State of Irrigated Agricultural Water Reuse – Impediments and Incentives

Proposal prepared for WaterSMART: Water Reclamation Research Under the Title XVI Water Reclamation and Reuse Program for Fiscal Year 2016

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California State Water Resources Control Board
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Executive Summary

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Sacramento, Sacramento County, California

This project will include assembly of a global inventory of successes, delays, and set-backs in the process of switching from various traditional sources of irrigation water to recycled water. For each successful case, the incentives that gave rise to adoption of recycled water will be identified and catalogued. For each case of a set-back, the reasons for the set-back will be identified and catalogued. In such cases, any failure(s) of offered incentive(s) will also be identified and catalogued. The final products of this research will be (a) a white paper on the efficient ways to promote use of recycled water for agricultural irrigation and (b) a guidance document for utilities and agricultural enterprises in need of alternative sources of water.

This study is expected to take approximately 15 months with a June 2017 completion date. The study falls within the parameters for Funding Group I.

Technical Research Study Description

Our approach includes assembly of a global inventory of successes, delays, and set-backs in the process of switching from various traditional sources of irrigation water to recycled water. For each successful case, the incentives that gave rise to adoption of recycled water will be identified and catalogued. For each case of a set-back, the reasons for the set-back will be identified and catalogued. In such cases, any failure(s) of offered incentive(s) will also be identified and catalogued. This project is organized into seven main tasks.

Tasks 1 and 2 focus on understanding and documenting the current state of agricultural reuse both in the United States and abroad.

Task 3 deepens the knowledge base developed in previous tasks to conduct interviews with major recycled water producers and agricultural producers on the impediments and incentives they have faced in agricultural reuse. Interviewees will be selected to capture a range treatment technologies and geographies.

Task 4 will analyze interview responses on impediments to agricultural reuse and explore how these findings vary between contexts and the corresponding literature.

Task 5 takes a three-step approach to review of wastewater treatment technologies appropriate for treating wastewater before use for irrigation. First this task summarizes which technologies are currently mandated by existing regulations, next it evaluates which technologies are currently being utilized, and, lastly, it makes recommendations for which technologies hold the most promise for appropriateness and cost-effectiveness for future agricultural reuse.

Task 6 investigates the potential for on-site agricultural reuse. As of late, there has been much attention given to the localization of production of food supplies with urban agriculture. Task 6 reviews the literature from both the United States and abroad to summarize existing on-site reuse and make recommendations for future research in this area.

Task 7 focuses on analyzing which incentives have been most effective in facilitating agricultural reuse. Special attention will be given to understanding how different state regulatory frameworks have directly or indirectly supported (or suppressed) agricultural reuse.

Task 8 develops the final report and guidance document for the WRRF, State Water Board, and USBR.

Task 1: Conduct a literature review.

The objective of Task 1 is to synthesize existing scientific and trade-group literature on the direct reuse of treated wastewater in irrigated agriculture to:

- Characterize the diversity of drivers of existing agricultural reuse discussed in current literature;
  Distill these diverse drivers into typologies of recycled water in irrigated agriculture which can be used to develop selection criteria for case studies in subsequent tasks.

A standardized analysis approach will be used to evaluate the quality and relevancy of the identified literature sources. Literature selected for inclusion in this review will focus specifically on impediments and incentives to existing agricultural reuse of recycled water. The output of this task will be a rigorously developed, annotated bibliography documenting known examples of agricultural reuse from around the world.

In the global context, there is considerable spatial heterogeneity in the drivers of agricultural water reuse. Cropping patterns; regional climate; proximity and size of nearby municipalities; wastewater treatment infrastructure; proximity and access to traditional water sources; socioeconomic characteristics; and regulatory frameworks have all been demonstrated to impact the extent and characteristics of water reuse in agriculture.

This project brings together experts with region specific knowledge of agricultural reuse practices in more than 20 countries spanning North and South America, Asia, Australia, Europe, the Middle East, and Africa. Each team member will be assigned specialized segments of the literature to review. Scientific literature and trade group information related to recycled water and agricultural reuse, including Farm Bureau reports and State and local agriculture commissions will be accessed and reviewed. A new resource of particular relevance is the recently completed Clearinghouse of Knowledge-Based Resources on the Public Acceptance of Water Reuse, which was prepared by Dr. Sheikh for the WateReuse Association.

Task 2: Analyze current state of irrigated agriculture uses of recycled water.

This task is divided into two distinct subtasks 2A and 2B:

Subtask 2A: Develop a table summary of major agricultural uses of recycled water in the U.S. and worldwide, including California.

While there are numerous case studies of agricultural water reuse, the scope of these case studies presents a limited picture of the true scale or characteristics of agricultural reuse – instead focusing heavily on cities and growers with substantial capacity for reporting and/or the presence of long-term research projects. Relying entirely on existing, self-reported databases of reuse or scientific literature may exclude the numerous smaller utilities practicing agricultural reuse, either formally or informally. Understanding the extent and characteristics of these cases of 'unknown' reuse is important to better understanding, holistically, the incentives and impediments to agricultural reuse.

Given these considerations, our approach to the analysis for Part A takes a two-step approach to:

a) Ensure a comprehensive compilation and summary of existing data on agricultural reuse;
b) Identify where gaps in knowledge on existing agricultural reuse exist;
c) Develop spatial analysis methods to identify croplands and WWTP in the US exhibiting a high potential for agricultural reuse on both the demand and supply sides, respectively.

Step 1: Characterize Known Agricultural Reuse - Develop georeferenced database of existing cases of agricultural reuse and classify these cases by type of agricultural reuse.

As a first step, the WateReuse National Water Reuse Database will be queried for all agricultural uses of recycled water and as a source for contacts with agencies providing reclaimed water to irrigated agriculture. At the present time, this database contains annual reports of agricultural uses of recycled water from Florida and California (plus one Texas utility)[1]. Building on the structure developed through the existing WateReuse database, additional, more globally focused databases such as the FAO AQUASTAT database, data compiled by Jiménez and Asano, the IWMI 53 city agricultural reuse study, state and national databases will be queried and their results integrated in a compatible format. In addition, professional colleagues in Spain, Israel, Jordan, Australia, Mexico, and other countries will be solicited for similar information from their professional contacts and resources. Colleagues in these countries have already expressed willingness to collaborate on this project. (See organization chart in a following section.) Additional cases of agricultural reuse identified in literature and trade publications, but not otherwise included in the aforementioned databases will also be integrated at this point. Once the compiled data have undergone QA/QC procedures, this comprehensive geodatabase of 'known agricultural reuse' will be queried to develop tables summarizing major agricultural uses of recycled water both in California, the U.S., and worldwide.

