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A Scoping Study: Integrating Constructed Wetlands into Water Reuse and Stormwater Management to Enhance Water Supply and Multi-Purpose Benefits

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14. ABSTRACT A partnership between federal, state, and local officials was formed to evaluate how constructed wetlands can be designed, tested, and implemented to achieve dual water supply - stormwater treatment benefits at Lake Thunderbird, a Reclamation reservoir in central Oklahoma. Indirect potable reuse has been identified by local officials as a preferred alternative to meet water supply needs of customers that depend on Lake Thunderbird. The wetland will also be evaluated to assess whether it can treat stormwater that is currently impairing water quality. This scoping effort identified multiple tasks to be completed over a three-year period: (1) evaluate source waters and receiving waters to collect baseline data on parameters needed to meet regulatory and non-regulatory water quality targets; (2) evaluate water treatment configurations and a range of potential site locations for a demonstration wetland that can be used to perform testing prior to full-scale implementation; (3) develop conceptual designs of a wetland complimenting a preferred treatment configuration alternative, building upon previous work; and (4) develop a preliminary monitoring plan framework for the demonstration project.

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Acronyms and Abbreviations

AWT	Advanced Water Treatment
CEC	Constituents of Emerging Concern
COMCD	Central Oklahoma Master Conservancy District
EDC	Endocrine Disrupting Chemicals
EPA	Environmental Protection Agency
M&I	Municipal and Industrial
NUA	Norman Utility Authority
IPR	Indirect Potable Reuse
ODEQ	Oklahoma Department of Environmental Quality
O&M	Operations and Maintenance
OTAO	Oklahoma-Texas Area Office
OU	Oklahoma University
OWRB	Oklahoma Water Resources Board
SWS	Sensitive Water Supply
S&T	Science and Technology
TMDL	Total Maximum Daily Limit
TBL	Triple Bottom Line
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
WWTP	Wastewater Treatment Plant

Contents

Executive Summary

Through this scoping effort, a partnership between Federal, state, and local officials was formed to evaluate how constructed wetlands can be designed, tested, and implemented to achieve dual water supply - stormwater treatment benefits. A case study was selected at a Reclamation project (Norman Project, Lake Thunderbird) in central Oklahoma. Lake Thunderbird provides Municipal and Industrial (M&I) water to approximately 250,000 people in three cities: Norman, Midwest City, and Del City. The three cities make up the Central Oklahoma Master Conservancy District (Water District), which is a political subdivision of the state, established to operate and maintain the Norman Project through a contract with Reclamation, and to administer water sales as the owner of the M&I water right. Recent studies show that during times of severe drought, Lake Thunderbird's supply is insufficient to deliver the full water right held by the Water District. One of preferred alternatives to make up for this deficit is to divert the city's treated municipal wastewater effluent into Lake Thunderbird, where it would be blended with the water held in storage and then distributed to M&I customers through the existing pipeline distribution system. This scoping study performed an initial evaluation on the role that a constructed wetland could play in treating the effluent prior to discharge into Lake Thunderbird. Of particular interest is making sure regulations can be met while also addressing stakeholder concerns about the existence of non-regulated constituents of emerging concern (CECs) in the discharge effluent. At the same time, the wetland could be used to treat stormwater that is currently impairing the quality of Lake Thunderbird. Overall, the long-term objective is to protect and enhance federally authorized benefits of Reclamation's Norman Project, including multi-purpose recreation and fish and wildlife benefits, as well as single-purpose benefits to M&I water supply. Benefits also extend to the scientific and water

resources planning community in terms of contributing to the state-of-the science on the role of engineered wetlands in attenuating non-regulated CECs, as well as in reducing or even replacing advanced water treatment (AWT) processes that are often costly and require brine management.

