Professional Leave Report Cover Sheet

Name: William Wright

Department: Civil & Geomatics Engineering

College: Lyles College of Engineering

Leave taken: ◉ Sabbatical ○ Difference in Pay ○ Professional Leave without Pay

Time Period: ○ Fall

◉ Spring 2023

○ Academic Year

○ Other

Your report will be sent to your Dean for your PAF and to the Library Archives.

Sabbatical Report for Spring 2023

Analyze Data, Publish, and Pursue Funding to Advance Research on the Efficient Extraction of Water and Nutrients from Contaminated Water Sources for Municipal and Agricultural Use During Drought

William Wright,

Oct. 27, 2023

Introduction

Achievement of sustainable agriculture and communities in arid and semi-arid regions of the United States (U.S.) will require advancements in salinity management strategy, salt extraction technology, and development of reliable supplies of water and crop nutrients. The long-term overarching goal of the research engaged in during the Spring 2023 sabbatical leave was to accelerate the development of technology that can efficiently extract water and beneficial constituents from nontraditional water sources thereby improving salinity, water, and nutrient management in drought-impacted regions of the U.S.

Arid and semi-arid regions of the United States are increasingly experiencing water scarcity and higher source salinity due to climate change and population growth, limiting agricultural production opportunities. Increased utilization of impaired water sources, such as brackish groundwater, agricultural drainage water, oil and gas produced water, and effluent from wastewater treatment processes is required to address these water shortage and impairment issues.

An innovative ion separation and recovery process is being developed that will expand the range of water sources that can be utilized for agricultural production and other uses in drought-challenged regions, resulting in more sustainable water and crop nutrient supplies with a lower carbon footprint. The Spring 2023 sabbatical leave allowed me to devote all my time to the effort, permitting me to make critically important progress towards reaching project goals that would not be possible with the normal workload. The scope of work is summarized as follows:

1. Analyze and evaluate experimental data is generated from ongoing experiments;
2. Develop grant proposals to advance the lab-scale research and demonstrate the technology at field-scale;
3. Develop materials for presentation at technical conferences, to write a manuscript for submission to a journal, to share the news of the innovative technology to our local communities; and
4. Develop instructional material so that our students can learn about this research.

The success of the leave, benefits to me as a faculty member, benefit to our university, and a tentative date for delivering a seminar on the sabbatical to faculty colleagues are described below. A copy of the original proposal is attached to this report.

1. Success of the Leave

This section of the report presents (a) an analysis of the accomplishments of the leave in relation to the objectives of the original proposal; (b) a description of the modifications of the original proposal and the circumstances with which necessitated these modifications; and (c) the goals of the original proposal that were not accomplished.

a) Analysis of the accomplishments of the leave in relation to the objectives / goals of the original proposal

Objective 1: Develop and be lead author of at least one conference manuscript and technical presentation and submit it to at least one local and one state or national technical conference.

Results: Work on a manuscript and presentation titled "Production of Water and Nutrients from Nontraditional Water Sources - a Path to Sustainable Agriculture in Arid and Semi-Arid Regions of the Southwestern USA" began during the Spring 2023 sabbatical. However, the manuscript was not completed due to a shift in the project schedule that resulted in significant delays in generating test data. Those delays were caused by COVID-19-related restrictions, supply chain interruptions, and anomalies encountered in test equipment performance during the start-up phase of the project. These challenges were largely resolved by the end of the summer in 2023 and a new testing schedule has been implemented. The project is currently progressing according to the new schedule. We are collecting data and should have enough for a manuscript by the Spring 2024. This week a call for abstracts was announced by the American Society of Agricultural and Biological Engineers (ASABE) for their annual conference next summer. An abstract for a conference paper and presentation will be submitted to the ASABE before the closing date of January 20, 2024.

