaction products and rates for selected materials was consistent with their iron mineralogy. These results represent an important step toward elucidating the reactivity of heterogeneous iron-bearing materials towards sulfide and developing applications of natural iron-bearing material for sulfur treatment system.

Multisite, Multiyear Iron-Enhanced Sand Filter Performance Assessment in the TCMA
David Fairbairn, Minnesota Pollution Control Agency

Iron-enhanced sand filters (IESFs) are the most commonly installed stormwater control measure to control dissolved phosphorus in Minnesota. Most IESF field monitoring analyses to date focused on 1-2 sites. This allows for detailed within- and paired-site assessments. Yet, quantitative analysis and understanding over a range of IESF sites remains a critical need to more broadly understand reported performance variabilities and important situational and design factors. This in turn will strengthen stormwater and receive water assessment, management, and quality protection. To begin addressing this need, MPCA collaborated with several local partners to monitor six IESFs for at least two years apiece in 2015-2018. This presentation focuses on dissolved phosphorus performance and variation among these IESFs. Supporting discussion includes additional chemicals, external data, and multi-dataset analysis methods.

Geochemical and Mineralogical Processes Within Iron-Enhanced Sand Filters (IESFs) that Lead to Effective Removal of Phosphorus

Beth Fisher, Minnesota State University, Mankato; *Joshua Feinberg,* University of Minnesota

To optimize the trapping of phosphorus in Iron Enhanced Sand Filtration systems (IESFs), we identified the sequence of minerals that form as Zero Valent Iron (ZVI) corrodes in the environment and observed that IESFs that successfully remove P also contain goethite and hematite. We determined that iron-phosphate minerals did not precipitate in IESFs, and suggest that the primary mechanism for trapping phosphate is adsorption to the surfaces of iron oxide minerals formed during ZVI corrosion. The natural variability of pH in IESFs in the Twin Cites region has the potential to cause important P-adsorbing minerals to periodically change their net surface charge from positive to negative and thus lose their ability to electrostatically attract negatively charged phosphate ions. This could result in the release of previously adsorbed P.

To address filter longevity, we performed a column aging study that magnetic susceptibility decreases with each inundation of iron-sand filter media. This magnetic susceptibility decrease is tracking the conversion of high susceptibility materials (metallic iron and magnetite) to lower susceptibility minerals, such as goethite and hematite. We observed how ZVI is converted to high-surface-area iron oxide minerals that have large capacity for P-adsorption, but we recognize that the iron oxide surfaces can “fill up” and lose their capacity to trap P over time. New iron oxides will form as long as ZVI is present (and geochemical conditions remain favorable), but eventually all ZVI will be converted after which new P-adsorption will cease. Magnetic susceptibility is easily measured in the field. If practitioners measure an initial magnetic susceptibility of newly installed IESF media, continued measurements will indicate the remaining capacity of the media to provide additional corrodible iron.

Use Salvage Peat and Taconite Tailing in Stormwater Biofiltration System

Meijun Cai, Kurt Johnson, Marsha Patelke, Natural Resource Research Institute; *David Saftner, Adam Whitcomb,* University of Minnesota Duluth; *Josh Swanson,* State of Minnesota; *Chanelle Cruz,* US Army Corps of Engineers

The accumulation of pollutants on roadways can result in contaminated stormwater runoff that has a negative effect on receiving water quality, groundwater quality, and aquatic ecosystems. Additionally, roadways increase impervious surface area resulting in an increase in runoff volume, peak discharge intensity and stormwater runoff with accumulated pollutants. Following national regulation, the Minnesota Department of Transportation (MnDOT) requires the first inch of stormwater runoff to be retained in order to reduce pollutant loads from entering local water systems. Biofiltration systems are often used to capture runoff and remove pollutants. The treatment efficiency of a constructed biofiltration system is largely dependent upon the properties of the filter media.

The use of salvage material locally available for biofiltration media has economic benefits, but the biological, hydraulic, and water quality improvement capabilities are largely unknown. A multidisciplinary effort to determine these abilities includes investigations of soil fertility,

infiltration capacity, water retention capacity and pollutant removal efficiencies of peat, compost and taconite tailings collected from northern Minnesota. Soil fertility is evaluated through the use of greenhouse growth trials.

Results of a series of laboratory experiments indicated that salvaged peat performed as well or better than compost as it has high moisture holding capacity, hydraulic conductivity, pollutant removal efficiency, and supports plant establishment and growth. Taconite tailings and sand have similar hydraulic and geotechnical performance, making them interchangeable from a civil engineering perspective. Taconite tailings showed the potential to remove phosphate from water. Therefore, salvage peat and taconite tailing were selected to be tested in an ongoing field pilot experiment and one roadway bioslope to investigate water retention capacity, chemical removal efficiencies and vegetation growth.

Concurrent Session II, Track D

Zooplankton Community Structure in Summer and Winter Across 13 Diverse North Temperate Lakes

Kirill Shchapov, University of Minnesota Duluth, Large Lakes Observatory; *Paul Wilburn,* NASA Ames Research Center; *Andrew Bramburger,* Watershed Hydrology and Ecology Research Division, Environment and Climate Change Canada; *Greg Silsbe,* University of Maryland; *Leif Olmanson,* University of Minnesota; *Christopher Crawford,* US Geological Survey, Earth Resources Observation and Science Center; *Ted Ozersky,* University of Minnesota Duluth, Large Lakes Observatory

Despite increased recent attention to ecological processes during winter, relatively few studies have examined under-ice zooplankton communities in temperate lakes. Zooplankton are a key energy link in lake food webs, and it is important to understand what controls zooplankton abundance, community composition, and trophic dynamics throughout the entire year. Summer zooplankton communities vary among lakes with lake characteristics including morphometry, and trophic status, but environmental controls on winter zooplankton have not been characterized. To better understand controls on zooplankton community and trophic structure in winter and summer, we sampled 13 Minnesota lakes across a large trophic status gradient. We assessed zooplankton abundance, taxonomic and functional classification and C/N stable isotope composition in relation to environmental parameters. Zooplankton densities were lower in winter (17.9 #/L ± 31.2SD) than summer (26.9 #/L ± 24.3) across the study lakes. Proportionally, cladocerans were more abundant in summer than winter (50 ±11.9 vs. 22.2±13.9%), while the opposite pattern was true for calanoids (16.2 ±10.3 vs. 38.5±14.2%) and cyclopoids (33.6 ±10.5 vs. 39.2±8.8%). While feeding group classification showed a decrease in the relative abundance of herbivores and an increase in predators from summer to winter, delta 15N-inferred trophic position of bulk zooplankton did not reflect this change. The results of this study help characterize variations in the zooplankton community between winter and summer and the effect of lake type on zooplankton seasonality.

Carp Management Results in a Vegetation Response but Proves Not to Be a Silver Bullet for Deep Lake Management

Jill Sweet, Tom Langer, Brian Beck, Anna Brown, Minnehaha Creek Watershed District

From 2014 to 2016 Minnehaha Creek Watershed District (MCWD) partnered with the University of Minnesota to assess the impact of common carp (Cyprinus carpio) on several lakes within the Six Mile Creek-Halsted Bay Subwatershed, which included a dimictic lake with a littoral area that accounts for 70% of its total area that was impaired for excess nutrients (Wassermann Lake). The carp assessment indicated the average carp biomass in Wassermann Lake was 523 kg/ha. In 2017, MCWD implemented a carp management project that targeted reducing carp biomass below 100 kg/ha to restore habitat and improve ecosystem health. Carp management was identified in the watershed management plan as a critical step to improving the quality of Wassermann Lake. MCWD has taken a holistic and comprehensive approach to manage carp

consisting primarily of three management strategies that include adult biomass removal, restricting movement, and suppressing recruitment to ensure success. The carp biomass in Wassermann Lake was reduced to an average of 56 kg/ha in 2018-2019. The reduced density of carp resulted in an increased occurrence and biovolume of curlyleaf pondweed (Potamogeton crispus) in the spring. By midsummer there did not appear to be significant change in species richness, biovolume, occurrence, maximum depth of plant growth, or water clarity. These results suggest that the impact of reduced carp densities in Wassermann Lake are seasonal and limited. These results also suggest that the water quality response to common carp management in dimictic lakes is difficult to predict since it is dependent on the percentage of area disturbed by carp, watershed loading, sediment phosphorus release, and maximum depth. Continued management efforts targeting internal load will be the necessary next step to meeting water quality standards and habitat goals.

Connecting Water Color and Water Quality Properties for Minnesota Lakes Using Sentinel-2 Satellite Imagery

Martha Burket, Department of Civil, Environmental, and Geo- Engineering, University of Minnesota; *Leif Olmanson,* Forest Resources, University of Minnesota; *Benjamin Page,* Water Resources Center, University of Minnesota

While remote sensing using satellite data such as Landsat and Sentinel has been commonly used to measure water quality variables such as water clarity, chlorophyll and colored dissolved organic matter (CDOM) in Minnesota lakes (https://lakes.rs.umn.edu/), surprisingly there has been less attention to the classification of water color into different optical water types (OWTs). Satellite data can be used to measure the apparent optical properties of surface water color (hue angle and dominant wavelength). The goal of this study (which will be completed by the end of summer) is to establish a relationship between chromaticity coordinates, water quality variables and OWTs for lakes in Minnesota (MN). Remote sensing reflectances (Rrs) over lake pixels from multi-temporal composites of cloud-free Sentinel-2 imagery were used to derive chromaticity coordinates. Hue angle and dominant wavelengths for 4056 lakes were analyzed and used to classify lakes into discrete OWTs. There were distinct patterns throughout Minnesota for chromaticity with a concentration of blue lakes in northeast MN, yellow and green lakes in central MN, and yellow lakes in southern MN. These patterns and associated relationships with OWTs will be discussed.

The Merits of Continuous Monitoring for Management Decisions in Lakes and Stormwater Ponds

Anne Wilkinson, Wenck Associates

Continuous monitoring can fill data gaps left by conventional discrete sampling that are imperative for lake and stormwater pond management strategies. This presentation will highlight how continuous monitoring programs in lakes and several stormwater ponds throughout the metro and greater Minnesota area improve study conclusions and management costs. In each example, I will compare the results and management decisions made based on the continuous monitoring data versus the corresponding discrete samples. The examples highlighted include:

effects on alum application strategies, dissolved oxygen modeling results for internal loading studies, and studies determining drivers for harmful algal blooms. In each case, the data gaps resulting from discrete sampling made a significant difference in study conclusions, management decisions and cost. Finally, I will discuss the applicability and accessibility of continuous monitoring programs for lake and stormwater projects. This study highlights potential data gaps that occur in discrete sampling and how to determine when continuous sampling should be utilized to fill those gaps.