The scoping study identified four main goals to be accomplished over a three-year period: (1) evaluate source waters and receiving waters to collect baseline data on parameters needed to meet regulatory and non-regulatory water quality targets; (2) evaluate water treatment configurations and a range of potential site locations for a demonstration wetland that can be used to perform testing prior to full-scale implementation; (3) develop conceptual designs of a wetland complimenting a preferred treatment configuration alternative, building upon previous work in California and Texas related to CEC removal using wetlands; and (4) develop a preliminary monitoring plan framework for the demonstration project. Once this S&T work is completed, if applicable, local sponsors would be expected to build and monitor the demonstration project, and ultimately implement full-scale construction outside the S&T program.

Background and Needs

Research Questions and Tasks

The proposed project aims to answer several important research questions about the implementation of wetlands to accomplish engineering goals to meet water supply needs while simultaneously achieving multiple ancillary benefits.

1. Can constructed wetlands address dual Indirect Potable Reuse (IPR) and stormwater treatment needs, thereby facilitating both water supply augmentation and water quality improvement of impaired water bodies?
2. More specifically, how can constructed wetland designs be optimized to treat IPR water and stormwater, which have different flow regimes and water quality profiles?
3. Can constructed wetlands replace or reduce costly advanced water treatment (AWT) processes that are typically used for IPR projects?
4. After compiling existing wastewater, stormwater, and environmental CEC datasets, what additional data collection/analyses are needed and most beneficial for site selection and design?

We hypothesize that constructed wetlands can be optimized to achieve IPR water supply augmentation benefits while also being able to treat stormwater. We also hypothesize that constructed wetlands can reduce and potentially even replace AWT processes that are typically used to ensure IPR projects meet regulatory requirements and address stakeholder needs.

Research Need

The need for this research exists both locally and nationally. Lake Thunderbird, constructed by Reclamation in the early 1960s, is the main feature of the Norman Project. It provides Municipal and Industrial (M&I) water to approximately 250,000 people in three cities that

comprise Central Oklahoma Master Conservancy District (Water District), a political subdivision of the state established to operate/ maintain the Norman Project through a contract with Reclamation, and to administer water sales as the owner of the M&I water right. There is not enough supply in Lake Thunderbird to meet combined demands of the three cities where Norman's needs are the most immediate and pressing. Norman has and continues to utilize its entire water right allocation on an annual basis, and additional water supplies are necessary to meet the city's current and growing demands. Norman's demands are expected to double over the next 40 years. One of Norman's preferred alternatives to make up for this deficit diverts the city's treated municipal wastewater effluent into Lake Thunderbird, where it would be blended with the water held in storage and then distributed to customers through the existing distribution system.

The term "indirect potable reuse" (i.e., IPR) refers to the "indirect" blending of the city's treated wastewater effluent into the reservoir, and then the subsequent "reuse" (recycling) of that effluent by distributing the water into the "potable" (drinking) water supply. Reclamation's draft AWT Roadmap defines IPR as "water that is further treated after leaving a wastewater treatment facility and is then discharged to an environmental buffer, such as a groundwater aquifer, wetlands, or reservoir, before re-entering the water supply system." The effluent is currently discharged into the Canadian River, which is viewed as a lost resource because there are no downstream water rights or flow requirements in the river. This project proposes to divert the treated effluent into Dave Blue Creek which flows into Lake Thunderbird, both of which would act as "environmental buffers". This would increase reservoir storage, thereby making more M&I water available to the three member cities, namely Norman. The main challenge is ensuring regulatory requirements are met while also satisfying stakeholder concerns related to the impacts this could have on lake water quality and drinking water quality.