Step 2: Use spatial analysis methods to identify areas with high potential for agricultural reuse and identify gaps in the documentation of existing agricultural reuse.

Developing a comprehensive, up-to-date database of agricultural reuse at scale presents both practical and methodological challenges. First, existing databases of agricultural reuse only

1 Based on query performed by Julie N. Minton, Director of Research Programs, WateReuse Research Foundation.

capture the direct (formal) reuse of wastewater. However, across the United States, much of the agricultural reuse that is occurring is the indirect or *de facto* reuse of WWTP effluents discharged to surface waters. Second, the implicit question in most discussions of reuse is whether and how to scale up the practice of direct reuse to maximize water use efficiency at the catchment scale. Understanding areas of potential or probable agricultural reuse (both direct and indirect) can both lend insights into the full scale of agricultural reuse in the United States and identify regions where the increase of direct reuse may be favorable from both an energy and demand perspective.

Focusing on the United States, we propose to quantify the spatial relationships between municipal wastewater treatment facilities and nearby irrigated croplands. Specifically, this analysis seeks to evaluate both the elevation and linear differences between irrigated croplands and the nearest municipal WWTP.

Key data sources in this analysis include the:

- EPA Clean Watershed Needs Database (CWNS) (2008/12) – georeferenced details on WWTP design, flows, and type/level of treatment[4] (http://ofmpub.epa.gov/portal/page/portal/CWNS%20Reports/download)
- EPA Envirofacts (ICIS-NPDES) database – georeferenced record of NPDES permits issued to municipal WWTP[5] (http://www3.epa.gov/enviro/facts/pcs-icis/search.html)
- USGS 2012 Irrigated Agriculture Dataset for the United States (MIrAD-US) (250 m resolution)[6] (http://earlywarning.usgs.gov/USirrigation)
- USGS 2015 national hydrography dataset[7] (http://nhd.usgs.gov/)
- USGS National Elevation Dataset[8] (http://nationalmap.gov/elevation.html)

Using these data, all municipal WWTP in the United States will be categorized according to their potential for nearby demand for recycled water (e.g., area of irrigated croplands within a 10 km radius) and a proxy for the energy required to supply recycled water to growers (e.g., elevation difference and distance from WWTP to irrigated croplands). Conversely, all irrigated croplands will also be classified according to these same criteria – except that this second analysis will evaluate all irrigated croplands on their proximity to WWTP.

Next, the georeferenced cases of known agricultural reuse identified in Step 1 of this task will be overlaid with the classified municipal WWTP and irrigated croplands dataset developed earlier in Step 2. Through this spatial overlay analysis, all municipal WWTP and irrigated croplands in the United States will be classified as:

1) Known providers/users of recycled water for agricultural irrigation;
2) Areas with a high potential for recycled water use in irrigated agriculture;
3) Areas with low potential for recycled water use in irrigated agriculture.

The purposes of this analysis are two-fold. First, those utilities and growers falling into the class, 'areas with a high potential for recycled water use in irrigated agriculture' point to regions where there may be either undocumented agricultural reuse or impediments to reuse. Identifying these regions will prove helpful in developing a representative selection of utilities and growers for

Task 3. Second, when considering the potential for increasing recycled water use in irrigated agriculture, identification of these regions where reuse would make practical sense, but is not occurring could lend useful insights to planning discussions.

Subtask 2B. Review the legislative and regulatory framework for irrigated agricultural uses of recycled water.

In the United States, the 2012 EPA *Guidelines for Water Reuse* provide recommendations on regulations for different types of reuse, but ultimately, the responsibility of specifying regulations falls within the purview of each state[9]. Some states allow for irrigation of food crops, while others do not or only allow such uses with specific methods of irrigation. Other states do not specify regulations for reuse per se, and instead regulate on a case-by-case basis through the NPDES permit system. The 2012 NRC report on reuse details some of the challenges posed by not having federal standards[10]. The EPA guidelines provide a table summarizing regulations for agricultural reuse on a state-by-state basis.

We will first update the 2012 EPA table (as needed) then develop a series of thematic maps detailing agricultural reuse regulations. This series of maps will be designed with the intent of creating a resource for practitioners and the public to be able to quickly answer practical questions on a state-by-state basis such as, 'where can fruit crops be irrigated with spray irrigation?'; 'what levels of *E. coli* are acceptable for the irrigation of fodder crops?'; 'could my tomato crop be furrow irrigated with effluent from the local WWTP?' Agricultural extension agents from a representative group of states would be contacted to help guide selection of maps for inclusion.

Building on the geospatial database of existing and potential reuse developed in Part A, we will employ spatial overlay analysis to assess the relationship between the extent and nature of agricultural reuse and the regulatory frameworks present in different states.

Task 3: Interview major recycled water producers and agricultural producers

Both in the United States and abroad, agricultural reuse occurs in a diverse range of contexts. Understanding how impediments and incentives for recycled water use vary in these different contexts is central to successfully increasing recycled water use. To ensure that our interviews capture the range of recycled water and agricultural producers, the findings of Task 1 and 2 will be used to develop a rigorous sample frame for the selection of interviewees. Examples of some key variables which would be used in development of this sample frame include:

- Volume of recycled water being supplied and used
- Types of treatment technology utilized
- Classes of crops being produced with recycled water
- Climate zone and intra-annual variability in precipitation
- Geographic region (both US and international)
- Regulatory infrastructure for recycled water use in agriculture
- Socioeconomic status of surrounding communities
- If and how growers account for the nutrients embodied in the recycled water

Given the emphasis of this work on both impediments and incentives to recycled water use in irrigated agriculture, selection of recycled water and agricultural producers who have experienced varying levels of success in the supply or use of recycled water will be critical. In the case of California, in particular, it will be important to include not just wealthier, coastal cases, but also utilities and producers from inland cities (e.g., Bakersfield, Chico, Modesto, Redding, etc.) as they are also the ones with the closest proximity to agricultural lands.