Tuesday October 20, 2020

Concurrent Session II, Track E

Learning from Leaders of Successful Water-Quality Case Studies in the Minnesota River Basin

Kimberly Musser, Tyler Grupa, Water Resources Center, Minnesota State University, Mankato

Citizens and local conservation partners need a richer understanding of how to develop successful partnerships and effective pollution reduction strategies. Who better to provide insight than people who have actually gained ground and improved water quality. This project distills the experience of successful subwatershed scale water quality partnerships across the Minnesota River Basin.

Leaders of these initiatives reflected upon key strategies that made their projects successful and provided advice for others who may want to consider taking a similar approach. Common themes emerged. Collectively, many of these groups developed a cohort of informed and active citizens, increased capacity among partners and allies, and fostered an ethic and expectation for cleaner water within their communities. Above all, their collective advice centered on the need to build relationships and trust, to listen, to seek to understand your community and social norms. They emphasized the power of building enduring partnerships. Most had a clear plan and goals as well as strong leadership and vision. They also underscored the importance of a multi-pronged approach, using different tactics and diverse BMPs. Leaders stressed the importance of communicating widely, getting creative with funding, and being it in for the long haul with patience and persistence.

Learning from successful case studies that have measurable water quality improvements in agriculturally dominated landscapes can help to clarify models, strategies and approaches that others can emulate to accelerate water quality improvement."

Exploring Minnesota Water Resources Conferences History

Adam Wilke, Archie MacKinnon, Jeffrey Peterson, Water Resources Center, University of Minnesota; Tina Carstens, Ramsey-Washington Metro Watershed District; *Drew McGovern,* Hennepin County; *Wayne Sicora,* Environmental Resources Management; *Rick Voigt,* Voigt Consultants, LLC; *Jim Stark,* Legislative Water Commission; *Warren White,* W. White PE

The Minnesota Water Resources Conference is one of the oldest and most highly attended state water conferences in the United States. After the 50th conference anniversary in 2018, a Conference History Committee was formed to collect and analyze historical documents. The goals of this project will be to analyze trends over time. By looking back at the development of the conference over time, we might gain a better understanding of where the conference is headed moving forward. Through content analysis of conference documents and interviews with leaders throughout conference history, we will develop a timeline of key events in Minnesota and United States water resources history that have shaped, and have been shaped by, the

Minnesota Water Resources Conference. These events include policy, technological, and biophysical events, such as the Clean Water Act, the advancement of remote sensing data, and extreme events such as drought and floods. We will use a unique, interactive format to share historical information, pose questions, and gain feedback from conference participants. This effort helps preserve the conference legacy for future generations while also providing insights for other similar state water conferences.

Bridging the Gap between Science and the Public Through Watershed Education and Engagement

Janine Kohn, MN Department of Natural Resources

Problem: In Minnesota, people view healthy waters as an important quality-of-life indicator. Yet, not all Minnesotans know how to be effective stewards of water resources or understand the importance/connection to their local watersheds. Additionally, there is a need to translate important scientific data/research so the public cares about the findings and engages in actions to improve Minnesota's watersheds.

For Example: Stream monitoring is an important tool scientists use to understand specific water systems. Many times, data generated may not resonate with the public. Perhaps findings are not plain-language or engaging enough for individuals to care or become involved with understanding and changing potential outcomes.
Simply, individuals may not care about findings, so how do we change this?

Solution: Education & Outreach
The MN DNR offers Project WET and its resources to help communities create active water conservation networks that result in actions. As part of a world-wide network-MN WET, over the past 26 years, has reached thousands of individuals through a wide array of programming to help bridge this gap. This presentation will highlight the methods/tools that have evolved over the years to address local/global challenges pertaining to water and new resources available.

Ex.of Tools/Methods used:

- Building of partnerships which has increased capacity and resulted, in last several years, to over 22,000 individuals reached
- Citizen Science engagement I.e. monitoring
- Service learning/hands-on youth studies
- Successful measures locally/globally

Summary:
Finally, Project WET has developed new tools to address current problems facing our environment such as climate change/effects, conservation efforts & ultimately citizen engagement of their local watersheds. In partnering with experts around the globe, we enter a new era focusing on new audiences beyond educators and showcasing novel resources to address the ever-changing challenges of our water future.

Aquatic Invasive Species: Boater Behavior and Willingness to Pay for Local Management
Lucia Levers, Amit Pradhananga, Kasey Rundquist, University of Minnesota

We conducted summer lake surveys in Minnesota to examine recreationists' perceived risk of aquatic invasive species (AIS), knowledge about AIS, AIS awareness of problem, boater behaviors to prevent the spread of AIS, perceived lake quality changes, and to estimate willingness to pay for local lake AIS management in the form of a daily lake access fee. Similar pairs of lakes with differing infestations of zebra mussels, Dreissena polymorpha, and starry stonewort, Nitellopsis obtuse, were used as study sites to estimate how being at an infested lake (Koronis and Gull) vs. being at an uninfested lake (Minnewaska and Pokegama) would impact responses. We estimate mean willingness to pay to be $10.23 per day, which did not differ significantly by lake. However, there were some differences between individual lakes with knowledge and perceived risk. We also report on a boater behavior predictive model, discussing the relationship between actions and knowledge, location, and values. Results could have important ramifications for AIS management.

Tuesday October 20, 2020

Concurrent Session III, Track A

Community-Centered Stormwater Management with Environmental Justice Communities
Yordanose Solomone, Laura Scholl, Rebecca Rice, Metro Blooms

Mitigating environmental challenges without addressing environmental justice is exclusionary and ineffective to us all. This is especially impactful to residents in vulnerable, low-income Black Indigenous People of Color (BIPOC) communities in the long run. Metro Blooms partners to co-create resilient communities (both in the restoration of the physical landscape and building capacity of disproportionately impacted communities) through equitable processes from planning, design, to care. When addressing environmental challenges, the residents of these communities perceive limited power to influence environmental outcomes and are typically perceived to have low motivation to participate in climate change efforts to improve the environmental function of their landscape, or in decision-making processes. Metro Blooms demonstrates case studies in which we've worked with affordable housing communities and environmental justice neighborhoods in Minneapolis to address environmental justice concerns through the co-creation, and community evaluation of stormwater management projects.

Our approach focuses on engaging underserved community members and leaders who have been left out of environmental conversations but are disproportionately affected. We strive to center community voices, values, and vision. We co-host leadership training and workshops for community members who act as a liaison between their community and our organization, and together we bring resources to the community to create a sustainable, healthy, and a more resilient community. As an organization, we acknowledge that we are not there to build a community, as the communities already exist, but rather build capacity through tangible economic and environmental investment. The result, which we demonstrate through our case studies, is a continuously evolving methodology demonstrating the benefits of stormwater-management through a community-centered lens that works to address more than environmental issues.

Why Accurately Estimating 7Q10 'Drought Flows' Matters: Accounting for Uncertainty, Climate, and Land-Use Changes
Scott Kyser, Emily Brault, Minnesota Pollution Control Agency

The Minnesota Pollution Control Agency (MPCA) is required to calculate wastewater effluent limits to protect downstream water quality at the 'drought flow' defined as the 7Q10. Correctly estimating the 7Q10 for a waterbody is critical to ensure that water resources are protected under drought conditions and that wastewater effluent limits are not unnecessarily restrictive. The MPCA's objective with this work is to determine the estimation method that will result in the least uncertainty in a 7Q10 estimation.

We considered drivers behind temporal and spatial trends in annual low flows, including historical climate cycles, land use changes, and historical shifts in annual flow patterns among

seasons. Overall, we found that the drivers of trends are not consistent throughout the state. Furthermore, we explored the differences resulting from utilizing various periods of flow gauge records to estimate 7Q10s. We discovered that 7Q10 values vary substantially depending on the period of record used and with the occurrence of extreme drought events. We have determined that a good way to account for future climate change is to consider Minnesota's climate past in regards to drought. We conclude by presenting best practices for estimating 7Q10s.

Understanding and Building Capacity to Address Changing Water Availability in the Upper Corn Belt

Amelia Kreiter, Mae Davenport, Bonnie Keeler, Kate Brauman, Maggie Rogers, University of Minnesota; *J. Arbuckle, Ray Arritt,* Iowa State University

How do farmers perceive water supply risk in the Upper Corn Belt where land use, climate change, and water use implications for groundwater supply have been uncertain? We explore this question and the multiple values and tradeoffs of water uses in Central Minnesota and Northwest Iowa, where existing agricultural systems are increasingly dependent on groundwater availability. Coupling social science survey and interview data with dynamically downscaled climate projections and spatially explicit representations of water vulnerability, we have developed integrative socio-climatic models of water supply risk. The most important outcome of this work has been to bring the scientific, management, and local producer communities together to reflect on the models and to prioritize action steps for individual and shared water decision making. In this presentation we discuss opportunities and challenges of integrative science, community engagement, and water supply management under uncertainty. The ultimate aim of this project is to enhance ongoing efforts to protect water supply and sustainable agriculture in the Upper Corn Belt.

Utilizing Machine Learning Techniques for Streamflow Prediction in Minnehaha Creek Watershed District

Brian Beck, Kailey Cermak, Tiffany Schaufler, Minnehaha Creek Watershed District; *Eric Waage, Emily Harrington,* Hennepin County Emergency Management; *James Fallon,* US Geological Survey; *Scott Pearson,* Minnesota Department of Natural Resources

Water systems throughout Minnesota were built for stable climate patterns that no longer exist. Extreme swings in precipitation are stressing our natural and built environments, impacting pollutant loading, stream erosion, wetland function, surface and groundwater interactions, habitat, and the safety of homes, public infrastructure, and businesses. In response, Minnehaha Creek Watershed District (MCWD) is deploying 25 real-time level and velocity remote sensing devices throughout the watershed to track streamflow, level, and pollutant loading. MCWD has partnered with the United States Geological Survey, Hennepin County Emergency Management, and the Minnesota Department of Natural Resources to combine meteorological, groundwater, lake level, and stream level data to develop state of the art watershed modeling tools.