During the Spring 2023 sabbatical a technical presentation was prepared titled "Production of Water and Nutrients from Brackish Sources - a Path to Sustainable Agriculture in Arid and Semi-Arid Regions of California." An abstract for this presentation was submitted to the 2023 WateReuse California Conference. The presentation was not selected for inclusion in the program. However, a second abstract, titled "Optimization of Ion Exchange Pretreatment for the Desalination of Agricultural Drainage Water" was submitted to the 2023 CSU Agricultural Research Institute's Annual Principal Investigator meeting and it was selected for inclusion in the program. The presentation was delivered on October 19, 2023 in Sacramento, CA.

Objective 2: Develop and be lead author of at least one journal manuscript for submission to at least one national peer-reviewed journal.

Results: An expanded version of the ASABE conference manuscript will be developed for submission to a peer-reviewed journal after sufficient data is generated from the ongoing

experiments. This paper will contain a detailed discussion of the role of separation and recovery processes in expanding the range of water sources that can be utilized for augmenting agriculture and small community water supplies in drought-challenged regions of the USA. I will be the lead author.

The time that would have been devoted to working on the journal paper was redirected to solving test equipment performance issues and working on two related journal manuscripts that were being developed by Professor Pei Xu and doctoral student Thiloka Edirisooriya at New Mexico State University (NMSU). One of the papers is a review of desalination technology and the other is an opinion piece. The Fresno State contributors to this effort were Sankha Banerjee, Karl Longley, Walter Mizuno, three graduate students (two from mechanical engineering and one from civil engineering) and me. The paper topics are as follows:

1. "Sustainable distributed treatment of inland brackish water for agricultural uses" (*technology review paper*)
2. "The economic feasibility of developing alternative water supplies for agricultural irrigation" (*opinion paper*)

The opinion paper was submitted to *Current Opinion in Chemical Engineering* (Ref. No. COCHE-D-23-00067R1). Work on the technology review paper is on-going.

Objective 3: Work with communication specialists to develop at least two news pieces to inform local and regional communities about the innovative technology that we are developing.

Results: In spring 2023 my Fresno State research project coworkers and I arranged interviews with two communication specialists to inform local and regional communities about the innovative research project. The interviews took place in the summer of 2023 and we are waiting to see if the editors will publish the story. The venues and reporters are as follows:

1. California Farm Bureau Ag Alert reporter Cyndee Fontana-Ott.
2. Fresno State's Lyles College of Engineering communication specialist Yersinia Yesenia Fuentes.

Objective 4: Be the lead or second author of a grant proposal developing field trial testing of optimized IX technology with nutrient recovery and/or advanced ion separation technology for additional nutrient recovery. Proposal submission will take place in accordance with the schedule published in the RFP guidelines.

Results: A grant proposal was developed and submitted in Spring 2023 for purchasing an electrodialysis reversal (EDR) water treatment unit that, when incorporated into the water and nutrient recovery system, will enable use of high salinity water thereby expanding the pool of potential water supplies. The EDR unit will also be used to separate beneficial

potassium ion from phytotoxic sodium, increasing the efficiency for nutrient recovery. Details of the submission are as follows:

> "Capacity Building for Production of Agricultural Water and Nutrients from Nontraditional Water Sources." By **W. Wright (PD)**, S. Banerjee (Co-PI), W. Mizuno (Co-PI), F. Cassel (Co-PI), S. Benes (Co-PI), K. Longley (Co-PI), Pei Xu (Co-PI; New Mexico State University College of Engineering). Submitted to the ($185,484).
>
> Submitted to: The USDA NIFA Equipment Grant Program May 3, 2023.
>
> Results: Not funded

The EDR component research is an important step in the development of the nutrient and water recovery process that will lead to field trial testing. For this reason our team will continue to write and submit proposals for purchasing this equipment.

Objective 5: Develop curricular material for insertion into the following courses: CE 85 Introduction to Civil Engineering, CE 142L Environmental Quality Laboratory, CE 144 Design of Water Quality Control Processes, and CE 247 Water Treatment Processes.

Results: Curricular material on the innovative nutrient and water recovery technology topic has been developed for insertion into the following courses: CE 1 Civil Engineering Orientation (Formerly CE 85); CE 176L Environmental Quality Lab (formerly CE 142L); CE 177 Water Treatment Process Design (formerly CE 144), CE 178 Wastewater Treatment Process Design, and CE 247 Water Treatment Processes. The research was presented to students in three courses in early October 2023 CE 128, CE 177, and CE 240).

b) Description of the modifications of the original proposal and the circumstances with which necessitated these modifications.