In addition to the immediate water supply needs, Lake Thunderbird was listed in 2013 as an impaired water body requiring total maximum daily limit (TMDLs) to be established for its beneficial uses due to high concentrations of chlorophyl-a, low concentration of dissolved oxygen, and a high concentration of biological oxygen demand (ODEQ, 2019). Being on the ODEQ's List of Impaired Waterbodies means there are to be no new loadings (IPR or stormwater), regardless of the IPR water quality, thus requiring stormwater management and IPR to be managed under a one water framework. Reclamation has placed emphasis on improving the knowledge of AWT processes that remove constituents that are not easily removed by conventional treatment. Reclamation's draft AWT Roadmap identifies constructed wetlands as a key strategy to advance IPR projects. Three of Reclamation's AWT goals: 1) augment the supply of usable water in the U.S., 2) understand and minimize the environmental impacts of AWT, and 3) lower the financial costs of AWT are all identified in Research Tasks. This research further advance IPR across the West, which has the potential to significantly alleviate water deficits, especially during drought periods; assess efficacy of treatment wetlands for constituents including CECs to reduce the levels of these in our potable water supplies, thereby improving environmental sustainability; augment treatment wetlands to AWT processes to reduce energy/chemical needs and lower the cost of treatment.

In the United States, it has been shown that many organic contaminants present in municipal wastewater treatment plant (WWTP) effluent are also widespread in surface and groundwaters that receive WWTP discharges (Kolpin and others, 2002; Barnes and others, 2008; Focazio and others, 2008). One of the issues of concern is the potential for estrogens and other Constituents of Emerging Concern (CECs) in WWTP effluent to elicit adverse ecological or human health

outcomes (Jobling and others, 1998; Sumpter and Johnson, 2005; Ankley and others, 2007; Vajda and others, 2008; Barber and others, 2011). A number of chemicals widely present in WWTP effluents (including steroidal hormones, alkylphenol nonionic surfactant degradation products, bisphenol A, natural products) have been shown to cause reproductive impairment in fish (Barber and others, 2007; Vajda and others, 2011). Likewise, it has been recently shown at the operational scale, that advanced treatment can remove EDCs as well as endocrine disrupting effects in exposed fish (Johnson and Sumpter, 2001; Barber and others, 2012).

Westerhoff et al., (2014) echoed these similar benefits and pointed out while constructed wetland design has been optimized for denitrification and/or establishment of ecological habitat, few design guidelines exist for removing contaminants of emerging concern (CECs) in these engineered systems. This deficiency therefore directed research at identifying factors for influencing removal of organic and nano-material CECs in constructed wetlands, with the goal of establishing design criteria for CEC removal in wetlands located between CEC sources and raw potable water supplied. Further, although researched for the purpose of agricultural irrigation but relevant for other reuse of wastewater reclamation, Shingare et al. (2019) illustrated that despite its wide application for the role of macrophytes that form an integral part of constructed wetlands and specific mechanisms involved in pathogen removal by them is still barely understood due to complexities involved and influencing factors.

Benefits and Impacts

Similar to the needs identified above, the benefits are both local and national, and they are both immediate and long-term. The Norman Project (Lake Thunderbird) is a Reclamation project. It provides multi-purpose benefits, including M&I, recreation, and fish and wildlife benefits. From the IPR water supply augmentation context, the benefit to Reclamation is longer-term. The Norman Project is considered a "transferred works" project, meaning water deliveries and O&M have been transferred to the Water District through a repayment/O&M contract with Reclamation, which maintains ownership of the Project and oversees management and dam safety. The Water District holds a M&I water right of 21,600 acre-ft per year out of Lake Thunderbird. Reclamation recently performed a yield analysis on Lake Thunderbird and found that the yield is not sufficient to deliver the full 21,600 acre-feet per year water right during critical drought periods. In fact, during a repeat of the drought of record, Reclamation found that the reservoir can only supply 10,400 acre-ft per year, which is less than 50 percent of its design capacity. The objective of the IPR project is to increase reservoir storage and make up for this deficit during drought periods. By improving water supply reliability, the financial solvency of the Water District is improved, which helps the District fulfill its contractually-obligated O&M requirements at the Norman Project. A properly maintained Norman Project benefits Reclamation and the public for many reasons. Benefits to Reclamation also are derived through benefits to recreation and fish and wildlife, which are authorized purposes of the Norman Project. Reclamation (the U.S.) proportioned the repayment of the Norman Project in accordance with multi- versus single-purpose (M&I) benefits, with the U.S. (Reclamation) paying for the former and the Water District paying for the latter. As such, the IPR project is helping maintain authorized multi-purpose benefits, which effectively helps solidify Reclamation's return on investment in the Norman Project.