One of the primary tools that MCWD has begun utilizing is machine learning (ML) to harness the wealth of precipitation, soil moisture, air temperature, groundwater, and streamflow data available to help predict water levels in lakes and streams. In recent years, ML techniques have become increasingly popular in the field of hydrology due to their ability to accurately predict water level and flow conditions using readily available data. The objective of developing a ML model by MCWD staff is to determine if it could accurately simulate stream flow and level. The results of the analysis demonstrated that ML, specifically recurrent neural networks, can accurately predict water level and flow, which will provide a powerful tool for watershed management, emergency response, and dam operations within Minnehaha Creek Watershed District.

Concurrent Session III, Track B

Tracking Watershed BMP Adoption Progress Throughout Minnesota

Dave Wall, David Miller, Minnesota Pollution Control Agency; *Matt Drewitz,* Board of Water and Soil Resources; *Jeppe Kjaersgaard,* Minnesota Department of Agriculture

To guide Minnesota's progress toward the Nutrient Reduction Strategy (NRS) goals, the 2014 NRS included example cropland Best Management Practice (BMP) adoption goal scenarios. These scenarios were intended to serve as examples of the level of cropland BMP adoption needed to achieve the nutrient reduction goals and milestones in major river basins, when combined with urban nutrient source reductions. Achieving NRS goals depends on large-scale, multi-million-acre new adoption of cover crops and other continuous living cover vegetation, optimal use of nitrogen fertilizer and manure, cropland erosion control practices, and storing and treating tile drainage waters. In addition, urban wastewater and urban runoff nutrient reductions are important for meeting NRS goals. Minnesota has recently developed several tools and systems to assess BMP adoption progress. BMPs adopted through all major government programs are tracked through a new web-based tracking system housed at the MPCA. From 2014 to 2018, cumulative new BMP adoption through government cost-support programs contributed the following fractions of needed acreages outlined in the NRS 2025 milestone scenarios: 1% of nutrient efficiency acres 10% of cover crops and perennials 6% of conservation tillage and erosion control acres, and 2% of the tile drainage treatment acres. Additional adoption occurs privately outside of government programs. New and existing methods provide indications of overall adoption rates that reflect the combination of private actions and government programs. Most of the indicators over the past five to ten years suggest that the pace of new BMP adoption is not on track to reach the scales of adoption outlined in the Nutrient Reduction Strategy.

Assessing Soil Residue Cover, Cover Crops, and Erosion Using Remote Sensing and Modeling

David Mulla, Leif Olmanson, Dan Wheeler, University of Minnesota; *Brian Gelder,* University of Iowa; *Brent Dalzell,* USDA ARS Soil & Water Management Research Unit; *Matt Drewitz,* Board of Water & Soil Resources

The purpose of this study is to develop a long-term assessment of crop residue cover in spring and cover crop emergence in fall. These results help in estimating trends in adoption of soil conserving practices and rates of water and wind erosion on agricultural landscapes in Minnesota. Satellite remote sensing in spring and fall are used to estimate crop residue cover at planting across or cover crop emergence across all agricultural counties of Minnesota. Ground truth data are collected across representative counties to develop satellite based algorithms that predict percent crop residue cover in spring and acreage of germinated cover crops in fall. Example results from spring of 2017 indicated that crop residue levels of less than 15%, 15-30%, 30-50% and greater than 50%, respectively, occurred on 12%, 41%, 30%, and 17% of Minnesota's agricultural acreage. Example results from fall of 2016 indicated emergence of

cover crops on 213,000 ac across southern Minnesota. About 40% of this was planted after harvest of corn, about 30% after harvest of soybean, and the remainder was planted after short season crops. Remotely sensed based satellite estimates of crop residue cover from this project are used as an input for the Iowa State University Daily Erosion Project (DEP) Model. The four major DEP components are the water erosion prediction project model (WEPP) the soil, topography, and land management input database daily weather information and a sampling and scaling approach for the daily modeling and reporting of hillslope soil erosion and water runoff. DEP outputs are reported for each Minnesota agricultural HUC 12 watershed, and include average daily precipitation, average soil detachment per hillslope and average delivery of detached sediment to the base of the modeled hillslope. In regions of Minnesota where wind erosion is important, we are integrating DEP with elements from the Single event Wind Erosion Evaluation Project (SWEEP).

Modeling Agricultural Best Management Practices for the Minnesota River Basin Sediment Strategy

Michelle Schmidt, Jennifer Olson, Jonathan Butcher, Saumya Sarkar, Tetra Tech; *Dave Wall,* Minnesota Pollution Control Agency

Minnesota's Sediment Reduction Strategy was initiated in 2015 to mitigate high levels of suspended sediment and to achieve the turbidity TMDL goals for the Minnesota River. Agricultural Best Management Practices (BMPs) are needed to reduce upland sediment loading and limit flows that cause channel erosion. While literature provides general sediment removal efficiencies for BMPs, site characteristics, such as soil type, field topography, crop type, and operation methods, and seasonal and interannual weather variability impact BMP performance. Evaluating the collective benefits of widespread BMP implementation requires a basin-scale approach that considers both sediment and flow. Our approach combines information on BMP performance with process-based watershed models to evaluate potential sediment reduction strategies using three of the linked HUC8-scale HSPF (Hydrologic Simulation Program – FORTRAN) models for the Cottonwood, Le Sueur, and Middle Minnesota watersheds. Field-scale APEX (Agricultural Policy/Environmental eXtender Model) models that explicitly simulate crop lifecycle and management operations were developed and used to refine the expected performance of BMPs in the HSPF models as a function of field characteristics. We evaluated sediment load reductions achieved at the watershed-scale for multiple levels of implementation of individual and combinations of BMPs including fall cover crops, conservation tillage, treatment wetlands, conversion to perennials, riparian stream buffers, and ravine mitigation. This technical work is supporting a revision to the overall Sediment Reduction Strategy for the Minnesota River Basin, helping to guide BMP selection that results in multiple benefits.

What Affects Farmer Decision-Making About the Use of Cover Crops?

Amit Pradhananga, Mae Davenport, University of Minnesota

Farmers' use of conservation practices such as cover crops provide important ecological benefits including improved water quality and soil health, and enhanced wildlife habitat. However, the adoption rate of cover crops in Minnesota is low. While current approaches to

addressing agricultural runoff rely on voluntary behaviors of farmers, the drivers and constraints to farmer adoption of cover crops are not well understood. To be successful, strategies and programs aimed at increasing cover crop adoption among farmers must be based on an understanding of the drivers of and constraints to adoption.

This study examines the social-psychological factors that influence farmer adoption of cover crops. We developed and applied an integrative theoretical framework drawing on the norm-activation theory, theory of planned behavior, and diffusion of innovations. We conducted a survey of 4000 farmers in four Minnesota watersheds: Cannon River, Cottonwood River, Watonwan River, and Yellow Medicine River watersheds. Data were analyzed using structural equation modeling. Study findings show that beliefs about cover crops and water pollution, and norms are important predictors of cover crop adoption. This study offers strategies for policy-makers and resource professionals to best design conservation programs that address constraints to practice adoption.

Concurrent Session III, Track C

Infiltration Measurement Accuracy in the Field and in Numeric Simulations
Nicholas Tecca, John Gulliver, John Nieber, University of Minnesota

Infiltration is an important process in many green stormwater infrastructure (GSI) practices. Yet, the failure rate immediately following construction may be approximately 30%. One major reason is a lack of knowledge on the infiltration rate of the practice, which is often assumed and not measured. To solve this, GSI design and construction quality control need to utilize infiltration measurements. The focus of this study is to identify and document the systemic accuracy of infiltration measurements to increase certainty in design and construction quality control. Infiltration measurements were completed in a swale using the Modified Philip Dunne (MPD) infiltrometer, double ring infiltrometer, and Turf-Tec infiltrometer. Infiltration measurements were highly spatially variable spanning over 2 orders of magnitude. Variability between infiltration measurement methods including at the same location were identified. In light of this measurement uncertainty, a transient finite element analysis (FEA) implementing the Richards equation was utilized to clarify the accuracy compared to a given saturated hydraulic conductivity (Ksat) and investigate potential systemic bias in each infiltration measurement method. For each simulation, soil properties are input to the FEA and the simulation is run in accordance with field procedures used to make infiltration measurements. The FEA then outputs the synthetic data that mimics the kind of output that would be observed in the field. This synthetic data is post-processed in accordance with the applicable method to generate a synthetic Ksat or infiltration rate. The synthetic output is compared to the known Ksat input to the FEA to determine the accuracy of each method. The accuracy of each method is considered in the context of the observed field variability. Methods to aggregate individual infiltration measurements into a representative site level infiltration rate are evaluated.

Comparison Between Modified Philip-Dunne and Double-Ring Infiltrometers for Basin Performance Verification
Rena Weis, Wenck Associates; *Dwayne Stenlund,* Minnesota Department of Transportation; *Jeremy Walgrave,* SEH, Inc.; *Joel Toso,* Barr Engineering

Siting, construction, and performance testing of infiltration practices are time consuming and costly tasks under current ASTM standards and contract specifications. This field-based study investigated whether the Modified Philip-Dunne Infiltrometer (MPDI) is a suitable alternate for the traditional Double Ring Infiltrometer (DRI) for determining infiltration rates, and what minimum test number and spacing would be necessary for quality assurance of the measured results. The two devices were compared at five existing MnDOT infiltration basins across the Twin Cities metro. The results indicated varying accuracy of both devices. The high variability of MPDI tests and the limited number of DRI tests made the analyses difficult. The take away points include: 1) use of MPDIs show promise as a quick, cost efficient indicator for basin function during and after construction and 2) recommendations were developed to inform future MnDOT guidance on the use of MPDIs, including a suggested sampling pattern and MPDI infiltration rate threshold.

Becker Park: Local Partnerships Leading to Water Quality Improvements via Underground Infiltration

Mark Ray, City of Crystal; *Rena Weis, Ed Matthiesen, Diane Spector,* Wenck Associates

In 2019, the City of Crystal constructed a 2.2 million gallon underground infiltration gallery, designed by Wenck Associates. The site, Becker Park, was identified by a subwatershed assessment completed in 2015 for the Shingle Creek Watershed Management Commission. The gallery, which consists of 1.4 miles of 72" perforated metal pipe, collects water from a highly urbanized environment which would otherwise flow directly to an Impaired Water, Upper Twin Lake. The installation of the infiltration gallery was coordinated with a park redesign project, which converted softball fields to walking paths, an accessible play area, a splash pad, and an amphitheater. The design team and City partnered with agencies to secure five grants, totaling $1.475 million of the $2.2 million project cost. The presentation will include a summary of water quality and quantity monitoring completed during the summer of 2020.