Objectives 1 and 2: The COVID-19 pandemic, a breakdown in the supply chain of equipment and supplies, and unexpected challenges encountered in system start-up caused delays in progress, resulting in less data being available in the sabbatical semester (Spring 2023) than envisioned when the sabbatical proposal was submitted in 2021. The development of the conference and journal manuscripts for which I am the lead author were hindered as a result and the experimental plan is being carried out under a revised schedule. Both papers will be completed after sufficient data is generated. A no-cost extension was secured from one of the funding sources (CA Dept. of Water Resources) and approval is expected from the second funding source (Agricultural Research Institute) when the request is submitted in Spring 2024. In lieu of this effort my time was spent on resolving design and operation problems encountered during testing and on contributing to the development of two journal articles that were being developed by our collaborators in New Mexico. Those papers are directly related to the sabbatical work.

Objectives 3, 4 & 5: No modifications to Objectives 3 through 5 were needed.

c) Goals of the Original Proposal That Were Not Accomplished

Completion and submission of a conference and a journal manuscript for which I am lead author was not achieved during the sabbatical leave due to hindering impacts from COVID-19 and a broken supply-chain. However, as noted above, progress on these manuscripts is on-going as more experimental data is collected and I am a co-author of two collaborative journal manuscripts that relate directly to the sabbatical work. One of the manuscripts was submitted to the journal and the other is expected to be submitted soon.

2. Benefits to the Faculty Member

The sabbatical work has enhanced and extended the work of two funded research projects in 2021 that are extensions of earlier work funded by the California Department of Water Resources. Since 2016 the ion exchange water treatment process has been my primary research focus, and my expertise has increased considerably in this field. This places me in a position to secure additional funding to continue development of a technology that has potential to make significant contributions to the problem of water scarcity in our Central Valley and beyond.

3. Benefits to the Department, College, and University

Inland regions like our Central Valley are increasingly experiencing water scarcity and higher salinity in water sources because of climate change and population growth. The line of research engaged in during the sabbatical leave is extending existing knowledge on precision and sustainable extraction of water and crop nutrients from nontraditional brackish water sources, leading to creation of new water sources for farmers and communities experiencing scarce water conditions. The material has been (and will continue to be) disseminated to the general population and targeted audiences, including the scientific community, farmers, policy makers, and students.

My department, the Lyles College of Engineering, and Fresno State University is benefitting from the sabbatical work on several levels by having its faculty engaged in research that is geared towards attaining sustainable production of water and nutrients from nontraditional contaminated water sources. Development of this technology is critically important in our region where water scarcity and salination of freshwater sources are both increasing. This work is being disseminated in the classroom, at conferences, and soon in technical/ journal publications - all of which benefit my department and college, and Fresno State.

4. Original Proposal

The original sabbatical proposal is attached.

5. Seminar

A tentative date for a seminar has been arranged with my department chair. It is Nov. 22, 2023. The venue will most likely be a conference room in Engineering East.

CALIFORNIA STATE UNIVERSITY FRESNO

Department of Civil & Geomatics Engineering & Construction

Proposal for a Sabbatical Leave

Analyze Data, Publish, and Pursue Funding to Advance Research on Efficient Extraction of Water and Nutrients from Contaminated Water Sources for Municipal and Agricultural Use During Drought

By

William F. Wright

Proposed Sabbatical Leave: Spring 2023 Semester

Application Date: September 18, 2021

PROPOSED SABBATICAL WORK PLAN

Analyze Data, Publish, and Pursue Funding to Advance Research on

Efficient Extraction of Water and Nutrients from Contaminated Water Sources for Municipal and Agricultural Use During Drought

Abstract

Due to climate change, inland agricultural regions are increasingly experiencing water scarcity and higher salinity in water sources, putting pressure on farmers and public water purveyors to search for alternative sources of water to meet industry and community basic needs. Technology exists to remove salts and other undesirable constituents from water, but it is expensive, energy intensive, and creates a brine stream byproduct that has negative impacts if discharged into the environment.