With assistance from partner utilities (MRWPCA, City of Santa Rosa, PVMWD, IRWD, EMWD, CONSERVE II, etc.) and our overseas partners in Japan, Australia, Jordan, Spain, etc., we will contact recycled water producers and agricultural producers meeting the above criteria, with the following objectives:

(1) Determine whether they use recycled water and if not, why not.

(2) Identify impediments to the use of recycled water for agricultural irrigation.

(3) List incentives that have been used or might have been used to encourage recycled water use for agricultural irrigation.

Task 4: Identify and recommend ways to overcome impediments to using recycled water for irrigated agriculture

Previously identified impediments to the adoption of recycled water as a source for irrigation include:

- Salt content of recycled water, specifically total dissolved solids, sodium, chloride, boron, bicarbonates, pH, and sodium adsorption ratio (SAR)
- Nutrients in recycled water, specifically nitrogen, potassium, phosphorus, and micronutrients.
  - Nutrients posing excess availability at time of fruit set for certain crop rotations
  - Nutrients as pollutants to surface and/or groundwater
- Regulatory restrictions and prohibitions
- Water rights conflicts
- Public acceptance, perceptions, prejudices, stigma, “contagion”
- Perceived health issues
- Microconstituents in recycled water
- Treatment systems and inadequate effluent water quality for irrigation infrastructure
- Distribution system inadequacies
- Access to existing, low-cost irrigation water

Additional impediments will be identified as an output resulting from Tasks 1-3, above. The relevance and importance of each of the impediments already identified, plus those additionally identified in this task will be evaluated. Review of the existing literature on recycled water use in agriculture reveals that while the above impediments are significant, their relevance varies spatially. Interviewees in Task 3 will be purposefully selected to enable a comprehensive understanding of how the identified impediments vary both spatially and with utility size, water quality and quantity needs of growers, and regulatory and water rights frameworks. Context specific ways to overcome each of the identified impediments will be recommended based on the experience of producers of recycled water and growers already irrigating with recycled water.

Task 5: Conduct a review of wastewater treatment technologies appropriate for treating wastewater before use for irrigation.

Treatment technologies for production of recycled water have evolved rapidly over the past decades, offering an array of available options for different regions and for different end users of recycled water. These technologies will be reviewed with respect to the "right water for the right crop" concept. The treatment technologies will also be related to the regulatory frameworks of various regions and for various crop classifications.

- Review what technologies are mandated by existing regulations
    - Example: limits on ammonia nitrogen in recycled water used for food crops in North Carolina versus California
    - Water quality specification for recycled water (as in Texas), versus treatment technology design details prescription (as in California)
- Summarize what technologies are currently in use based on scientific and trade-group literature reviewed in Task 1
- Determine which of the many technologies approved in the State of California (i.e., those listed in the "Alternative Treatment Technology Report" from Division of Drinking Water, State Water Resources Control Board) are actually in use
- Identify which new technologies are the most promising for agricultural reuse, considering water quality, regulatory, cost, O&M requirements, and energy use
- Augment interviews from Task 3 with interviews with some of the vendors of the alternative treatment technologies, to find out what they think the market potential is for agricultural irrigation and what incentives/barriers they perceive?

When considering the full lifecycle energy and resource costs of a suite of options, it is often not the technology per se, but the pumping head and distance from treatment facility to grower that dominate energy and resource costs. Given these considerations, our analysis and discussion in this task is divided into both case studies and a larger scale landscape analysis to evaluate these trade-offs.

For a series of four in-depth case studies representing a range of infrastructure choices and geographic locations, we propose to:

1) Evaluate each class of technology relative to the quality of water produced;
2) Quantify the energy and resource costs associated with each class of treatment technology selected;
3) Evaluate the energy and resource costs associated with transporting WWTP effluent to growers;
4) Evaluate the energy and resource costs associated with the use of recycled water as compared to conventional irrigation water sources.

Financial, energy, and regulatory considerations all still loom large in increasing agricultural water reuse in the United States. We propose building on the spatial analysis begun in Task 2a to characterize the regulatory limitations to agricultural reuse faced by each WWTP in the United States. More specifically, this analysis will classify each WWTP on the basis of which types of agricultural reuse (if any) would be allowable given current state regulations and treatment technologies currently in place. These results will then be overlaid with the 'reuse potential' maps from Task 2a, to further refine estimates of areas with potential for increased agricultural reuse.

These two components, case studies and a landscape analysis, will both offer insights into the specific trade-offs of different types of recycled water infrastructure and allow for further consideration how the appropriateness of different types of infrastructure varies at much larger spatial scales.

Task 6: Explore the possibilities, impediments, and incentives of on-site reuse in regards to irrigated agriculture.

On-site water reuse is gaining more widespread application in many urban areas of the world. Green building certification programs have pushed this trend and water shortages and droughts have played a role in increasing the attractiveness of on-site reuse. This concept is also referred to as sewer mining (in Australia), distributed reuse, and decentralized water recycling. Graywater reuse[2] has also become a type of on-site reuse, especially in Japan and some communities in California. Nearly all of the on-site reuse is applied to landscape irrigation and some to toilet flushing (allowed in Arizona and Japan). Because of the urban nature of on-site reuse, its applicability to agricultural irrigation can prove challenging—both in volume of water generated, and in distances to farm fields. Nonetheless, there has been a growing trend toward urban agriculture to meet some portion of the demand for vegetable and fruit crops in urban areas—e.g., urban gardens, schoolyard gardens, even some urban farms. Producing food closer to the place where it is consumed reduces the greenhouse gas emissions embodied in the production, transport, and supply of produce significantly.

In many low and middle income countries, small urban plots and kitchen gardens have been shown to make significant contributions to household nutrition and income in lower income communities[11]. However, the water used to irrigate these plots is commonly untreated wastewater from open drains and waterways[12]. While this situation can present substantial public health risks, it also presents tremendous opportunities for re-thinking the way sanitation infrastructure is implemented in cities. In the United States, many cities are struggling to maintain their extensive wastewater infrastructure as populations decline and/or infrastructure reaches the end of its design life. The parallels between these two very different situations could provide opportunities for learning and thinking creatively about the potential and challenges of urban agricultural reuse and decentralized wastewater management. This task would review the extensive literature on urban agricultural water reuse in low and middle income countries and

2 Sheikh, B., "Graywater White Paper", prepared for WateReuse Association Board of Directors, April 2010.

develop comparative analogies with the much more limited literature on urban agricultural reuse in high income countries. The objective of this task would be to identify clear areas for cross-context learning and make recommendations for further areas of research.