Downscaling Water Storage: Assessment of Storage-Discharge Dynamics with Hydrological Simulation Program-Fortran at the Rum River Watershed and the Wild Rice River Watershed

Pai-Feng Teng, John Nieber, Xiang Li, Bruce Wilson, Vipin Kumar, University of Minnesota; *Chuck Regan,* Minnesota Pollution Control Agency

Water resources, which play a critical role in the functioning of ecosystems and human well-being, can be managed by estimating their storages and movements in groundwater, lakes, streams, snowpacks, and soil moisture. Even though the Gravity Recovery and Climate Experiment (GRACE) satellite allows us to monitor the anomalies of total terrestrial water storage (GRACE TWSA), it cannot be used for studying the details of storage-discharge dynamics because it has coarse resolutions (100-350 km) and lacks identification of different components in the terrestrial water storage. In this project we are developing the downscaling of monthly GRACE TWSA with knowledge-guided machine learning (KGML), where machine learning (ML) algorithms are applied along with physically-based models and ground truth data. Our application is to two HUC-8 Minnesotan watersheds, the Rum River Watershed and the Wild Rice River Watershed, for the time period between 2002 and 2015. We are using the Hydrological Simulation Program-Fortran (HSPF), the hydrological model with the capacity of simulating non-biased discharge (Q) and change of water storage (ΔS), and partitioning of the total water storage into it various terrestrial components. In the downscaling process we will validate the HSPF-simulated ΔS with GRACE TWSA and simulate storage-discharge dynamics by training ML algorithms with ΔS and Q from both the validated HSPF simulations and the field data. This downscaling process is expected to spatially downscale monthly GRACE TWSA into the resolutions of HUC-12 watersheds, vertically disaggregate monthly water storage into surface water, groundwater, and soil moisture, and calculate the storage-discharge dynamics with an ML algorithm for both watersheds. The method applied and tested will be of assistance in water management decision-making, and to provide data for drought or flood forecasting

Tuesday October 20, 2020

Concurrent Session III, Track D

Coastal Engineering Fundamentals
Al Kean, Retired, Board of Water and Soil and Resources

Precipitation and lake levels in many areas of the upper Midwest have been much higher than normal in recent years. Lake Superior and other inland lakes are at or near record highs. As a result, there is more shoreline erosion and associated needs for shoreline stabilization and infrastructure protection. These are water resource problems and needs involving coastal engineering applied to lakes. This session will introduce fundamental coastal forces and processes, as well as coastal engineering design considerations and key sources of information. Coastal engineering is a relatively unique and challenging area of practice that is also very interesting.

Topics to be briefly outlined:

- Wind direction, frequency, and duration
- Lake water levels
- Wind setup
- Seiche
- Deep water wave dynamics (height, period, spectrum)
- Wave diffraction, refraction and shoaling
- Breaking waves
- Wave runup, rundown and reflection
- Types of shoreline stabilization
- Littoral drift
- Baymouth bars
- Shore-parallel sand dunes
- Ice effects
- Key references

Mill Pond Shoreland and Aquatic Habitat Restoration Project
Laura Cummings, WSB; *Todd Tuominen,* City of Champlin

The Mill Pond is a reservoir lake within the City of Champlin that was created in 1867 with the construction of the first Mill Pond Dam on Elm Creek, at the outfall to the Mississippi River. Since that time, the Mill Pond has become an important water feature for fishing and recreational activity in the region.

Over the years, the Elm Creek and Mill Pond has been classified as impaired due to agricultural practices and upstream erosion. In a multi-phased project the City of Champlin reversed the decline of Mill Pond by removal of 275,000 tons of phosphorus laden sediments, installation of deep-water and shallow water habitat, in-lake structures, and shoreland and stream restoration.

The project included water management across a 50 acre project area, dewatering a 42-acre pond, public outreach, extensive agency involvement, grant and bonding bill funding, and new public involvement opportunities to enjoy Mill Pond and the surrounding area.

The project restored approximately 42 acres of shoreland area and aquatic habitat, reduced erosion, and improved water quality of Upper, Middle, and Lower Mill Pond restoration of 1,200 lineal feet of Elm Creek. Final plantings were completed summer and fall of 2019 and the next phases of Elm Creek restoration are in progress.

Sand Creek Bluff Erosion Mitigation Projects
Maren Hancock, Inter-Fluve; *Ryan Holzer,* Scott County

In Scott County, the Sand Creek flows through a bluff zone created by the remnant valley walls of glacial River Warren, and discharges to the Minnesota River. This bluff zone consists of sharp breaks in slope from low-gradient upland farm lands to steep sandy clay hillsides dropping to the elevation of the Minnesota River floodplain. Previous studies have determined that the bluffs and ravines in this area contribute a disproportionate volume of sediment to the Minnesota River as compared to farm field streambanks. In order to improve the stream habitat impairment, meet water quality standards, and meet TMDL goals for the Minnesota River, Scott County has been working to address sediment loading in many ways, including through the implementation of capital improvement projects that target reducing sediment sourced from bluff and ravine erosion. This presentation will discuss how a watershed-wide assessment was completed to prioritize project locations and how the County engaged private landowners in the projects. These projects target erosion reduction through the construction of engineered large wood toe protection and deflector structures placed at the bluff toes that redirect high velocity flow vectors, resulting in aggradation of sediment and shifting of the centerline of the creek away from the bluff toe. The site assessment, design progression, and construction will be discussed for three of these projects completed in 2017 and 2018, and 2020. The presentation will cover how each project is functioning and how they have responded to significant spring flood events.

Restoring Trout Brook at Afton Alps: A Tale of True Partnership
Maren Hancock, Jonathon Kusa, Marty Melchior, Sean Morrison, Inter-Fluve; *Wiley Buck,* Great River Greening; *John Loomis,* South Washington Watershed District

Trout Brook is a cold water trout stream that runs through Afton State Park and along the base of the ski hill at Afton Alps before discharging directly to the St. Croix River. The brook has historically been altered through straightening, ditching, floodplain filling and the addition of road crossings, which has resulted in degradation of geomorphic function, fish habitat, and native vegetative communities in and near the brook. With a diverse set of project goals South Washington Watershed District (SWWD) and Great River Greening partnered with Vail Properties to implement a restoration project that involved remeandering the brook. Project goals included improving stream connectivity, habitat diversity and availability, water quality, recreational opportunities, channel stability, and ecosystem resiliency, while maintaining and

improving operations and parking lot flow at the Afton Alps ski hill. This presentation will focus on the history of the site, how the project partnership came to be, the design and permitting process, and implementation and construction. We will discuss lessons learned throughout the project and how those lessons learned are being applied for the next phase of the project scheduled for construction in 2021. Funding for this project came from the State of Minnesota Outdoor Heritage Fund and South Washington Watershed District.

Tuesday October 20, 2020

Concurrent Session III, Track E

Thoughtful Planning of a Real-Time Sensor Network to Assist with Water Resource Decisions, City Planning, and Emergency Management Operations
Kailey Cermak, Minnehaha Creek Watershed District

Minnehaha Creek Watershed District (MCWD) has been faced with unprecedented amounts of rainfall, causing staff to reevaluate the tools it uses for water management, project identification, and climate adaptation planning.

MCWD's hydrology and hydraulics model is a tool staff heavily rely on to answer quantitative questions, however, it's limited by its granularity and agility, both of which would need to be overcome to remain nimble in the face of a changing climate. To address these limitations, a multi-disciplinary team recognized the need to begin collecting data at specific locations throughout the district to support and inform the potential to update MCWD's watershed model. The installation of continuous level sensors across the watershed was identified as an intuitive solution to a technical problem, however, MCWD realized external partners would also likely gain by utilization of these sensors. Discussions with partners provided MCWD with critical insights on flood prone areas for cities and parallel initiatives led by Hennepin County Emergency Management (HCEM). Convening partners allowed MCWD's technical staff to realize that the sensor network could support more than a future hydrology and hydraulics model. In addition, it would provide valuable real-time conditions to refine dam operations, help emergency managers make timely decisions, and better characterize stormwater inputs from across the watershed.

Many times the easiest solution for technical staff at any organization is to support technical initiatives. However, intentionally taking the time to plan has provided a big return on investment on the back end, as MCWD was able to leverage these sensors for stacked water quality, water quantity, and emergency management benefits while also revealing an opportunity to partner with HCEM. Planning with a cross-departmental team and gaining input from our partners was critical to growing a technical solution into a multi-purpose tool.

Slope Stabilization in Unprecedented Wet Times
Eric Roerish, SRF Consulting Group; *Steve Gale, Nate Lichty,* Gale-Tec Engineering, Inc

Increased rainfall depths and intensities, along with prolonged wet periods, have created instabilities along our roadways in Minnesota. The exact cause and solutions to these vary, but the threat to public safety is consistent. SRF Engineering and Gale-Tec Engineering are proud to have partnered with various agencies throughout Minnesota to assess the causes, evaluate alternative solutions, and design and permit resilient solutions for each unique challenge.

This session highlights four recent projects that balanced geotechnical needs, hydraulics, local and federal permitting requirements, wetland impacts, special river designations, costs, unique

site conditions, and aesthetic goals to arrive at cost effective solutions. Solutions range from hard armored riprap and sheetpile walls to vegetated geogrid Reinforced Soil Slopes (RSS) and shallow Platypus type anchors to conversion from rural to urban road sections. These solutions fit the context of the project location and provide low maintenance, long lasting, resilient protection. The projects discussed are:

- CSAH 1 Slope Failure and Reconstruction along the Rum River, Mille Lacs County
- Sakatah Singing Hills State Trail along an Unnamed Creek, Minnesota Department of Natural Resources
- CSAH 17 Slope Failure and Protection along the Crow River, Wright County
- CSAH 14 Outfall Slope Failure and Rebuild, Nicollet County"

Tracking Interactions of Geochemistry and Aquatic Plant Populations in Sulfate-Amended Mesocosms with Wild Rice
Sophia LaFond-Hudson, Nathan Johnson, John Pastor, Brad Dewey, University of Minnesota Duluth

Sulfate, a relatively unreactive compound in surface waters, can enter freshwater ecosystems naturally through precipitation, sediment resuspension, seawater intrusion, or anthropogenically through municipal wastewater effluent and industrial sources. Benthic organisms and aquatic plants are especially susceptible to sulfide, a byproduct of biological sulfate reduction in anoxic sediments. We used mesocosms to study how elevated sulfate affects population dynamics of a model organism, wild rice, in the context of microbially-driven cycling of carbon, nitrogen, and iron as well as macrobiological processes that introduce oxygen into sediment. With self-sustaining populations of wild rice, we tested the effects of sulfate, iron, and leaf litter (organic carbon) to elucidate how iron and litter may slow or accelerate extinction of populations exposed to sulfate for several generations. In our low sulfate mesocosms, wild rice populations oscillated stably over four-year periods, which is characteristics of natural populations. In high sulfate mesocosms, populations oscillated towards extinction, which took about five years and is consistent with the relative paucity of healthy reproducing stands of wild rice in most waters with elevated sulfate. These mesocosm results represent an intermediate scale in which interactions between bulk elements and plant populations can be examined in an ecologically relevant, yet tractable scale.