Funding has been secured to conduct initial studies to prove in concept that ion exchange (IX), advanced membrane nanofiltration (AMNF), and selective electrodeionization (SED) technology can be combined and operated in an innovative manner that will efficiently extract clean water and valuable nutrients from brackish water sources and reduce the amount of brine waste produced. A vast amount of experimental data will be generated from these experiments and a substantial amount of time will be needed to analyze and evaluate this data. Furthermore, there is a need to develop grant proposals to advance the lab-scale research and demonstrate the technology at field-scale. In addition, time will be needed to develop materials for presentation at technical conferences, to write a manuscript for submission to a journal, to share the news of the innovative technology to our local communities, and to develop instructional material so that our students can learn about this research. A sabbatical leave in the Spring of 2023 would be an ideal venue and perfect timing to accomplish these tasks.

An interdisciplinary team of technical experts has been assembled to assist with all phases of the work. The team includes Karl Longley, former Professor and Dean of the Lyles College of Engineering, Walter Mizuno, a member of the Mechanical Engineering faculty, and Mike Waite, an industry expert on ion exchange processes. Letters of their support for this sabbatical proposal are included in the proposal package.

Problem/Issue Being Addressed

California's Central Valley (Valley) is one of the most productive agricultural regions in the world, and it is estimated to be the home for 6 million residents in 2020 (USGS 2021). Continued California and Valley population growth greatly increases the competition for water, whether it be groundwater, the primary source of drinking water for many Valley residents, or surface water. However, elevated concentrations of salts and nitrates in Valley waters renders many groundwater sources unsafe or unpalatable for consumption by humans, livestock, and wildlife, and saline water "poisons" soil making it unfit to grow most commercial crops and, in some cases, removing land from beneficial use.

The economic impact of excessive salinity in many of the Valley's water supplies was described by Howitt *et al*. in 2009 as possibly exceeding $1.5 billion a year unless effective salinity management measures are implemented. However, salt removal processes are expensive, and the problem is compounded by the Valley having limited salt disposal options. Public and private

stakeholders have begun developing plans to mitigate both the increasing salinity and nitrate levels as part of a long-term management strategy (CVSALTS 2016, Kuriger et al. 2017). The most promising methods of extracting salt from saline waters are variants of reverse osmosis and thermal distillation processes (SSALTS 2016), but both methods are subject to costly maintenance and repair due to the presence of multivalent cations in the water, which cause scaling on both membrane and heat exchanger surfaces (Hchaichi et al. 2013, Niederholzer 2019). Successful application of desalination technology to saline waters in the Valley, such as agricultural drainage waters, will require effective pretreatment (water softening) to remove multivalent cations from that water, and to do so with low levels of waste generation. Cation exchange (CIX) is accepted as the best available technology for waters with low to moderate levels of salinity, and the upper limit of salinity level where CIX is effective is an unresolved question that needs to be addressed.

Effective salinity and nitrate management measures for the Valley can only be achieved through the sponsoring of focused research to address the many technical issues that must be resolved first. The goals are to provide public health protection by ensuring the provision of a water supply that is compliant with drinking water standards, and provide water supplies suitable in quality, cost, sustainably, for the Valley's agricultural and industrial endeavors. The technologically advanced desalination process would not only produce de-salted water for irrigation but would also separate beneficial materials from phytotoxic materials, reducing salts requiring disposal and producing valuable fertigation components. The treatment system consists of CIX and anion exchange (AIX) pretreatment followed by a novel two-stage membrane salt recovery/ ion separation stage that will partially or fully regenerate the AIX resin, shifting the conventional approach towards a more sustainable process. As a result of this, the amount of phytotoxic waste produced by the process is minimized. More importantly nitrate in the water source would be 'harvested' as a usable fertilizer, transforming the 'nitrate time bomb' into a sustainable nitrate source, reducing or eliminating the need to import nitrate produced by the Haber Bosch process to the farm, which is costly to manufacture and transport. The proposed process would also innovatively use potassium chloride (KCl) as regenerant on the AIX resin rather than sodium chloride (NaCl), the conventional regenerant, thereby producing potassium nitrate (KNO_3) and potassium sulfate (K_2SO_4) that can be applied through drip irrigation as part of a fertigation program without additional processing, further reducing the dependence on importing fertilizer and reducing the carbon footprint of the process. There is further potential to recover calcium (Ca) and magnesium (Mg) as nitrate salts from the CIX stage to ad-mix with the products from the AIX stage, further improving the nutrient balance of the products.