Task 7: Identify and recommend ways to incentivize increased recycled water use for irrigated agriculture

There are significant benefits for the larger community to increased use of recycled water for irrigated agriculture. These benefits include:

- Diversification of water supply in the face of drought and climate change
- Reduction in a reliance on groundwater
- Alleviation of water rights issues
- Wastewater constituents as a soil amendment and fertilizer
- Reversal of seawater intrusion in coastal communities
- Enabling growers to switch to more intensive farming practices, thus increasing their profit margins, increasing their ability to create more jobs and improve the local economies

These benefits to the commons justify expenditure of community funds (tax revenue and/or rate payments) to incentivize the growers to use recycled water for irrigated agriculture. Using interviews with recycled water producers and agricultural growers as a base, the incentives currently in place will be identified and their effectiveness will be assessed. Each state's regulations for recycled water use in irrigated agriculture will also be evaluated in conjunction with interview responses. Specifically, this analysis will seek to understand the role of differential state regulations in incentivizing agricultural reuse. Based on these findings, a series of incentives will be recommended.

Task 8: Draft a final report/guidance document for the WRRF, State Water Board, and USBR

A final report and guidance document will be prepared based on results from the tasks identified above, including the literature review, analysis, interviews, recommendations, and final integration of the results. The final report will provide the outcomes and recommendations for review before publication as a white paper for public access.

A guidance document, more accessible to the general public, will be published to provide guidance that facilitates removal of impediments and implementation of effective incentives for use of recycled water for agricultural irrigation. All deliverables will be provided to USBR.

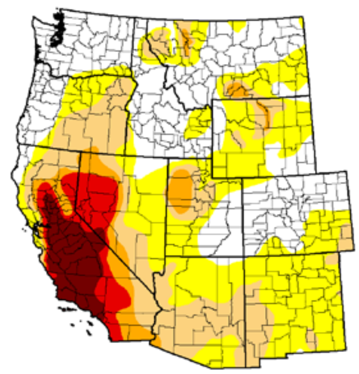
Evaluation Criterion 1: Statement of Problems and Needs

Does proposed research study address the needs of a specific applicant or locale.

This project is global in nature, with emphasis on California and other US States having water scarcity issues, especially for their agricultural needs. The global nature of the project aims to bring into focus lessons learned from Australia, Israel, Spain and others having implemented measures to extend their water resources and expand use of recycled water. These lessons will be applied to conditions in the states where Reclamation is particularly involved in extending water resources.

Identify the water supply imbalance that the research study will address for the area of responsibility of the applicant.

The Western United States is in the fifth year of a drought that is classified by USDA and other government agencies from abnormal (yellow shading) to exceptional (brown shading), as shown on the U.S. Drought Monitor map posted on March 29, 2016. It is clear that most of the landmass of California is gripped in the most severe of the drought categories shown on the map. While the map shown here is but a snapshot in time, it is typical of the similar weekly maps posted over the last five years for this region.



This pattern of elongated drought in the West is deemed by some climate scientists as a consequence of the global climate change that is inexorably exacerbating water supply imbalances, especially in California now and into the future. The proposed research project will point the way forward to more widespread utilization of a water resource that is now going to waste—the 3+ million acre-feet of wastewater effluent that is flushed out to saline sinks every year. If treated to proper levels and provided to some of the farmers in the productive growing regions of the state, the recycled water resource can make up a significant portion of the losses in water that historically was stored in the Sierra snowpack and surface and groundwater reservoirs of the state.

If the proposed research study aims to address broader needs of the industry in terms of technology or practices, describe these needs as they occur on a watershed, regional, and/or national scale.

The proposed study includes Task 5, conduct a review of wastewater treatment technologies appropriate for treating wastewater before use for irrigation. The product of this task will be a clear roadmap, on a national scale, for utilities that need to upgrade their process train in order to divert the wasted effluent toward a useful resource for crop irrigation. The additional funding from the Bureau will enable inclusion of economic factors for decision-making by utilities as well as farmers in making the switch to using recycled water for irrigation.

Evaluation Criterion 2: Water Reclamation and Reuse Opportunities

Describe the source(s) of water that will be investigated for potential reclamation, including impaired surface or ground waters.

All sanitation entities, including wastewater collection districts, treaters of wastewater will be considered as potential sources of recycled water for irrigation. We plan to include large, medium and small entities, urban and rural agencies. Our research included on-site use of recycled water for irrigation. One favorable feature of recycled water is that the volume of raw material for it increases as populations increase, moderated somewhat with conservation efforts that have become necessary due to long-term droughts in California and the rest of the West. Currently, California's beneficial reuse of recycled water is at less than 15 % of the available raw material in the state. The remaining 85 % is estimated to be about three million acre-ft per year. This is a huge volume of additional water supply, when all the obstacle to its reuse are eliminated.

Describe how the research study will help to eliminate obstacles for using reclaimed water as a supply within and/or outside the area of responsibility of the applicant.

This is the thrust of the proposed research study—to identify the obstacle to using reclaimed (recycled) water and find ways to eliminate the impediments. The work plan elaborated in the above sections details the steps to doing just that and providing the guidance for future providers and customers of recycled water. This will be in part based on the successes and failures of past efforts to get recycled water used on the farms for irrigation. Lessons learned by a global survey conducted by the project team, composed of experts in water reuse in various parts of the world. The results would be applicable, not only in California, but also anywhere else in the world where water supply imbalances exist.

Describe how the research study will expand a water market and promote implementation of new uses or expand existing uses for reclaimed water

Recycled water, produced with a view toward "fit for use" quality, can be applied not only to agricultural irrigation, but to any and all other uses to which water is normally applied—including environmental restoration, fish and wildlife, groundwater recharge, potable reuse, etc. California has led the way in innovation of uses of recycled water with examples of nearly all categories of uses of recycled water in abundance.

Describe how the research study will help establish or expand a water market to use reclaimed water outside your specific locale, including providing regional or West-wide benefits.