For the cities (namely Norman) that depend on Lake Thunderbird, the IPR project will provide

single-purpose M&I benefits, which will allow the cities to deliver safe drinking water and continue to prosper economically. In addition to M&I benefits, benefits to recreation and fish and wildlife also benefit the local communities. As previously stated, when the reservoir drops below 1,031 ft in elevation, boat access is eliminated. Maintaining lake levels through IPR would benefit a portion of the one million visitors that enjoy Lake Thunderbird each year. Furthermore, it is worth noting that there is an immediate benefit to Reclamation politically by merely partnering on this research, which is considered a fairly high profile and potentially contentious effort in Oklahoma and beyond. In fact, there are few if any projects of its kind in the U.S. in terms of using a Reclamation reservoir as part of an IPR project. Reclamation's involvement will be critical towards providing technical credibility to the process, and this will benefit Reclamation staff and help build trust between the Oklahoma- Texas Area Office, which is overseeing Reclamation's involvement, and the Water District, cities, and the public. While the results of this research will provide immediate benefits to a specific Reclamation stakeholder and project, they will also provide future benefits to other stakeholders, projects, and communities. The results will be applicable to many other Western communities facing similar challenges, and to Reclamation reservoirs with high nutrient loads. A very important part of this project will be documenting the evaluation, decision- making, and conceptual design processes and considerations to make the project results more beneficial and transferable to others.

Previous Work

This research that was awarded a FY 2022 S&T grant (Project ID 220006) will build upon previous constructed wetlands research Reclamation conducted in collaboration with USGS, beginning with initial designs developed by USGS, and more recently in Texas. Between 2012 and 2015, the S&T Program invested significant funding to support efforts to identify, evaluate, and select a preferred wetland design and demonstration site for testing. A demonstration site was selected in Waco, TX adjacent to the Brazos River, and designs were completed, as well as a monitoring plan. The goal of the Brazos Demonstration Wetlands was to test a new and innovative wetland design that incorporated a unique combination of surface and subsurface treatment zones, as well as passive aeration units including cascades and turbulent stream channels. Designs, engineering, and monitoring plans were prepared and reviewed by an expert, multi-disciplinary team of Federal, state, local, academic, and private entities. Following a ribbon cutting ceremony, construction of the demonstration site was set to begin in January 2016, and initial findings were expected in 2018 after a three-year monitoring period. However, unexpected changes in city leadership caused the project to be halted at the last minute.

Since that time, Reclamation and USGS have been searching for a new entity with similar needs that could sponsor a similar type of project; one that could build upon and utilize the knowledge and data that came from the previous S&T work in Waco, TX. Norman, Oklahoma is home to University of Oklahoma (OU) and is highly regarded as one of the leaders and trend setters in Oklahoma when it comes to water and wastewater management. The water and stormwater utility directors at Norman are relatively new to their positions, visionary, highly energetic, and passionate about innovative solutions. If implemented, this IPR project would be the first of its kind in Oklahoma. In fact, recognizing Norman and others' growing interest in IPR, the Oklahoma Department of Environmental Quality (ODEQ) recently approved new IPR regulations that will be incorporated into this research. Back to Texas, the goal is to build upon the previous work in TX, but not to repeat it. Norman's needs are different than those in Waco, primarily because the