Background

Because of significant impacts of salinity on the Valley's economy and water quality, the Central Valley Salinity Alternatives for Long-Term Sustainability (CVSALTS) efforts were initiated in 2006. The focus was on salinity and nitrate management for both the Tulare Lake Basin Plan and the Sacramento-San Joaquin Basin Plan. Results of the Strategic Salt Accumulation Land and Transportation Study (SSALTS) in 2016 indicated that "current salinity management activities may only address about 15% of the annual salt load; long-term solutions, including development of regional de-salters, a regulated brine line, or other projects that would allow containment or removal of salt, are needed to address the other 85% (CVSALTS 2016, SSALTS 2016)." Phase 2 of the SSALTS study concluded that disposing of significant percentages of the annual salt accumulation in the Valley could only be accomplished with out-of-valley disposal options, and

that a regulated brine line appeared to be the best way to transport the brine. However, considerable focus on an in-Valley solution for salinity management continues.

The basin plan amendments developed by CVSALTS were adopted by the Central Valley Regional Water Quality Control Board (CVSALTS 2018) on May 31, 2018 with approval by the State Water Resources Control Board (SWRCB 2019) and final approval by the Office of Administrative Law (OAL 2020). Implementation of these basin plan amendments is underway, but their full implementation is estimated to require 35 years due to their complexity and the need for research focused on technical issues, such as reduced importation of salts into the Valley, improvement in desalination pretreatment processes, and resolution of brine disposal issues.

Management of Salt Consumption and Disposal from IX Pretreatment

Reverse osmosis (RO) and other desalination processes require pretreatment to remove hardness ions to mitigate against the harmful accumulation of minerals in the desalination unit. While it is known that CIX is an effective method of removing hardness from water, only a paucity of literature exists involving the application of CIX technology to Valley drainage water. The most recent work appears to be a study conducted by Longley et al. (2020) in which it was shown that elevated levels of hardness can be reduced to low levels consistently, and that concentrate from the desalination unit can be used to regenerate the IX resin to some degree, thereby reducing the need for imported salt. According to Bergquist et al. (2016) the most substantial drawbacks of IX operation is the cost and burden of salt consumption and waste production. Answers to questions like "how much salt is required for optimum IX operation" and "can the waste brine be reclaimed and used again" are difficult to determine due to the complexities of the processes. Flodman and Dvorak (2012) evaluated brine reclamation approaches and concluded that "significant potential exists to reduce salt use and discharge of ion-exchange water softeners by implementing brine reclamation systems …". One hurdle when using reclaimed brine is to ensure brine quality suitable for regeneration. The waste disposal of NaCl from conventional IX operation raises important environmental concerns and may be impeded by regulations that limit production of concentrated brine waste (Choe 2015). Those concerns would be mitigated if alternative regenerants to NaCl were used that resulted in a brine product that could be reclaimed for beneficial use. Potassium nitrate and sulfate salts are very suitable for fertigation application with both being important plant nutrients and sulfate being a soil pH buffer. Calcium sulfate (gypsum) and sulfuric acid fulfill important roles as soil amendments. Tokmachev (2008) and Boodoo (2011), among others have reported that it is possible to achieve long-term self-regeneration of CIX units upstream of a desalination unit by using the concentrate from the desalination unit to regenerate the CIX resin. This can be achieved if only a small fraction of the resin exchange capacity is utilized each run and the ratio of hardness to sodium in the regenerant brine is maintained at a low value. Additional details of this work can be found in Appendix A. The research being conducted at Fresno State will extend Boodoo's work by developing technology to separate beneficial potassium from phytotoxic sodium in the brine stream for use in cyclic regeneration of the AIX resin, and producing valuable fertigation products. Both outcomes promote sustainability in irrigated agriculture. Reduction of salt consumption and waste generation using cyclic regeneration addresses primary drawbacks of IX operation and therefore warrants further investigation.