The work products of the proposed research study, including a guidance document, will be available to anyone, anywhere in the West, in fact in the world at large. Based on prior research in the field, the obstacles to water reuse do not vary much from one region to another. The variation might be in intensity rather than in the nature of the obstacle. For example, if the cost to the farmer is the primary obstacle to use of recycled water, and if the societal benefit for subsidizing the cost of water to the farmer exceeds the monetary cost of the subsidy, the solution becomes obvious. The only remaining question is which societal entity can/should bear that cost and provide the subsidy. This scenario is already being replicated in numerous different areas of the world.

Evaluation Criterion 3: Description of Potential Alternatives

Describe objectives of the proposed research study and how the proposed research is innovative in advancing water reclamation knowledge and/or practices relative to existing knowledge and/or standard practices.

Objective 1 is to identify obstacles, challenges, and impediments that currently keep farmers from using recycled water as a resource to replace their diminishing supplies from traditional water resources.

Objective 2 is to provide proven incentives and pathways that would help remove the obstacles for utilities that provide the recycled water and for growers that would use the available new water resource

Existing knowledge of recycled water and its characteristics is currently fragmented, scattered, and limited to a very small group of academics, consultants and utility personnel involved in the practice of water reclamation and reuse. Much can be learned with the proposed research study and extended to the community of treaters of wastewater and farmers who would be their customers.

If applicable, describe alternative water reclamation measures or technologies that will be investigated as part of the research study.

The research study includes Task 5, conduct a review of alternative water reclamation technologies appropriate for treating wastewater before use for irrigation. Also, appropriate low-tech methods will be explored to the extent applicable under existing or anticipated future regulations.

Describe any collaborators involved with the research and their respective roles.

The role(s) of each member of the research study team is presented in the tabulation below:

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Name: **Kara L. Nelson**	Organization: Civil and Environmental Engineering, University of California, Berkeley
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Name: **Anne L. Thebo**	Organization: Civil and Environmental Engineering, University of California, Berkeley
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Name: **Brent Haddad**	Organization: Center for Integrated Water Management, University of California, Santa Cruz
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Name: **Avner Adin**	Organization: Department of Soil and Water Sciences, The Hebrew University of Jerusalem
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Name: **Ted Gardner**	Organization: ARRIS Water; Adjunct academic appointments at a number of universities and CSIRO, Australia
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Name: **Ryujiro Tsuchihashi**	Organization: Independent Consultant
Title: Consultant	Project Role: Provide contacts in Japan and Jordan

E-mail: Ryujiro.Tsuchihashi@aecom.com Phone Number: (530) 792-8294	for irrigated agriculture use of recycled water
Name: **Shannon Spurlock**	Organization: Denver Urban Gardens
Title: Executive Director E-mail: shannon@dug.org Phone Number: (303) 875-2249	Project Role: On-Site water reclamation and urban community gardens use of recycled water for food production.

Please describe the credentials, experience, and past performance of the research team.
A summary of the research team members' credentials, experience, and past performance is included in the table below. Resumes available upon request.

Team Member	Credentials	Experience	Past Performance
Bahman Sheikh	PhD, PE	>30 years	Consulting engineer, agronomist
Kara Nelson	PhD	15 years	Professor at UC Berkeley
Anne Thebo	PhD	8 years	Graduate student research
Brent Haddad	PhD, MBA	20 years	Professor at UC Santa Cruz
Avner Adin	PhD	>30 years	Professor at Hebrew University
Ted Gardner	PhD	>30 years	Consulting, research
Jim Kelly	Dip Ed	15 years	Consulting, research, development
Ryujiro Tsuchihashi	PhD	15 years	Consulting engineer

Evaluation Criterion 4: Stretching Water Supplies

At your specific locale and/or on a regional or West-wide scale, if applicable, describe how the research study could promote the establishment or expansion of a market for water reclamation and reuse that will reduce, postpone, or eliminate the development of new or expanded water supplies.
Experience has shown that every acre-foot of recycled water developed releases an equal volume of water from traditional resources for higher uses, such as domestic or industrial use. In the West, in particular, development of new sources of water—other than recycled water and conservation—is practically infeasible due to environmental constraints and increasing pressures from the impacts of global warming on water supply availability. Thus, the proposed research study would help remove the existing obstacles to expansion of a market for water reclamation and reuse. As the water reuse market expands in the future, and as water use efficiency measures are put into practice on the farms, pressures for development of new expanded water supplies will be reduced, postponed, or totally eliminated.

Describe how the research study could or will streamline the implementation of a project that will reduce or eliminate the use of existing diversions from natural watercourses or withdrawals from aquifers and improve available supplies during droughts.
A grower in the Central Valley of California gaining access to recycled water for the first time (as a direct result of removal of obstacle using guidance from this project's end results) will

cease pumping water from the wells tapping an over-drafted aquifer in these drought periods. Another grower in similar circumstances, relying on diversion of water from a natural watercourse will similarly be inclined to shift to using recycled water with the added benefit of nutrients in the water. In both examples, the project would need to steer clear of any damage that this shift might cause to the farmer's pre-existing water rights. That is another of the many impediments to agricultural use of recycled water that will be a subject of this research study.

Describe how the research study could or will streamline the implementation of a project that will reduce the demand on existing Federal water supply facilities.

Growers who currently receive water from Federal water supply facilities have long-term attractive contracts for a reliable and high-quality water supply source, as long as natural precipitation maintains supplies in the reservoirs that feed those facilities. In drought years, demand on Federal water supply facilities exceeds available supplies and many farmers have been forced to fallow their lands, cut down orchards, and in some cases, go out of the farming business altogether. These drastic consequences can be avoided if obstacles to use of recycled water are removed and if the farmers become familiar with the safety and quality of recycled water that can become available to them. The proposed research study will help streamline the process of converting many farms to use of recycled water for irrigation.

Evaluation Criterion 5: Environment and Water Quality

Describe the potential for the research study to identify methods or produce results that improve the quality of surface or groundwater, including description of any specific issues that will be investigated or information that will be developed as part of the research study.