Norman wetland proposes to integrate stormwater treatment into the IPR treatment designs. The interesting challenge for this project will be transferring the design knowledge from TX to Norman while considering the different physical and hydrologic landscape, regulatory framework, as well as overall research objectives. That said, some of the key outcomes in terms of design constraints learned from TX that will be incorporated into the identification of a demonstration site in Norman are as follows: (1) the presence of a nearby source of wastewater and an area to discharge where additional permitting is not required; (2) a minimum flow of 1.0 cfs (~645,000 gpd); (3) an approximate site size (including water surfaces, berms, O&M access, and side slopes) between five and thirty acres; (4) an elevation change of at least five feet from the inflow water surface to the outflow; (5) the presence of nearby source materials, including earth, high humus soils, impermeable soils, cobbles, pea gravel, sand, river boulders, and wetland plants; (6) no extreme earthwork or rock excavation required; (7) existing of in-kind construction capabilities; (8) site access and sampling locations; and (9) on-site logistic and staff support to include storage and lab space, and assistance with collecting samples.

Facilitated Adoption

One of the primary outcomes of this research will be facilitating operational decisions while ensuring compliance with water quality regulations. The city of Norman is currently pilot testing multiple advanced water treatment processes (AWT), namely biological filtration and ultraviolet (UV) disinfection and is evaluating the costs and efficacy of removing target constituents from its wastewater effluent as part of its future IPR project. The proposed Title XVI project includes a critical, 30- month field research study to evaluate advanced treatment processes against anticipated effluent water quality limits for IPR via reservoir augmentation in accordance with the requirements for IPR in Oklahoma. The field research will also determine the physical viability of advanced treatment processes for an inland IPR application, without the use of high-pressure membranes (nanofiltration or reverse osmosis). The question remains as to what role constructed wetlands may play in this project. Depending on the results of this S&T study and that of future demonstration-scale testing, a decision will be made to either use the constructed wetland alongside existing AWT processes, or to replace AWT altogether, whether to place the wetland before or alongside Dave Blue Creek or whether or not to integrate stormwater treatment/management. These have very real-world adoption implications in terms of how the IPR project will be operated and adopted. As it currently stands, Norman's goal is to have the IPR project running within five years. Assuming a full-scale, IPR project is implemented, two options are being considered in terms of when/how to discharge the treated effluent into Lake Thunderbird. The first option is continuous, year-round discharge into the reservoir, and the other option is to discharge into the reservoir only during drought periods when pre-determined reservoir elevation trigger points are reached (i.e., when the reservoir drops to elevation 1,035 ft (30 percent drop), the IPR discharge is turned on. The ultimate role of the constructed wetland in the IPR process will partly determine with operational scenario to adopt.

The operational implications discussed above need to be placed on the context of meeting regulatory requirements. Lake Thunderbird has been designated as a Sensitive Water Supply (SWS) by the State of Oklahoma in 2002. Lake impairments include low dissolved oxygen, high Chlorophyll-a, and high turbidity caused by stormwater flows and nonpoint sources during runoff events. A Total Maximum Daily Load (TMDL) for these constituents also has been established, and

as an SWS, additional restrictions are placed on discharges into the reservoir. The Oklahoma Water Resources Board (OWRB) and Oklahoma Department of Environmental Quality (ODEQ) ensure requirements associated with TMDLs and SWS are met. Both State agencies are key partners of this project. By demonstrating effective treatment of source waters (wastewater effluent, advanced treated effluent, stormwater) and anti-degradation of receiving waters (Dave Blue Creek and Lake Thunderbird), this research paves the way for regulatory approval of discharges into Lake Thunderbird that otherwise could not be obtained.

Finally, the results will be used by research sponsors and partners to build community trust and stakeholder/public acceptance regarding the extent to which the treatment regime removes CECs and protects public and ecological health. Even though CECs are non-regulated, garnering support will facilitate adoption of constructed wetlands as a preferred method to facilitate IPR and water supply augmentation.