Beneficial Reuse of K-Based Byproducts and Other Benefits from CIX Regenerated with KCl

Agriculture must increase productivity to supply an increasing population, while reducing water and fertilizer use. Controlled environment agriculture has a role, but there will remain a reliance on conventional field agriculture for producing the bulk of food supplies. The most water and fertilizer efficient method used in field agriculture is smart (variable rate fertilization) irrigation. This market is showing strong growth of 16% compound annual growth rate (CAGR), as is the market in liquid and water-soluble fertilizers (6.3% CAGR). The key crop nutrients required are potassium, nitrogen, phosphorus, and sulfur.

Potassium is necessary in relatively large amounts for crops grown in the valley. Plants that are deficient in K do not utilize other nutrients as efficiently and can require additional water when compared with a healthy plant, compounding the overall problem. Current estimates indicate that in the Valley only half the potassium being removed in crops is being replaced by fertilization (Niederholzer 2019). Results of studies conducted by UC Davis and presented at the California Plant and Soil Conference in 2019 maintain that crop export of potassium exceeds all other nutrients (Niederholzer 2019). In conventional agriculture, potassium is applied as potash, potassium chloride (KCl) being the most common and least expensive form, which in itself contributes to salinity build up in the Valley.

Ion exchange systems could use KCl in place of conventional NaCl substituting a plant nutrient (K) for an element (Na) that has little beneficial use. The higher costs of KCl and inherent inefficiency of conventional regeneration have discouraged its use. However, recent developments in IX technology have identified that it is feasible to regenerate an IX resin with close to 100% efficiency, potentially reducing the amount of regenerant required and producing low-chloride fertigation solution byproduct. Thus, additional benefits accrue through replacing conventional potash applications with low-chloride fertigation, notably the reduction in chloride added to the soils through potash application. Likewise, high efficiency IX regeneration, applied to a number of processes, significantly reduces the brine load received at water recycling facilities. The waste streams generated from the desalination unit and the CIX unit would contain many nutrient compounds typically applied to crops in the Valley.

Research Focus

Precision separations are required to remove salts and phytotoxic constituents from brackish water sources, enabling their use and reuse as irrigation water, and to recover valuable nutrients in the process, reducing agriculture's dependence on fertilizers. Precision separations are also required to remove harmful contaminants from potential community water supplies, particularly during drought conditions when traditional water sources are not adequate. Agua DB (industrial partner) has demonstrated the recovery of nutrients from impaired water sources that have relatively low levels of total dissolve solids (TDS) using IX technology, but this process is less efficient for waters with higher levels of TDS. The impetus to reclaim impaired inland water sources, such as brackish groundwater, agricultural drainage water and oil & gas produced water, is growing as both water scarcity and restrictions on discharges of these waters are increasing. Agriculture must increasingly move to smart (variable rate fertigation) irrigation to produce more, using less. Municipalities are increasingly looking to nontraditional water sources to supplement existing water sources to meet water demands.

Initial studies are beginning this fall that will demonstrate that efficient recovery of water and nutrients can be accomplished at higher levels of TDS, making new water supplied available in

areas where fresh water is scarce, using a novel approach to cation and anion exchange combined with AMNF and SED technologies. The system is expected to recover nutrients in a form ideal for application in smart irrigation by selectively removing phytotoxic sodium (Na^+) and chloride (Cl^-) ions as either a pre-treatment stage and/or as a final treatment stage in the process. The process is expected to produce new water for irrigation and community water supplies and recover valuable crop nutrients that is estimated to supply 60% of crop nutrient needs, with additions of other plant nutrients, dependent on existing soil nutrients levels, producing a complete liquid fertilizer product, significantly reducing fertilizer, transportation, and environmental costs.