Minimizing Wastewater Nutrient Pollution Through POTW and Industrial Technical Assistance
Matt Domski, Jon Vanyo, Josh Kirk, Daniel Chang, Laura Babcock, Minnesota Technical Assistance Program

Wastewater treatment is a vital operation, which serves to protect the environment from contamination and preserve water resources for residential, industrial, and recreational use. Treatment must be done in ways that minimize impact on wildlife and aquatic species. Cities throughout the state of Minnesota are responsible for providing effective, affordable wastewater treatment services for residents and businesses within their communities. This can be a difficult

task, as treatment facilities face challenges associated with incoming nutrient pollution loads that are sent from a variety of industrial, commercial, and residential wastewater sources.

To assist communities with wastewater nutrient management, MnTAP has designed a two-part outreach and assistance approach. The first part involves working with mechanical wastewater treatment plants and wastewater ponds to optimize nutrient pollution removal with existing infrastructure. The second part involves working with industrial facilities located upstream from the treatment plants, to implement strategies that minimize nutrient pollution load before it makes its way to the treatment facility.

Through this approach, MnTAP staff teams and interns have provided technical assistance to more than 15 Minnesota communities, resulting in recommendations that will lead to reduction in nutrient pollution, as well as operating cost savings for treatment facilities and businesses. MnTAP continues to identify opportunities to work with communities through financial support from the Legislative-Citizen Commission on Minnesota Resources (LCCMR) and partnerships with the Minnesota Rural Water Association (MRWA) and the Minnesota Pollution Control Agency (MPCA).

Concurrent Session IV, Track A

Using Random Forest Regression and Dimensionless Sediment Rating Curves to Estimate Suspended Sediment in Minnesota Rivers

Joel Groten, US Geological Survey; *Greg Johnson,* Minnesota Pollution Control Agency

A thorough understanding of fluvial sediment transport is critical to addressing many environmental concerns, such as exacerbated flooding, degradation of aquatic habitat, excess nutrients, and the economic challenges of restoring these systems. Fluvial sediment samples are integral for addressing these environmental concerns but cannot be collected at every stream of interest across Minnesota. Therefore, methods must be developed or improved to provide estimates where measurements of sediment do not exist. To gain a better understanding for streams where direct measurements have not been made, the U.S. Geological Survey, in cooperation with the Minnesota Pollution Control Agency, estimated annual and daily loads of suspended sediment at streams without measurements. This was accomplished using basin characteristics, developed regions, and recurrence intervals to develop random forest regression models and dimensionless sediment rating curves. The results indicate this approach is useful in estimating sediment at streams lacking sediment data. Results also showed regionalization is an important factor controlling sediment concentrations in Minnesota's rivers. The southeastern Minnesota region produced higher estimates of suspended sediment than the other four regions in the study. This is a promising step forward in using sediment measurements throughout Minnesota to estimate sediment at rivers without sediment information and will be a useful tool to assist in restoration activities.

Projecting Changes in Culvert Passability from Present to Future

William Herb, Jessica Kozarek, University of Minnesota

Road crossings and culverts can create barriers to movement within a stream network that can have dramatic consequences for fish populations by fragmenting habitat. Culverts can become barriers when flow conditions exceed fish (or aquatic organism) swimming ability, e.g. for excessive drop at the outlet, insufficient depth, excess flow velocity, or excessive turbulence. In this project, we utilizing a simple modelling framework to assess 50 culverts throughout Minnesota to: a) determine what fraction of these culverts currently present a fish passage barrier for both high flows (velocity barrier) and low flows (depth barrier), and b) to summarize design parameters that most affect passibility (e.g. culvert width). Some culvert sites have nearby flow gages, but most sites will be assessed using USGS Streamstats flow estimates. The observed or estimated high and low flows are fed into the HY-8 culvert hydraulics model, and the resulting velocity and depths are compared to published fish swimming capabilities for several different fish species. We are assessing future (mid-century) high and low flow fish passage conditions for several culvert sites using global climate model outputs, HSPF runoff models, and the fish passibility modelling framework. The results of this project will help inform culvert design guidance for fish passage and will further evaluate the resiliency of culvert designs to future flow scenarios. This talk will focus on the preliminary results for assessment of changes in culvert passability from present to future climate conditions.

Evaluation of Temperature, Streamflow, and Hydrogeologic Impact on Brook Trout Habitat

Robert Tipping, Minnesota Department of Health; *John Hoxmeier,* Minnesota Department of Natural Resources; *Tony Runkel, Julia Steenberg, Andrew Retzler,* Minnesota Geological Survey; *Nicholas Budde,* University of Minnesota Duluth

The recent discovery of resurgent brook trout populations in southeastern Minnesota streams has led to increased interest in documenting and improving critical habitat for this native species. Distributed Temperature Sensing (DTS) technology using fiber optic cables, combined with detailed mapping of geologic conditions and hydraulic head were used to identify areas of preferential base flow at three southeastern Minnesota trout streams. Results were compared to fish inventories to evaluate influence of focused groundwater input on brook trout distribution and abundance. Continuous stream temperature measurements along one-meter segments over distances up to 1900 meters were taken in winter when air and groundwater temperatures are most different. At the regional scale, artesian conditions were compared to bedrock geology and brook trout abundance. Transition from mixed populations of brown and brook trout to predominantly brook trout corresponded to specific stream reaches showing preferential base flow inputs from groundwater. Brook trout are found almost exclusively in streams where the Oneota Dolomite and underlying bedrock units are uppermost bedrock. Streams in these settings have springs characterized by relatively constant temperatures, and are supplied by groundwater from deep aquifers in generally poor connection to the land surface compared to near-surface aquifers. As such, they have relatively low susceptibility to high turbidity and contaminant pulses resulting from extreme storm events. At both regional and local scales this work demonstrates geologic control on hydraulic head conditions – particularly on vertical head gradients between bedrock layers and the role they play both in stream base flow and brook trout distribution and abundance. Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

Freshwater Mussels and Clean Water Regulation in Minnesota: The Importance of Water Quality Standards in Sustaining Ecosystem Services by Protecting Freshwater Mussels

Baishali Bakshi, Will Bouchard, Minnesota Pollution Control Agency; *Daniel Hornbach,* Macalester College; *Bernard Sietman,* Minnesota Department of Natural Resources; *Dennis Wasley,* Minnesota Pollution Control Agency

Freshwater mussels are threatened with extinction in North America. They are a sentinel species for ecosystem function and contribute substantially towards many ecosystem services. Ecosystem services being essential for human well-being, there is a need to protect freshwater mussels both for conserving the species and for sustaining the flow of ecosystem services for current and future generations. As mussels require clean water to survive, and since conserving ecosystem services is implicit in the federal Clean Water Act, incorporating mussel conservation into clean water goals could serve multiple conservation goals. Yet current clean water regulation is not sufficiently protective of mussels. We synthesize and present information on the status of freshwater mussels, their contribution to ecosystem services, threats to their conservation, and gaps between their water quality requirements and current water regulation, to help inform clean water and conservation goals in Minnesota

Concurrent Session IV, Track B

Occurrence of Neonicotinoid Insecticides in Minnesota Waters and Their Effects on Algal Bloom Formation
Matthew Berens, Paul Capel, William Arnold, University of Minnesota

The detection of neonicotinoid insecticides in natural and engineered waters necessitates an understanding of their occurrence and potential effects in Minnesota waters. Neonicotinoid insecticides are a group of synthetic chemicals broadly used in domestic and agricultural areas and are highly toxic to many aquatic and terrestrial organisms. Due to their high water solubility and low dissipation rate, neonicotinoid insecticides are highly persistent in the environment and present a significant risk for transport away from an application site. Moreover, neonicotinoid insecticides produce a number of breakdown products but little is known about the occurrence and behavior of these products in the environment. In this study, we collected water samples from over 65 sites throughout Minnesota representing a wide range of land use regimes and quantified the occurrence of neonicotinoid insecticides and their breakdown products. The potential for these compounds to influence the formation of algal blooms and modify the distribution of aquatic taxa was also assessed. Sampling sites included both natural and engineered (e.g., wastewater, drinking water) waters and were routinely monitored throughout 2019. This survey is the first of its kind in Minnesota and is critical to the development of safe use guidelines and regulations.

Detection of Cyanazine Degradates in Minnesota Groundwater
Heather Johnson, Minnesota Department of Agriculture

Cyanazine, a triazine herbicide, was used extensively to control weeds in corn in Minnesota from the early 1970s through the 1990s. Use of cyanazine stopped in 2002 after registration was voluntarily cancelled nationally due to human health and environmental concerns. The published cyanazine degradation pathway identifies seven different possible degradates, two of which are common to atrazine, another corn herbicide that is still in use. Following product cancellation, analysis for the cyanazine specific degradates in water samples was limited to the US Geological Survey Organic Geochemistry Research Laboratory, resulting in limited surface water and groundwater data collection nationally. In 2019, the Minnesota Department of Agriculture (MDA) and a contract laboratory successfully developed LC-MS/MS methods for the analysis of the cyanazine degradates. Samples collected from MDA's ambient surface water and groundwater network along with over 1,100 private drinking water wells were analyzed in 2019. Results indicated limited detections in surface waters (rivers and streams) and shallow groundwater. However, detections were frequent in private drinking water wells in some areas with vulnerable groundwater, with some detections exceeding the state drinking water human-health risk limit for total cyanazine of 1,000 ng/L. Among the cyanazine specific degradates, deethylcyanazine acid was detected most frequently and at the highest concentrations in private drinking water well samples indicating long-term persistence of this

degradate in groundwater. The effectiveness of home point of use, reverse osmosis (RO) water treatment systems were also evaluated in select wells with pesticide detections. In the 44 RO treatment systems evaluated, the cyanazine degradates were completely removed along with most of the other pesticides detected in pre-treatment samples.