Proposed Wetland Pilot Project Configurations and Locations

It became clear early in the scoping study which was further reinforced during the formation of the partnership (a list of study partners is provided in the section below) that the City of Norman has two primary needs that could be addressed (at least in part) by constructed wetlands. While the main objectives for Norman would be supporting their IPR project and stormwater treatment needs, they also expressed interest in the ancillary benefits that constructed wetlands can provide (e.g., social, economic, and ecological benefits). In discussing potential project configurations to maximize benefits and potential project locations, it became apparent that several alternatives for implementation of constructed wetlands were possible. As is usually the case with integrative projects that will address multiple needs and provide multiple benefits, it was not immediately obvious which alternative (i.e., potential solution) was the best (i.e., would provide the most benefit at an acceptable cost). Therefore, as the first steps in the proposed conducting study, it was decided to perform an evaluation of alternatives and collect additional data to help Norman reach a decision on how to best incorporate constructed wetlands into their "one water" strategy, as well as to provide a road map for other communities and utilities considering similar scenarios.

The seven alternatives that were identified in the scoping study are shown in Figure 1 below. The current plan (which is not final) for Norman's IPR project involves treating secondary effluent from their wastewater treatment plant (already meeting requirements to be discharged to the Canadian River) with several advanced water treatment processes. The advanced treated water, now the IPR source water, would be pumped uphill to Dave Blue Creek, one of two major tributaries that flow into Lake Thunderbird, via a pipeline. The IPR source water would commingle with the creek water and flow into Lake Thunderbird.

The goal of the proposed evaluation of alternatives process is to select a sustainable, multi-benefit wetlands implementation scenario for Norman, and to help ensure that the planned demonstration project represents the full-scale configuration and goals. By considering the importance of various evaluation criteria to Norman and other interested parties, and by documenting the evaluation process and benefits of the selected alternative, the aim is to proceed with a plan that will maintain momentum. Another important goal of the evaluation of alternatives is to document the process

and decisions made to serve as a road map for other communities considering constructed wetlands, or even other types of green infrastructure.

The evaluation of alternatives process will be based on an abbreviated triple bottom line framework, meant to provide a more comprehensive understanding of value and success, considering three bottom lines: environmental, financial, and social. As opposed to evaluating alternative treatment trains for a treatment plant, for example, evaluating alternative plans for constructed wetlands can be more complex in some ways in that they can provide multiple benefits beyond water treatment. Unlike treatment plants, they provide great opportunities for environmental/habitat benefits and social (e.g., aesthetic, educational, recreational, public acceptance of IPR) benefits that should be considered. Scoring criteria will be identified based on these factors, practical considerations/input from Norman's utilities, and more standard economic and treatment performance considerations. Implementation risks and the design constraints previously identified in the Brazos Wetlands project in Texas will also be incorporated into the scoring criteria (e.g., minimum flow, acreage, topography, soils, etc.). Alternatives will be ranked based on the scoring criteria, weighted according to relative importance based on input from the team and stakeholders, to make "the best" decision for Norman, and the process will be documented to outline for other communities how to make "the best" decision for them.

Lastly as earlier stated, the city of Norman is currently implementing a 30- month field research study to evaluate advanced water treatment processes against anticipated effluent water quality limits for IPR via reservoir augmentation in accordance with the requirements for IPR in Oklahoma. The field research will also determine the physical viability of advanced treatment processes for an inland IPR application, without the use of high-pressure membranes (nanofiltration or reverse osmosis). The question remains as to what role constructed wetlands may play in this project.