Research Project Goals:

1. Creation of new water and nutrient sources in areas where conventional water sources are diminishing by expanding the upper limit of water TDS that IX-based nutrient recovery technology is effective through incorporation of AMNF and SED technologies that can selectively separate valuable nutrients and non-beneficial ions (salts) from the water;
2. Improved water and energy efficiency, fertilizer management and productivity in agriculture; reduced transportation of fertilizers and wastes with corresponding reduction in energy use (fuel, chemical manufacturing);
3. Reduced Cl application to land as potash, with reduced dependence on the Haber Bosch and Mannheim processes for nitrogen and sulfate fertilizer production;
4. Recovery of Na and/ or K to regenerate the IX resin, reducing the need for imported salt to regenerate the IX units (i.e., approaching cyclic/ self/ sustainable IX resin regeneration); and
5. Significantly reduced concentrated brine production and greenhouse gas production though reduction in IX salt requirement, the recovery of nutrients, and the increased adoption of smart irrigation.

Specific Objectives for the Sabbatical Leave, and Procedures Employed

Objectives for the proposed sabbatical leave are listed below. The work will be completed during the sabbatical leave period.

Task 1: Develop and be lead author of at least one conference manuscript and technical presentation and submit it to at least one local and one state or national technical conference.

Example venues: The American Water Works Association (AWWA) Annual Conference; the AWWA California-Nevada Section Annual Conference; the Annual WateReuse Symposium; the WateReuse California Annual Conference; and The Central California Graduate Research & Creative Activities Symposium (local venue).

Task 2: Develop and be lead author of at least one journal manuscript for submission to at least one national peer-reviewed journal.

Example venues: Water Research Journal, the Desalination Journal, and the Journal of Water Reuse and Desalination.

Task 3: Work with communication specialists to develop at least two news pieces to inform local and regional communities about the innovative technology.

Example Venues: Fresno State Magazine and/ or other University social media platforms, Fresno County Farm Bureau Agriculture Today publication, and Water Education Foundation publications.

Task 4: Be the lead or second author of a grant proposal developing field trial testing of optimized IX technology with nutrient recovery and/or advanced ion separation technology for additional nutrient recovery. Proposal submission will take place in accordance with the schedule published in the RFP guidelines.

Example Venues: The National Alliance for Water Innovation (NAWI), the National Science Foundation, or the US EPA's National Priorities: Water Innovation, Science, And Engagement to Advance Water Reuse grant programs.

Task 5: Develop curricular material for insertion into the following courses: CE 85 Introduction to Civil Engineering, CE 142L Environmental Quality Laboratory, CE 144 Design of Water Quality Control Processes, and the CE 247 Water Treatment Processes.

Schedule:

Task	January	February	March	April	May
1. Conference manuscript and submission					
2. Journal manuscript and submission					
3. Local news manuscript and submission					
4. Grant proposal to advance the technology					
5. Add technology to department curriculum					

Benefits to Me as a Faculty Member

The work proposed here would enhance and extend the work of two funded research projects that are starting now, that are extensions of earlier work funded by the California Department of Water Resources in 2016 on agricultural drainage water desalination. Since 2016 ion exchange water treatment processes has been my primary research focus and I am seeking to become an expert in this field during the next three years. These projects and the proposed sabbatical leave will allow me to reach that objective. The work is highly technical and complex, and there is a lot of material that I will need to learn. Acquisition of this knowledge will position me to make significant contributions towards solving water scarcity and contamination in our Central Valley and beyond.

Benefit to Fresno State, the Region and Engineering

As noted in the research description above, inland regions like our Central Valley are increasingly experiencing water scarcity and higher salinity in water sources because of climate change and population growth. Precision separations are required to extract phytotoxic constituents and nutrients from brackish water sources enabling use as irrigation water and reducing agriculture's dependence on fertilizers. The line of research our team is engaged in will extend existing knowledge in science and engineering on the extraction of high-quality water and crop nutrients from nontraditional brackish water sources, leading to creation of new water

sources for municipalities and farmers experiencing scarce water conditions. The results will need to be disseminated to the scientific community, the general community, farmers, policy makers, and students. These will be accomplished under the proposed sabbatical leave project. Funding is needed to develop and demonstrate the technology at pilot and field scale, and this funding will be pursued as part of the proposed sabbatical leave project.