When wastewater effluent is treated to a higher level, suitable for reuse, and its discharge to the environment is reduced or eliminated, in most cases this change brings about a significant improvement in the quality of the receiving water bodies thus enhancing and restoring habitats for various species—nonlisted and federally listed threatened or endangered. In rare cases, removal of effluent discharged into ephemeral streams might have an adverse impact on habitats if effluent is the only source of water for that habitat. In those cases, discharge into the stream might well be the best reuse for the water resource. In California, the environmental review process ensures that any adverse impacts are thoroughly mitigated or the project will not proceed to implementation.

Describe the potential for the research study to identify methods or produce results that improve flow conditions in a natural stream channel that benefit the environment, including a description of any specific issues that will be investigated or information that will be developed as part of the research study.

This question is not applicable to this research study.

Describe the potential for the research study to identify methods or produce results that provide water or habitat for non-listed, sensitive, or federally-listed threatened or endangered species, including description of any specific issues that will be investigated or information that will be developed as part of the research study.
This question is not applicable to this research study.

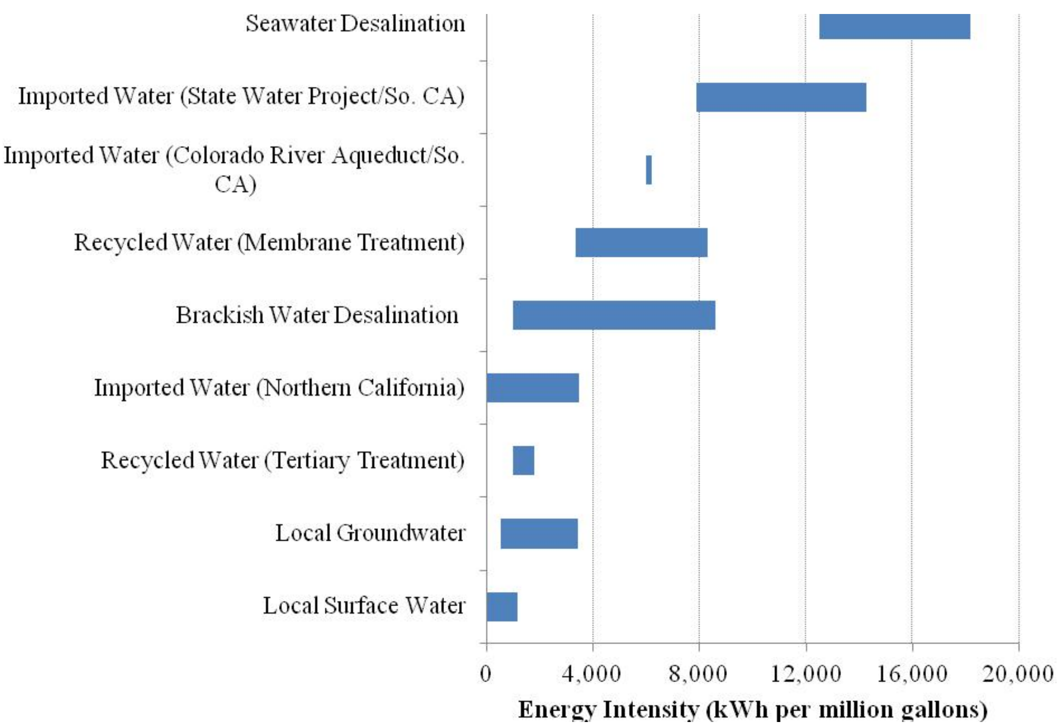
Evaluation Criterion 6: Legal and Institutional Requirements

For planning related research, describe how the research study will to identify methods or produce results that help to eliminate obstacles for using reclaimed water as a supply in the research study area.
Eliminating obstacles to using reclaimed (recycled) water is the essence of the proposed research study. Tasks 1 through 8, described in detail in above sections show how we propose to identify methods and produce results that help eliminate impediments to using recycled water as a source of water supply for agricultural irrigation. Water rights issues, perception problems, costs, geographical and topographic constraints will all be reviewed and studied to produce results that help eliminate the obstacles.

For field research studies focused on state of the art technology deployment describe the readiness to proceed in terms of.
This question is not applicable to this research study.

Evaluation Criterion 7: Renewable Energy and Energy Efficiency

Water recycling projects are far more energy efficient than most of the other sources of water as shown in the graphic below.



SOURCE, Pacific Institute, Desalination and Energy UseReuse Association Board of Directors, April 2010.t al., 2012, GEI Consultants/Navigant Consulting, Inc. 2010

Removing obstacles to use of recycled water will go a long way to reducing demand for energy in the West. This will help reduce the carbon footprint of water supply in general. Use of renewable energy in water recycling is relatively new and will be investigated in the research study as one more incentive for the farmers to adopt recycled water as an environmentally preferred source for irrigation water supply.

For research studies that include evaluation or incorporation of renewable energy, please describe the proposed or existing renewable energy system and the research objectives proposed to evaluate the integration of renewable energy into the research study area or project.
This question is not applicable to this research study.

For research studies focused on improving energy efficiency, describe the full scale plant energy requirements, if applicable, proposed efficiency improvements, and reduced carbon footprint. Provide calculations and describe assumptions and methodology.
This question is not applicable to this research study.

Please quantify the energy savings that are expected to be identified in the research study through renewable energy or improved facility efficiencies. Include support for how energy savings were calculated.
This question is not applicable to this research study.

Evaluation Criterion 8: Watershed Perspective

Describe whether or the extent to which the research study is based off of recommendations from an existing plan that is sponsored or otherwise recommends research needs on a regional or national scale.

The research study is based off of a recently commissioned research project by WateReuse Research Foundation (WRRF15-08). A 25% contribution from the US Bureau of Reclamation is expected to strengthen the outcome of the project in the following ways:

- More states in the West will be included in the study
- More interviews with utilities and farmers will be conducted
- Additional topics will be included as impediments and incentives (Federal water supply facilities, species habitats, water rights, etc.)

Explain any additional benefits of, or specific need for, the proposed research study within the sponsors watershed, regional area, and nationally.
Aside from providing a new water supply to the farming community, the research study will have the following additional benefits to the region and nationally:

- Removal of a significant discharge of effluent from the water environment
- Reduced pressure on existing water resources and the habitats from which they are drawn
- Reduced use of energy in nearly all instances where a traditional water source is replaced with recycled water

- Increased employment opportunities for professionals and skilled workers in the water/wastewater management field
- Increased reliability of water availability all around, benefiting industry as well as agriculture

Describe how the research objectives will benefit other locations and the technical, economic, or institutional questions that will be answered by the research study.
The benefits described above ill accrue anywhere the results of the project are used and put into practice, regionally, in the West, nationally, and internationally.