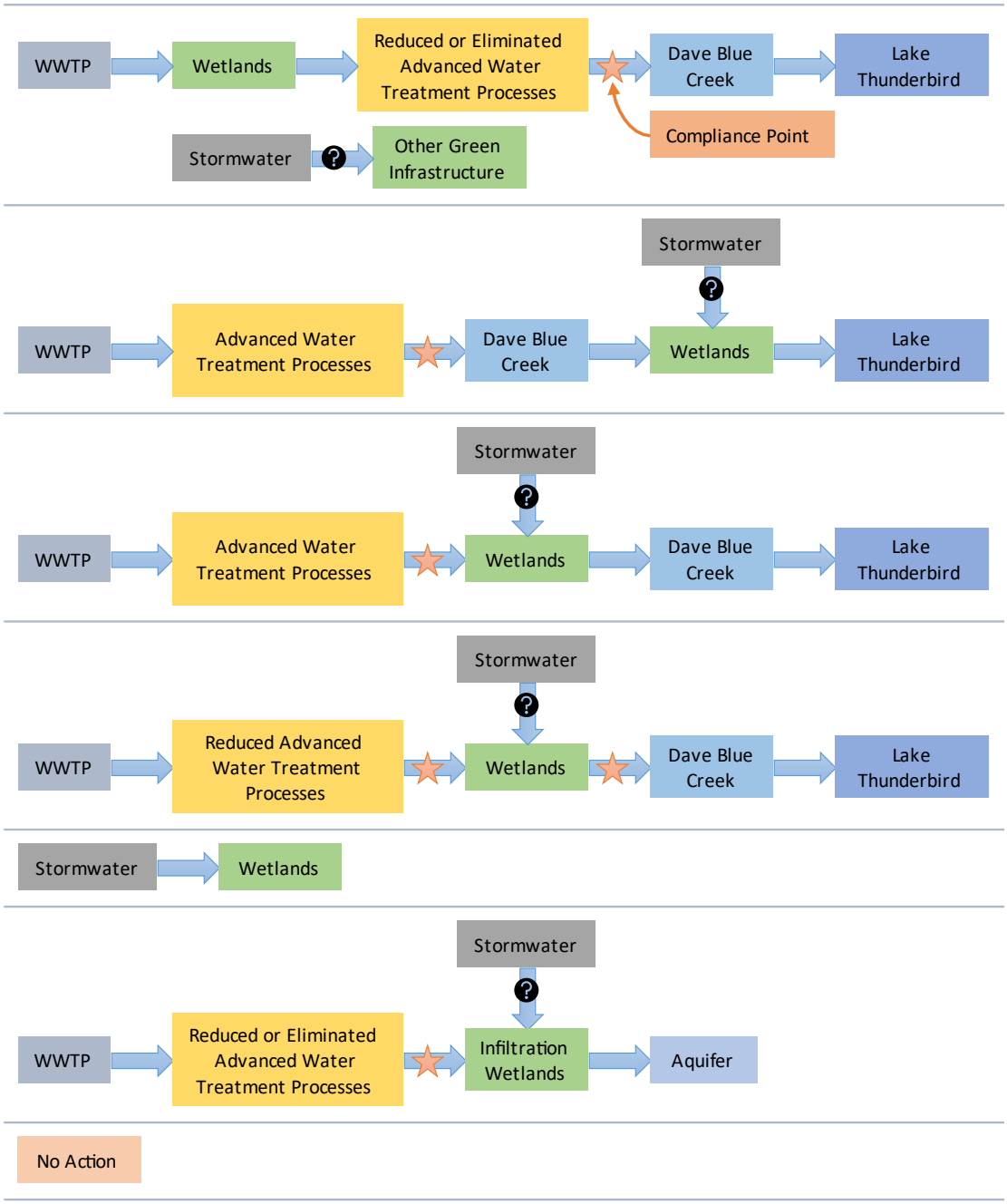

Figure 1. Seven alternative constructed wetlands implementation scenarios that were identified in the scoping study, and that will be evaluated and ranked in the proposed conducting study.
Note: WWTP = wastewater treatment plant

Methods and Study Partners

Several key partners were identified in the scoping study, including:

- Local Partners: Central Oklahoma Master Conservancy District and member cities Norman, Midwest City, and Del City
- Federal Partners:
  - Reclamation's OTAO and TSC
  - USGS multi-disciplined integrated science teams and labs (Columbia Environmental Research Center, Toxic Substances Hydrology and Ecosystems Research
  - EPA Office of Research & Development
- State Partners:
  - Oklahoma Department of Environmental Quality (ODEQ)
  - Oklahoma Water Resources Board (OWRB)
- Academia Partners: University of Oklahoma Center for Restoration of Ecosystems and Watersheds.