Our department, the Lyles College of Engineering, and Fresno State University would benefit on several levels by having its faculty engaged in research that is geared towards attaining sustainable production of water and nutrients from nontraditional contaminated water sources. This work would be disseminated in the classroom, at conferences and in technical/ journal publications. The knowledge gained from the proposed sabbatical leave will be disseminated to students in a similar manner as my research on geosmin in the Clovis water supply, which was introduced to students in CE 85 Introduction to Civil Engineering as an example of research being conducted in the Civil Engineering Program; in CE 144 Design of Water Quality Control Processes in the context of treatment processes, and in CE 145 Design of Wastewater Management systems.

Why the proposed activity cannot be accomplished in less than the leave time, but can be completed in the time requested.

The chemical and physical processes associated with the design and operation of ion exchange, membrane, and electro deionization technology are complex and challenging to comprehend. This is a learning experience for all of us involved in this research. Large blocks of time with no distractions will be necessary to analyze the massive amount of data that will be collected, understand the fundamental principles impacting the behavior of the IX units under a variety of loading and regeneration conditions, write manuscripts for presentation and publication, write proposals for further funding, and incorporate the research into our curriculum. This work cannot be accomplished by our graduate students, it will need to be done by myself and team of expert partners, who are ready to join me in this work, and I look forward to the possibility of it happening. It has been 12 years since I have had a sabbatical, and this would be the second one in my 22 year tenure at Fresno State.

Travel

Travel to a technical conference is planned.

University Resources

University/ department resources will not be required to accomplish the proposed work plan beyond providing a one semester full-time leave to accomplish the proposed objectives.

Previous Leaves: Spring 2009 (12 years ago*)

* Full-time faculty, including full-time lecturers, are eligible to apply for a subsequent sabbatical leave after an additional six (6) years of full-time employment at this campus during the last seven (7) years (Janette Redd Williams, 9/12/06). This makes me eligible twice over.

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William Wright Sabbatical Leave Application Basic Information

September 19, 2021

Purpose of the leave:

To analyze experimental data, publish, and pursue funding to advance research on the efficient extraction of water and nutrients from contaminated water sources for municipal and agricultural use during drought:

Brief description of the proposed project

Due to climate change, inland agricultural regions are increasingly experiencing water scarcity and higher salinity in water sources, putting pressure on farmers and public water purveyors to search for alternative sources of water to meet industry and community basic needs. Technology exists to remove salts and other undesirable constituents from water, but it is expensive, energy intensive, and creates a brine stream byproduct that has negative impacts if discharged into the environment.

Funding has been secured to conduct initial studies to prove in concept that ion exchange, advanced membrane nanofiltration, and selective electrodeionization technology can be combined and operated in an innovative manner that will efficiently extract clean water and valuable nutrients from brackish water sources and reduce the amount of brine waste produced. A vast amount of experimental data will be generated from these experiments and a substantial amount of time will be needed to analyze and evaluate this data. Furthermore, there is a need to develop grant proposals to advance the lab-scale research and demonstrate the technology at field-scale. In addition, time will be needed to develop materials for presentation at technical conferences, to write a manuscript for submission to a journal, to share the news of the innovative technology to our local communities, and to develop instructional material so that our students can learn about this research. A sabbatical leave in the Spring of 2023 would be an ideal venue and perfect timing to accomplish these tasks.

An interdisciplinary team of technical experts has been assembled to assist with all phases of the work. The team includes Karl Longley, former Professor and Dean of the Lyles College of Engineering, Walter Mizuno, a member of the Mechanical Engineering faculty, and Mike Waite, an industry expert on ion exchange processes. Letters of their support for this sabbatical proposal are included in the proposal package.

University Resources Required

University/ department resources will not be required to accomplish the proposed work plan beyond providing a one semester full-time leave to accomplish the proposed objectives.

Amount of time requested

A leave of one semester (Spring 2023) is requested..