Explain how the research study includes or promotes and encourages collaboration among parties.
Collaboration among water purveyors and wastewater managers is key to the success of any water recycling and reuse project. In fact, lack of such collaboration was identified in 2003 by Sheikh *et al.*[3] as a major obstacle to implementation of water reuse projects in California. Since that time, several notable collaborative efforts have resulted in implementation of major successful water recycling projects in the state. The recently innovated "one-water" concept is embracing the importance of combining diverse water interests under one tent.

Identify if there is widespread support for the research study.
Widespread support for the proposed research study is evidenced by the number of utilities and a major grower in Salinas Valley who have pledged to provide in-kind support for this project.

Environmental Compliance

1. A major benefit of this study is that there are no anticipated adverse environmental impacts. This research study is desktop based and does not include experimental work. Thus, the study will not disturb the air, water, or animal habitats. Impacts on the surrounding environment will be minimalized due to electronic transfer of documents as opposed to hard copies when possible.

2. This research study entails the compilation of data through interviews, literature reviews, and case studies. Activities associated with this study have no probable impact on any Federal endangered or threatened species or designated Critical Habitats.

3. This research study is desktop based and no wetlands or surface waters under the Federal Clean Water Act jurisdiction "waters of the United States" will be directly disturbed.

4. As this is a desktop based study, there are no known archeological sites in the research study activities area and no impacts on such sites are estimated.

5. This study will not have adverse effects on low income or minority populations, as it is a desktop based research study based on gathering and compiling information.

6. This research study will not disturb or affect Indian sacred sites or tribal lands.

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[3] Sheikh, B, York, D., Hartling, E., Rosenblum, E. 2003 "Impact of Institutional Requirements on Implementation of Water Recycling / Reclamation Projects", proceedings AWWA-WEF Water Sources Conference

7. This study will not contribute to the introduction, existence, or spread of invasive species or noxious weeds. This research will be completed in the various offices of the research team personnel and no sampling or land disturbance will occur

Required Permits and Approvals

To complete this research study, no special permits or approvals are required and as such, there is no waiting period to obtain approval.

Official Resolution

On the State Water Board adopted Resolution No. 2003-0008 that demonstrates the applicant has met the financial and legal obligations associated with receiving Federal Financial Assistance. Resolution No. 2003 – 0008 can be found here:
http://www.swrcb.ca.gov/board_decisions/adopted_orders/resolutions/2003/rs2003-0008.pdf

The State Water Board is capable of providing the required funding contributions and the WateReuse Research Foundation and subcontractors are also capable of providing $102,372 in-kind contributions. For additional detail regarding the budget, funding sources, and in-kind contributions, please see below.

The State Water Board's funds for this project have been approved by the Executive Director of the State Water Board, the Agency Secretary of California Environmental Protection Agency, and the Program Budget Manager in the State's Department of Finances. The funds are encumbered under contract #15-053-250 and $100,000 of the total funds for that contract has been budgeted for this project. The contact was approved under Governor Brown's April 1, 2015 Executive Order resolution B-29-15 that stressed the need for water conservation and the development of new and underutilized water supply options (e.g. water recycling) to respond to California's severe drought conditions. If the USBR grant is awarded, the contract approved under Executive Order B-29-15 would be revised.

The State Water Board will work with Reclamation to meet established deadlines for entering into a cooperative agreement.

Funding Plan and Letters of Commitment

The non-Reclamation funds will be obtained from multiple sources. The main sources of funding are California State Water Resources Control Board and WateReuse Research Foundation with a combined $150,000 cash funding commitment plus a $3,630 in-kind services pledge. The second source of funding comes from utility partners and one major farming enterprise with pledges committing a total of $39,000 in in-kind services. A list of these committed pledges is shown on Table 1.

Table 1: Pledged In-Kind Contributions from Research Study Partners

Name of Organization	Name of Contact Email Phone Number	Amount of Support Specified in Letter of Commitment
Monterey Regional Water Pollution Control Agency, CA	Mr. Bob Holden | bobh@mrwpca.com (831)883-9044	$10,000
OCEANMIST Farms, Castroville, CA	Dale Huss | daleh@oceanmist.com (831)970-6694	--
City of Santa Rosa Subregional Operations, CA	Mr. Mike Prinz | MPrinz@srcity.org (707) 543-3357	$10,000
Dublin San Ramon Services District, CA	Mr. Bert Michalczyk michalczyk@dsrsd.com | (925) 875-2200	--
Denver Water, CO	Damian Higham Damian.Higham@denverwater.org (303)633-7206	$7,000
Denver Urban Gardens, CO	Shannon Spurlock | shannon@dug.org (303)292-9900	--
Department of Environmental Quality, Idaho	Tressa Nichols | Tressa.Nicholas@deq.idaho.gov (208)373-0116	$5,000
ARRIS Water, Australia	Professor Ted Gardner/Jim Kelly jkelly@arris.com.au | [08] 8313 6706	$7,000
	Total:	**$39,000**

Letters of commitment are available for each of these sources. Due to size restrictions, not all letters could be included in the proposal. The remaining letters of commitment are available upon request.

The third source of funding is in-kind pledges of additional hours by each and every member of the research study team. These pledges total $59,000, included in column 5 of Table 4. All categories of funds will become available upon invoicing by the applicant with no time constraints or contingencies associated with the funding commitments. Commitment letters from the utility partners are reproduced in Attachment A.

Contributions to the cost share requirement will be made (a) by the California State Water Resources Control Board and WateReuse Research Foundation with in-kind from the Research Study and Project Managers and cash payments from the ongoing research budgets, (b) by utility partners with staff time performing data searches, interviews, and participation in meetings and field visits, and (c) by research study team members with expenditure of time, pro-bono, in addition to billable time assigned to each of them. Each team member has pledged to provide at least 25 % additional hours above and beyond the allocated hours for which they would be paid.

No in-kind costs will be incurred before the anticipated research study start date that we seek to include as research study costs.