Contaminant History of Nonylphenol and Its Ethoxylates in the Twin Cities' Urban Watershed

Robert McManus, Carrie Jennings, Freshwater; *Vania Stefanova, Mark Shapley,* University of Minnesota

Nonylphenol (NPE) and many Octylphenol Ethoxylates (APEOs) are compounds in laundry detergents, industrial surfactants, and are unmeasured byproducts of Wastewater Treatment Plants (WWTPs). NPE/APEOs are highly toxic to aquatic ecosystems and even in low concentrations may negatively impact human nervous system function, immunoregulatory processes, and fetal development. In 2008, North America produced up to 160 kilotons of NPE and APEOs. However, this quantity may have decreased since 2014 when the EPA began encouraging companies to phase them out due to their toxicity, environmental persistence (half-life ~60 years), and ability to bioaccumulate within aquatic food chains. The EPA now requires notification of significant new NPE and APEO use so that a risk assessment can be performed before commercial production begins. The state of Minnesota has yet to issue regulatory recommendations or implement water quality standards for the pollutants. As a result, the contaminants are still in commercial use and continue to be produced as a byproduct in wastewater treatment effluent. The goal of this study is to document the current concentrations of NPE and APEO within the Twin Cities' Urban Watershed and assess how they have changed over time.

Five lakes were selected along the Minnesota and Mississippi rivers: Rice, Snelling, Pig's Eye, River, and Pepin. The lakes are located upstream and downstream of WWTPs in order to assess the impact of the plants on sediment contaminant concentration over time. Cores samples were extracted, described, and archived at the National Lacustrine Core Facility (LacCore), University of Minnesota. Core chronologies were constructed using pollen-dating methods and verified with 137Cs-dating. Key intervals were sampled and analyzed through LC-MS to quantify NPE and APEO concentrations. We present the history of contaminant levels since their introduction and make recommendations on future management strategies.

Pathogen Task Force: Team Work Makes the Dream Work!

Nicolas Cantarero, Wenck; *Shahram Missaghi,* City of Minneapolis; *Mike Trojan,* Minnesota Pollution Control Agency

Bacteria and pathogens are the most frequent cause of water quality impairment in the U.S. In Minnesota, there are over 350 stream stretches and beaches impaired for bacteria.

The behavior of bacteria and pathogens in the environment is complex. Levels of bacteria and pathogens in a body of water depend not only on their source, but factors such as weather and water temperature. Testing for specific disease-producing bacteria or other pathogens (viruses,

protozoa, etc.) is difficult, expensive, and time-consuming. Consequently, fecal coliform and E. coli bacteria are often used as “indicator organisms” to denote the potential presence of fecal waste.

The City of Minneapolis recently completed a comprehensive study on the sources, pathways and potential impacts of E. coli bacteria in Minnehaha Creek. The goal of the study was to better understand potential causes of impairment to the creek and guide future City projects to reduce bacteria concentrations. In February 2020, the City hosted a work session with partners and stakeholders to share the results of this study and develop a framework to prioritize stormwater practices for pathogen reduction and monitoring. The group recommended forming a pathogen task force. The task force includes representatives from state and local governments and consulting firms.

In our presentation we will focus on three priority areas for the task force. For permit compliance, we will discuss flexible performance-based approaches that incentivize permittees to focus on source identification. This links directly to monitoring, where we discuss the use of techniques such as molecular markers, microbial community analysis, and direct measurement of pathogens instead of indicator bacteria. Finally, we will discuss the goals for the task force in identifying effective stormwater management practices, including both structural and non-structural practices.

Concurrent Session IV, Track C

Stormwater Quality Retrofit Prioritization Tool
Katie Kowalczyk, Justin Flannery, Minneapolis Public Works

The City of Minneapolis developed a tool for stormwater quality improvement that is used to inform infrastructure investment decisions in the city. The purpose of this planning-level, decision-making tool is to prioritize areas where stormwater retrofit should be incorporated. The prioritization tool is based on applicable data, such as soil information, slope, social equity, and other parameters drawn from the city's GIS-based water quality model, which are aggregated using GIS. The tool works by evaluating location priority for stormwater management projects, based on construction suitability and impact of providing stormwater treatment, relative to other areas of the city.

The City uses this prioritization tool to assess near-term infrastructure construction projects for inclusion of stormwater quality facilities and practices. Although Minneapolis is fully developed, regular infrastructure improvements present an opportunity to incorporate stormwater facilities on construction projects. The City also uses the tool to identify pipesheds for stormwater improvement studies. Long-term use of the tool involves developing a stormwater quality capital improvement plan, including monitoring decisions, funding requests, and stormwater treatment facility project identification. The ultimate goal of the stormwater quality CIP is to integrate with other infrastructure goals for a more comprehensive approach to selecting and scheduling city projects.

At this presentation, we will describe the information used to create the prioritization tool, the additional data sources being developed to continual improve the tool, and the ways that the tool is being used in decision-making. The presentation includes examples of how the tool is used and some of the projects that have been assessed.

Troubleshooting a Stormwater BMP: Case Studies in Industrial Stormwater
Phillip Taylor, Jeremy Fink, Hydro International

Industrial sites offer unique insight into stormwater BMPs as they are monitored as standard post installation practice. This ongoing monitoring is providing a long-term learning opportunity especially if the vendor is involved in the pre-testing of the site and follow up monitoring and maintenance.

This presentation looks at several sites where post installation monitoring indicated the BMP was not performing to the expected levels by the pre-installation testing. The learnings from these sites are informative and interesting and reveal that you may have to think outside the BMP box sometimes to get the answer. Using remote data loggers and visual inspections a big picture can emerge that can assist site owners to get a fuller understanding of how their day to day site operations and management can significantly impact water quality.

The studies include a large manufacturing facility that produces aluminum and titanium aircraft structural components and a small waste disposal facility. Different filter technology was used at each site and each presented unique challenges.

As part of the post installation troubleshooting, remote continuous sensing water level data loggers were installed. The information from these loggers revealed critical insight about the sites' stormwater flows that would not have otherwise been seen from periodic inspections. This was correlated with rainfall data and visual inspections to enable more detailed understanding of these sites and how best to manage them.

Comprehensive and Systematic Approach to Stormwater Treatment
Lisa Vollbrecht, City of Saint Cloud; *April Ryan,* SEH Inc.

Like most communities their age and size, the City of St Cloud has a number of areas with little to no stormwater treatment, multiple locations with ongoing drainage and flooding issues, and limited staff, time and funding. Over the past decade, St. Cloud has taken a systematic approach to Identifying high priority areas and leveraging resources and funding to address as many of these areas as possible.

This presentation will touch on how, already developed, areas of the City are targeted for stormwater management, how projects are identified and prioritized, an overview of the projects completed to date, which include numerous projects located on the NE side ranging from large regional treatment systems to greenification efforts and robust street sweeping program, in-lake alum treatments and watershed efforts to improve water quality in a 7.8-acre urban lake located at the heart of the city, and stormwater sedimentation and spent lime filtration projects to enhance the water quality of the City's source water, to name a few. The presentation will cover treatment expectations vs results, project costs, maintenance considerations for different systems, challenges of retrofitting into developed areas, lessons learned, and what the future holds for St. Cloud's stormwater management.

Concurrent Session IV, Track D

Wetlands Special Session: Wetland Quality, Resiliency, and Climate Change
Sheel Bansal, US Geological Survey, Northern Prairie Wildlife Research Center

This workshop will build collective wetlands knowledge and increase understanding of how wetlands integrate with water resources management throughout the State. The program may include topics such as, but not limited to, wetland soils, hydrology, plant communities, functions, values, mapping, assessment, mitigation, restoration, and wetland related policy. New in 2020, this workshop includes a hands-on/technical demonstration session that will engage the audience with opportunity for participation. This workshop was developed in coordination with the Minnesota Wetlands Professionals Association.

Solar Panel Impact on Wetland Quality Project
Roxy Robertson, Tony Havranek, Jordan Wein, WSB

The Solar Panel Impact on Wetland Quality Project is collecting baseline data that Local Government Units can use to make informed regulatory decisions about the installation of solar panels in wetlands.

Solar production in Minnesota has seen dramatic increases in the past few years and development of solar often requires large, vacant parcels which may also support natural habitats such as wetlands. It is unknown if solar panels influence the vegetation within a wetland and alter the wetland quality. The regulatory process for approving community solar can be challenging for local and state agencies, especially those who act as the local government unit (LGU) for the Wetland Conservation Act (WCA).
LGUs have had questions about whether the installation of solar panels may lead to loss in wetland quality over time which would be a violation of WCA. Regulating agencies have been struggling to make determinations for sites that install panels in wetlands because there is no data available that addresses the future outcomes. There is a need for baseline data about how the quality of wetland vegetation changes throughout the solar development process.

WSB is completing a pilot study to collect baseline data at solar sites in Minnesota. In 2019, WSB surveyed wetland vegetation under existing or planned solar panels at four solar farms in varying stages of development. Additional data collection is planned for 2020 and the project is seeking funding to expand the research to a larger scale in 2021-2024. FIREMON vegetative cover and frequency methodology is being used within sites containing wetlands. Plots are given a value representing the native diversity, habitat fidelity, and disturbance tolerance (Floristic Quality Index). Comparison of these values across years gives an idea of the change in wetland quality over time.

The regulatory challenges, data needs, pilot study framework/methods, and future of this project/data will be discussed in the presentation.

Concurrent Session IV, Track E

Brave New World: Redefining Our Relationship with Water
John Berrigan, Arcadis; *Jeannine Clancy,* Metropolitan Council, Environmental Services Division; *Sam Paske,* Metropolitan Council, Environmental Services Division; *Erin Niehoff,* Environmental Initiative

Brave Blue World is the first honest and hopeful documentary film that will paint an optimistic picture of how humanity is adopting new technologies and innovations to re-think how we manage water. We have been on an incredible journey to meet with pioneers and innovators who are addressing global water and sanitation challenges. Their stories reveal a hopeful and optimistic future for our most precious resource. This film will follow with a round table discussion of local stakeholder efforts as champions of clean water.