Study partners collaborated during this scoping effort and identified several tasks to be completed over the course of three years (Table 1).

Table 1. Tasks identified in this scoping effort.

Task	Schedule	Primary Entities Involved	Task Description
Task 0 – Project Management	Entire Project	OTAO, TSC, OU, USGS	• Service agreement for TSC • Cooperative Ecosystems Studies Unit agreement for University of Oklahoma • Interagency agreements for USGS
Task 1 – Communications Plan	Entire Project	OTAO, USGS, Norman	• Communications Plan to ensure proper messaging and public outreach.
Task 2 – Literature Review	Entire Project	OTAO, TSC	• Organize wetlands research conducted during FY 21 S&T Scoping Study • Gather/assess recent papers/publications on applications of financial, social, and economic criteria in support of alternatives analysis • Compile/organize data and publications related to the Brazos Demonstration Wetland project
Task 3 – Data Compilation, Data Collection and Technical Analyses	2022	TSC, USGS, OU EPA	• Conduct detailed and comprehensive chemical and microbial/pathogenic analysis of IPR source waters. • Provide a detailed characterization of source waters and receiving waters. • Coordinate with OU on existing NSF/EPSCoR grant to determine logistics/parameters in building the additional mesocosms. • Compile and summarize existing stormwater data collected from the USGS National Stormwater Dataset. • Compile and summarize existing baseline CEC data collected in the Lake Thunderbird watershed by Oklahoma University. • Ensure proper coordination among all partners ranging from planning, sampling, analyses and modeling. • Derive list of constituents that are critical for this study in relation to the

			alternatives analysis; WQ key characteristics we will be treating for.
Task 4 – Identification and Evaluation of Alternatives	2022	TSC, OTAO, Norman, USGS	• Refine the treatment configuration alternatives, if applicable, in terms of location of constructed wetland relative to advanced water treatment and Dave Blue Creek, in addition to integration of stormwater treatment. • Identify scoring criteria and rank alternatives based on scoring criteria, including anticipated treatment effectiveness, environmental and social factors, risks, and costs. • Perform technical analyses on removal of key constituents from the various source waters.
Task 5 - Selection of Preferred Alternative	2022	TSC, OTAO, Norman, USGS	• Prepare technical memorandum describing the process and results of the alternatives evaluation including a brief description of each of the seven (or more) treatment configurations/demonstration site alternatives, including: preliminary site plans, design considerations, engineering components, and costs; solicit feedback from project team, stakeholders, and peer reviewers.
Task 6 - Conceptual Design of Preferred Alternative	2023	USGS	• Develop a wetlands demonstration site design that utilizes gravity flow and reactors-in-series principles to optimize passive treatment mechanisms including aerobic and anaerobic biodegradation, sorption, photolysis, plant uptake. • Incorporate results and outcomes of Oklahoma wetlands mesocosm research into conceptual designs identified above; solicit feedback from project team, stakeholders, and peer reviewers.

Task 7 - Hydrological, Chemical, and Biological Monitoring Plan Framework	2023	USGS, EPA, ODEQ	• Identify performance data required to determine how well the constructed wetland meets design (water quality) objectives, including IPR and TMDL regulatory requirements, attenuation of CECs. • Identify performance data needed to characterize wetland startup conditions, evaluate attenuation functions, and to generate a comparison dataset for the evaluation of treatment performance as the wetland system matures. • Identify performance data and modeling tools needed to determine how the wetland could impact receiving surface waters, as well as shallow groundwater and river floodplain water quality, including bioaccumulation and biogeochemical impacts (e.g., denitrification, phosphorus cycling, organic carbon dynamics).
Task 8 - Communications and Project Close-Out	2023	OTAO, TSC, USGS, Norman	• Finalize technical memorandums (i.e., evaluation and selection of preferred alternative; conceptual design; monitoring plan framework). • Present findings to Water District board of directors; present findings to IPR Citizen Advisory Committee; present findings at an internal and external webinar.

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