No additional funding has been requested from another Federal entity and there are no pending funding requests that have not yet been approved.

Table 2: Summary of Non-Federal and Federal Funding Sources

Funding sources	Funding amount
Non-Federal entities	
CA State Water Board and WateReuse Research Foundation	$153,630
Partner Utilities (See Table 1 for Details)	$39,000
Research Study Team Members' In-Kind Contributions	$59,741
Non-Federal subtotal:	$252,371
Other Federal entities	0
Other Federal subtotal:	0
Requested Reclamation funding:	$75,000
Total research study funding:	**327,372**

Budget Proposal

Table 3: Funding Sources

Funding sources	Percent of total research study cost	Total cost by source
Recipient funding	77%	$ 252,372
Reclamation funding	23%	$ 75,000
Other Federal funding	0%	$ 0
Totals	**100%**	**$ 327,372**

Table 4: Budget Proposal

Budget Item Description	Computation		Type	State Water Board/ USBR Cost	In-Kind	Total Cost
	$/Unit	Quantity				
Salaries and Wages						
N/A	-	-	-	-	-	-
Fringe Benefits						
N/A	-	-	-	-	-	-
Travel						
N/A	-	-	-	-	-	-
Equipment						
N/A	-	-	-	-	-	-
N/A	-	-	-	-	-	-
Contractual						
WateReuse Research Foundation				$225,000	$102,372	$327,372
Environmental and Regulatory Compliance Costs						

N/A	-	-	-	-	-	-
Reporting						
Quarterly Reports	-	-	-	-	-	-
Final Reports	-	-	-	-	-	-
Final Presentation	-	-	-	-	-	-
Total Direct Costs	-	-	-	-	-	-
Indirect Costs	-	-	-	-	-	-
Total Costs	**-**	**-**	**-**	**$225,000**	**$102,372**	**$327, 372**

Table 5: Research Team Budget Proposal – California State Water Resources Control Board Control with the WateReuse Research Foundation

Budget item description	Computation		Quantity	Total cost (cash and in kind)	In Kind, *Pro Bono***
	$/Unit	Quantity	(hours/days)		
Salaries and wages*					
Kristan Cwalina	40	90	hours	$3,630	$3,630
Bahman Sheikh	200	580	hours	$116,000	$20,000
Kara Nelson	200	136	hours	$27,200	$5,000
Brent Haddad	200	48	hours	$9,600	$2,000
Anne Thebo	100	460	hours	$46,000	$9,000
Ted Gardner	143.62	130	hours	$18,671	$3,375
Jim Kelly	143.62	130	hours	$18,671	$3,375
Avner Adin	250	60	hours	$15,000	$3,750
Ryujiro Tsuchihashi	200	40	hours	$8,000	$1,300
Shannon Spurlock	100	60	hours	$6,000	$1,000
Naoyuki Funamizu	200	40	hours	$8,000	$1,200
Rafael Mujeriego	200	24	hours	$4,800	$4,800
Takashi Asano	200	24	hours	$4,800	$4,800
Fringe benefits					
Full-time employees				**Included**	
Part-time employees				**Included**	
Travel					
Car rental	50	10	days	**$ 500**	**$141**
Hotel	150	10	days	**$1,500**	
Equipment					
Item A				**$0**	
Item B				**$0**	
Supplies/materials					
Item A				**$0**	
Item B				**$0**	
Contractual/constructi					
Contractor A				**$0**	
Contractor B				**$0**	
Other					
In-Kind Utilities				**$39,000**	**$39,000**
Total direct costs				**$327,372**	
Indirect costs - 0%				$0	
Total study costs				**$327,372**	**$102,371**

* Salaries and wages are inclusive of direct labor + administrative costs. Each individual is independent contractor.
** The hours and dollars for in-kind, pro-bono contribution of research study team members' contributions are included in the total study costs shown in the previous column.

Budget Narrative

Indirect Costs

No indirect costs will be claimed as part of this project. All California State Water Resources Control Board salaries and expenses, aside from contractual costs, will be considered in-kind contributions.

Total Costs

The total cost of this project will be $327,372. Of this amount, $102,372 will be in-kind contributions and $50,000 will be cash contributions from the WateReuse Research Foundation. The federal cost-share will be $75,000, the State Water Board share will be $100,000.

BUDGET DETAIL

15-08 State of Irrigated Agricultural Water Reuse – Impediments and Incentives, FED ID #R16-FOA-DO-011
(Start Date:July 1, 2016 End Date: January 31, 2018)

CATEGORIES				FEDERAL	STATE MATCH	TOTALS
A. PERSONNEL	Annual Salary	PY(s)	F or S			
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
				$0	$0	$0
Subtotals:		0.0		$0	$0	$0
B. FRINGE BENEFITS @			43.21%	$0	$0	$0
TOTAL PERSONAL SERVICES:				$0	$0	$0
C. TRAVEL						$0
D. EQUIPMENT						$0
E. SUPPLIES						$0
F. CONTRACTUAL (insert additional lines if needed)						$0
WateReuse Research Foundation				$75,000	$100,000	$175,000
						$0
TOTAL CONTRACTS:				$75,000	$100,000	$175,000
G. CONSTRUCTION						$0
H. OTHER						$0
I. TOTAL DIRECT (C through I)				$75,000	$100,000	$175,000
J. *INDIRECT CHARGES @			94.64%	$0	$0	$0
TOTAL GRANT REQUEST:				$75,000	$100,000	$175,000

NOTES:

The total cost of this project will be $327,372. Of this amount, $102,372 are in-kind contributions and $50,000 are cash contributions from the WateReuse Research Foundation. The federal cost-share will be $75,000. The State Water Board share will be $100,000, which has already been allocated in contract #15-053-250 .

Form Approved OMB No: 2030-0020 Approval Expires 06/30/2017

U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

KEY CONTACTS FORM

Authorized Representative: *Original awards and amendments will be sent to this individual for review and acceptance, unless otherwise indicated.*

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Payee: *Individual authorized to accept payments.*

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Title: Chief, Accounting Branch
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Administrative Contact: *Individual from Sponsored Program Office to contact concerning administrative matters (i.e., indirect cost rate computation, rebudgeting requests etc.)*

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Principal Investigator: *Individual responsible for the technical completion of the proposed work.*

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