Concurrent Session V, Track A

Monitoring of Gross Solids in Residential Street BMPs to Determine Performance, Maintenance, and Costs

Sarah Wein, Joe Sellner, Capitol Region Watershed District

The Arlington-Pascal Stormwater Improvement Project located within the Capitol Region Watershed District in Saint Paul, MN became operational in 2007. Within this project, 30 catch basins and 16 manholes were designed as pretreatment to 8 underground infiltration trenches in residential streets with the goal of removing gross solids from stormwater runoff that eventually enters a local shallow lake. Monitoring and modeling have confirmed these practices reduce loading to the lake. To ensure long-term effectiveness of the practices and determine project performance, annual monitoring and maintenance is required.

Depth measurements of accumulated gross solids in the catch basins and manholes has generally occurred every spring and fall from 2007 - 2019 to calculate the total volume accumulated and to ensure debris depth does not exceed 50% of the total sump depth. Catch basin gross solids were sampled and analyzed for total phosphorus and bulk density, then applied to the calculated debris volumes in order to determine the total phosphorus load captured by the pretreatment practices.

Bi-annual hydro-vac maintenance has occurred since 2007 to remove the accumulated gross solids in the pretreatment practices. Using the monitored depth data, the current maintenance schedule was re-evaluated to determine if the current cleaning frequency was required. A cost-benefit analysis of the pretreatment practices was also completed. Overall, these pretreatment practices remove significant volumes of debris that would otherwise enter the underground infiltration trenches, resulting in costly maintenance and reduced functionality. Continued data collection will help inform long-term performance and future maintenance strategies.

A Street Sweeping Credit for Stormwater Practitioners and Permittees

Michael Trojan, Minnesota Pollution Control Agency; *Sarah Hobbie, Lawrence Baker, Jacques Finlay,* University of Minnesota; *Aileen Molloy, Jennifer Olson,* Tetra Tech

Studies suggest street sweeping can be one of the most cost-effective stormwater control measures. Minnesota currently lacks a state-certified credit for street sweeping. The University of Minnesota, Minnesota Pollution Control Agency, and technical experts collaborated on a study to develop a street sweeping credit, primarily focused on phosphorus. In this presentation we present the credit, including a summary of research conducted to develop the credit.

Wednesday October 21, 2020

Characterizing Runoff Quality from Low-Traffic Volume Roads
Poornima Natarajan, Saint Anthony Falls Laboratory; *John Gulliver,* University of Minnesota; *Peter Weiss, Valparaiso University; John Welle,* Aitkin County Highway Department

Vehicular traffic contributes a large fraction of the pollutant load in stormwater runoff from roadways. Characterization of the event mean concentrations and mass loads of runoff pollutants has historically been performed for urban roads with high average daily traffic (ADT). The runoff quality from paved rural roads that have relatively low ADT is, however, largely unknown. In this study, runoff was sampled at 10 sites along low traffic volume roads (ADT &lt 1500) in Minnesota during 173 rainfall events. The first-flush concentrations of total suspended solids, total phosphorus, nitrate and nitrite, and heavy metals in the runoff, and the relationship between measured concentrations and site-specific conditions were analyzed. Correlations of pollutants with catchment type and surrounding soil type were found to be strong. Comparison to existing urban runoff quality data was also performed to evaluate the potential implications for the level of stormwater treatment required for low volume paved roads.

The Metro Stormwater Geodata Project
Geoffrey Maas, Ramsey County and University of Minnesota

At present, no data standard has been developed that has been formally adopted or widely implemented for the efficient translation and aggregation of geospatial data representing stormwater assets in Minnesota. In April 2018, a partnership of private interests and public-sector agencies formed in the metro to meet this need and began by documenting their specific business needs for a standard of this kind to help bridge this gap. As of early 2020, after two years of continual work, a draft standard has been developed as well as a pilot data set for public review. This presentation will outline the benefit of developing this resource, its progress to date, and the anticipated steps toward its completion and implementation as a resource for the mapping, flow modeling, asset management integration and engineering uses for bringing data together and standardizing it across jurisdictions.

Concurrent Session V-VI, Track B

Watershed Scale Planning and River Restoration in a Changing Climate

Wade Johnson, Minnesota Department of Natural Resources; *Joe Magner,* University of Minnesota

Changing climate conditions continue to underscore the value of watershed scale planning and the need to adaptively manage river restoration practices. This special session will build off the success of the 2019 MN Water Resources Conference special session on Promoting Successful Stream Restorations and further explore topics and questions raised from last year's session. Specific topics will include:

- Planning for and applying adaptive management in stream restoration
- County Soil and Water Conservation District's shifting from acute stabilization practices to watershed storage practices
- Adapting floodplain and shoreland management and communicating to stakeholders in a changing climate
- Adapting watershed planning and modeling for climate change
- Application of climate change data and scenarios for stream restoration planning and design
- Implementation of watershed scale planning (MN Watershed Restoration and Protection Strategies, One Watershed One Plan)
- Findings from MN Legacy Fund Stream restorations and recommendation for improving practice

We intend to end the session with a panel discussion of challenges and opportunities for the future of watershed planning and stream restorations in changing climate regimes.

Wednesday October 21, 2020

Concurrent Session V-VI, Track C

Statewide Study of Pathogens in Minnesota Public Groundwater Supplies

Mark Borchardt, USDA − Agricultural Research Service; *Joel Stokdyk,* US Geological Survey, Upper Midwest Water Science Center; *James Walsh,* Minnesota Department of Health; *Tucker Burch,* USDA − Agricultural Research Service; *Trisha Robinson, Anita Anderson,* Minnesota Department of Health

At the request of the Minnesota State Legislature, from 2014-2016 the Minnesota Department of Health sampled 145 public water supply wells for a wide range of microbial pathogens and indicators. The majority of wells were sampled every other month for one year. Analysis by quantitative polymerase chain reaction (qPCR) showed that genetic material from these organisms was widespread, though occurrence was transient in nature. Ninety-six percent of wells had a detection of at least one microbe, while 70% were positive at least one time for a pathogen. Most wells had a mix of positive and negative samples, revealing the intermittent nature of microbial occurrence. The meaning of these findings is still being debated, from the hydrogeologic conditions that promote pathogen transport to the health risks these detections reflect. In this special session, study investigators will present their latest data analyses, place the Minnesota findings in the context of other studies on microbial contamination of groundwater, and describe MDH’s next steps to protect Minnesota’s public water supply wells.

Concurrent Session V, Track D

Anoka Sand Plain Wetlands: Have They Changed Over Time?
Elizabeth Flage, Joe Magner, University of Minnesota

Minnesota will have the wettest decade on record in 2020! Wetlands with poor surface-to-subsurface connections have enlarged in Minnesota however, wetlands in the Anoka Sand Plain (ASP) are connected to groundwater and reflect a measure of hydrologic resiliency.Is there an adverse threshold of impact with more precipitation and land-use change? We have examined 20 wetland stage records from an Anoka County monitoring network established and maintained since 1997. Because precipitation trends have increased, and perennial cover has decreased over the past 2 decades, we hypothesis that some wetlands may have crossed hydrologic thresholds of ecosystem resiliency. Results, to be finalized by October 2020, will hopefully help inform future management and regulatory decisions. This is particularly important for Anoka County because it is the fourth most populous county and one of the fastest growing in Minnesota. Many of the residents use the ASP Aquifer as a domestic water supply which is vulnerable to decreased water quality from changes in land-use management.

Planning for Resiliency: Natural Asset Valuation in a Changing World
Olivia Sparrow, Paula Kalinosky, Emmons & Olivier Resources

Wednesday October 21, 2020

In 2020, EOR conducted a study to help Credit Valley Conservation (CVC), a community-based conservation authority in Ontario, support municipalities in recognizing, measuring and managing the stormwater management services of natural heritage systems (e.g. forests) and natural infrastructure (e.g, wetlands). This talk will explore the methods developed by CVC to assign a dollar value to the stormwater services provided by wetlands and other natural assets.

Creating Dynamic Wetland Maps with Google Earth Engine
Audrey Lothspeich, Joe Knight, University of Minnesota Remote Sensing and Geospatial Analysis Laboratory

Wetland inventories, such as the National Wetlands Inventory, are important tools for water resource management, but they are a snapshot in time of a dynamic system. We present new research that developed a dynamic map of Minnesota wetlands. We used the archive of Landsat satellite imagery, the Landtrendr algorithm for summarizing time-series of spectral data, and the Google Earth Engine cloud-computing platform for geospatial analysis to summarize patterns in surface water presence over time. We describe progress in creating an understanding of how wetlands surface water change over time, and the applicability of Landtrendr and Google Earth Engine to increasing the information in wetland inventories for resource management.

The National Loon Center – A Premier Education Center for Our State Bird

Lorin Hatch, Widseth Smith Nolting; *Leah Heggerston,* National Loon Center Foundation; *Mike Angland,* Widseth Smith Nolting; *Carrol Henderson,* Minnesota Department of Natural Resources

The National Loon Center will be located in Crosslake, MN, with construction beginning in the fall of 2020. Initial work will consist of outdoor features including visitor watercraft mooring stations, boardwalks, and educational kiosks equipped with the latest technologies for participants. Upon completion students and visitors will have the opportunity to perform water quality sampling and testing, learn about a UMN-designed shoreland restoration, and view nesting loons at certain times of the year. A second phase of construction will consist of the National Loon Center building. The 15,000 square foot facility will bring the educational experience indoors, especially during the winter months. This is important because it isn't possible to have loons in captivity, unlike eagles or wolves at other Minnesota educational centers. In this presentation we will focus on the cutting-edge education technology that we will use to engage people.

Wednesday October 21, 2020

Concurrent Session VI, Track A

New Approaches for Improved Nutrient Management
Michael Ryan, HDR Engineering, Inc.

Federal and state regulators, clean water utilities, and watershed stakeholders in Minnesota and throughout the country face complex challenges that demand innovative solutions in nutrient management. Research from the Water Research Foundation (WRF) has been key to advancing not only the understanding of water treatment technology, but linking that technology with water quality and regulatory frameworks. This presentation aims to present the methodology used to advance water quality framework for nutrient management.

WRF is developing a Nutrient Roadmap, driven by established research and stakeholder involvement, in an attempt to capture the complexities of nutrient management and to develop best practices that inform future decision making. This process will provide effective strategies to take meaningful water quality improvement actions.

This presentation highlights three key aspects of the WRF Nutrient Roadmap Project:

1) A brief summary of the important work that WRF has led in the past that informs water quality, treatment technology, and regulatory requirements. This includes examples of various permit structures utilized across the country that demonstrate flexibility in protecting water quality using technically feasible strategies.

2) A detailed look into the ongoing efforts to improve nutrient management. This focuses on Phase 1 of the Nutrient Roadmap process, which is in progress. The goal of this phase is to conduct research and engage with point and non-point dischargers, regulatory agencies, and watershed stakeholders. The stakeholder engagement approach entails a progression of workshops, hosted by the Bay Area Clean Water Agencies, Philadelphia Water Department, and the Iowa Soybean Association, to provide diversity in region and perspective.

3) Next steps to develop a Research Roadmap, with new recommendations for policy, guidance to inform improved approaches to permitting, and regulatory frameworks that incentivize nutrient management.

Hot Shots of Roadway Salt: Balancing Environmental Protection with Winter Roadway Safety
Stephen Druschel, Emily Bollendorf, Tyler Bache, Minnesota State University, Mankato

Salt in our natural waterways causes aquatic toxicity and contributes to water anoxia, reduces ecological vibrancy and degrades our ecosystems. However, we need salt for winter roadway safety. When icy conditions develop on these trouble spots, state patrol shouts for more salt as vehicles are sliding sideways and crashes multiply, and people may be getting hurt. In times like these, the

consideration of environmental protection can be neglected, and much good work of deicer optimization can be negated.

Every roadway has trouble spots, prone to: drifting, ice fog, blow ice, shading, or perhaps refreeze on awkward cross slopes on curves. This study evaluated:
• The reduction in transportation levels of service caused by these trouble spots
• The frequency of occurrence
• The winter maintenance response, particularly the additional deicer resources, targeted to the trouble spots
• The length of the enhanced treatment zones related to the trouble spots, and,
• The downward adjustment in environmental protection caused by this response.

This study leveraged on-board applicator records of deicer applications, augmented by on-site photographic records and road-level weather measurement, for both trouble spots and ordinary roadway stretches. Results from this study can be used to justify speed reduction or road closure decisions, and provide strength for discussions addressing roadway salting and deciding how to protect the environment, specifically:
• Providing direction to target treatments to both normal and difficult roadway sections that support appropriate level of service at efficient cost while maintaining high environmental care.
• Quantifying the complete cost of keeping roadways open at a given level of service for both traffic and the environment.

This work is particularly helpful for transportation officials to argue for and support environmental protection decisions, leading to a balancing of both public safety and environmental protection.

Strategic Direction of the Clean Water Fund Through 2034: Clean Water Council Strategic Plan
Paul Gardner, Clean Water Council

The Clean Water Council--a group of citizens, government agencies, and legislators created in 2006 to advise on the implementation of the Clean Water Legacy Act--is tasked with recommending how to spend about $120 million a year from the Clean Water Fund. The Fund is derived from the Legacy Amendment sales tax increase approved by Minnesota voters in 2008. The Council has completed a strategic plan to determine how to spend those dollars to maximize clean water outcomes by the expiration of the Legacy Amendment in 2034. This session will describe the process by which the Council set these priorities, and describe how the Council is communicating outcomes from the Clean Water Fund to policy makers, the media, and the public.

The Future of Drinking Water: A Framework for Managing Risk

Peter Calow, Ann Lewandowski, Lucia Levers, Eileen Kirby, University of Minnesota

A joint project with the University of Minnesota and the Minnesota Department of Health (MDH), The Future of Drinking Water identified opportunities to better manage risks to drinking water in Minnesota, a state widely recognized for good drinking water management. This project spanned two years and developed recommendations based on literature and experience in other jurisdictions, discussions with a panel of research and policy experts, and meetings of stakeholders including representatives of large and small community utilities, the water technology industry, state agencies, and well owners. Main outcomes included 1) supporting the integration of drinking water governance through a statutory framework and development of a state drinking water plan, 2) suggesting the use of a Governance Assessment Framework (GAF) as the basis for assessing drinking water management, 3) encouraging comparative risk assessment for contaminant analysis, 4) proposing more comprehensive testing of private wells, and 5) promoting the engagement of broader audiences in decision-making and communication.

Concurrent Session VI, Track E

Reducing Soluble Reactive Phosphorus (SRP) in Outflow from Impacted Wetlands
Brian Kallio, Ed Matthiesen, Diane Spector, Wenck Associates

Wetlands receiving many decades of nutrient and sediment-rich runoff are at risk of transforming from nutrient sinks to nutrient sources. The hydrology has been altered by increased runoff volumes and ditching for drainage and flood prevention. These impacted wetlands are more susceptible to sediment nutrient release under anoxic conditions and discharge is often high in soluble reactive phosphorus (SRP) and low in dissolved oxygen.

Iron-enhanced sand (IES) filters have shown promise in reducing SRP, but require that the medium dry out between storm events. and remain aerobic. The Shingle Creek SRP Reduction Project is testing three kinds of sand filters - IES and two different proprietary media, a phosphorus sponge, the other an iron enhanced activated alumina - to determine which is the most cost-effective under saturated, anoxic conditions. In 2019 a wetland outlet weir was modified with the three filters in parallel to subject each to the same conditions. Flow through the filters was recorded, and inflow and filter discharge was tested for water quality.

Results from 2019 contradict the expectation that IES would not perform well under saturated conditions. The IES and the activated alumina performed better than the sponge, but the IES was far more cost effective in pounds per dollar removed. 2019 was an atypically wet year, and monitoring will be repeated in 2020. This presentation will overview the filter design and the assumptions and methods to calculate SRP removals and will present the 2019 and 2020 results.

Floristic Quality of Compensatory Mitigation Sites – Depressional Wetlands in Southern Minnesota
Carol Strojny, Tim Smith, MN Board of Water and Soil Resources

The Minnesota Board of Water and Soil Resources oversees wetland restorations for both conservation and regulatory programs. Over time, restoration guidance and requirements have evolved as state and federal programs incrementally gain experience with restoration techniques. This study aims to quantify how changing restoration techniques affect long-term vegetation quality. We selected 7 - 16 year-old wetland restorations either intensively restored (wetland mitigation sites with hydrology restored and wetland seed mixes installed) or passively restored (conservation program sites with hydrology restored and natural regeneration of wetland plants), and compared their floristic quality to naturally occurring wetlands. We targeted depressional wetlands in southern Minnesota, evaluating floristic quality of wet meadow, shallow marsh, and shallow open water communities. We sampled a total of 129 restored and naturally occurring sites using timed meanders. We assigned condition categories to each site using methodology developed by the Minnesota Pollution Control Agency. We also evaluated

native species cover and richness for each community. Overall, intensively restored wetlands were

similar to naturally occurring wetlands with higher condition scores than observed for passively restored sites. This result was driven by the wet meadow condition, in which intensively restored sites had higher native species richness and cover than passively restored and naturally occurring wetlands. Shallow marsh communities in naturally occurring wetlands had higher native species richness and cover than intensively and passively restored wetlands. Shallow open water communities showed no differences among populations. Our findings show intensive restoration strategies are beneficial to long-term vegetative quality of wet meadow and shallow open water communities, but greater attention to shallow marsh communities may be needed to achieve similar results.

Leveraging Wetlands for Climate Resiliency
Rosie Russell, Olivia Sparrow, Kerri Robinson, Emmons & Olivier Resources

In 2019, Emmons & Olivier Resources, inc. conducted research for Ducks Unlimited Canada to assess the applicability and viability of restoring and protecting wetlands for flood management in southern Ontario. More specifically, this study sought to understand if this is a current practice among municipalities and to determine the resources and steps needed to eliminate barriers of integrating wetland conservation into flood management and resiliency, particularly as they relate to this region. The findings from this study determined that utilizing the natural flood-management services of wetlands is cost-effective compared to traditional approaches. It also determined that there is a growing understanding of the benefits of wetlands as they relate to flood resiliency, but much of this knowledge has not yet been translated into meaningful action. For this study, two literature reviews were conducted to determine the current state of the practice of using wetlands for flood management and to understand the state of the science and practice surrounding the costs and benefits of this flood management approach. A survey of municipalities in southern Ontario was also conducted to understand the level of understanding these communities had on this topic and what (if any) steps they were taking to integrate this knowledge into flood resiliency planning. Lastly, five case studies were identified that exemplified the challenges and benefits associated with this practice and keyed in on specific steps that would be needed to properly implement this practice in southern Ontario. This research is another step towards ensuring communities have the tools they need to fully integrate natural infrastructure into their planning practices for a resilient future.

Sediment, Time, and Hydroperiod Influence Restoration Success In Depressional Wetlands
Sarah (Winnie) Winikoff, Jacques Finlay, University of Minnesota

Restoring agricultural wetlands to remediate nutrient runoff, increase ecosystem function, and decrease flood risk are areas of growing interest. One restoration strategy may decrease nutrient availability and increase water retention on the landscape by removing the accumulated eroded sediment from agricultural wetlands prior to restoration. We measured soil and water column nutrient availability and denitrification (DeN) potential in 54 restored agricultural wetlands in west-central Minnesota. In half of the wetlands hydrologic function was restored by

removing and plugging drainage tile and ditches hydrology was restored in the remaining basins following sediment removal (Excavation treatment), increasing basin depth by an average 30 cm. In addition to excavation, we considered the effects of wetland age since restoration and of hydroperiod by identifying basins as either seasonally or semi-permanently flooded. Soils nutrient content was lower in excavated basins compared to the control, but the effect was dampened by higher soil densities in the years immediately following restoration. Water column nutrient availability was significantly lower in excavated basins and phosphorus concentrations were lower in semipermanent compared to seasonal basins. Dissolved nutrient concentrations increased over time, regardless of hydroperiod and restoration strategy. Denitrification rates increased significantly as wetlands aged and seasonally flooded basins with short water residence times had significantly higher DeN potential than basins with longer residence times. Our results suggest that sediment excavation improved water quality by decreasing soil and water column nutrient availability, while potential DeN rate responded more to differences in hydroperiod. Accumulated sediment excavation may be a practical tool for improving water quality in restored depressional wetlands, but we need to consider how basins change over time.