

California Direct Potable Reuse Initiative Research Plan

Updated July 2014

WATEREUSE RESEARCH

WATEREUSE CALIFORNIA

Section 1: Background, Drivers, and Participants of the DPR Initiative

Goal of DPR Initiative

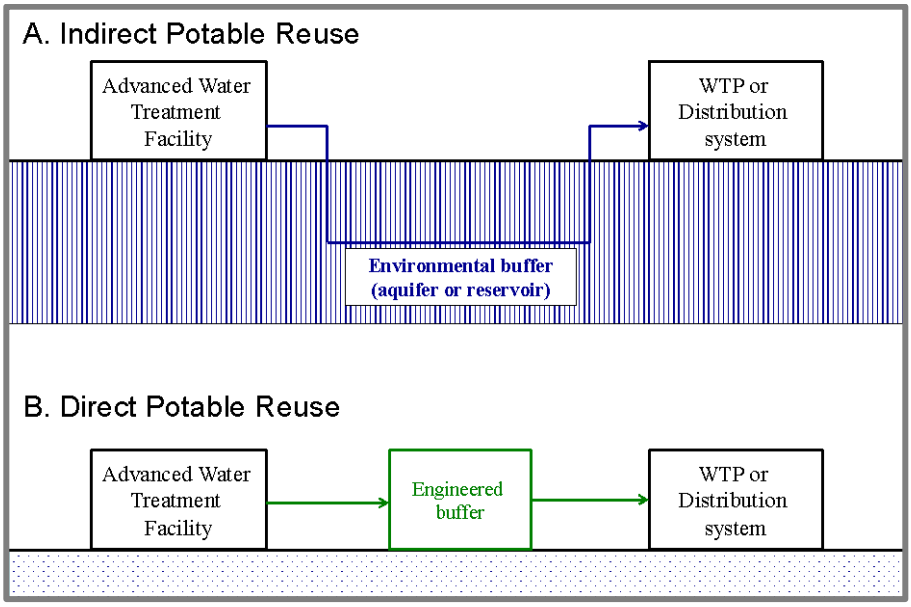
The WateReuse Research Foundation (WRRF) and WateReuse California (WRCA) have launched the CA Direct Potable Reuse (DPR) Initiative to establish DPR as a water supply option that is protective of public health and can be regulated by state agencies, can be implemented by water utilities in a safe and cost-effective manner, and is acceptable to the public.

Purpose of Research Plan

The purpose of this document is to guide the research of the DPR Initiative so that it can provide information for regulators, utilities, and communities as they consider the implementation of potable reuse in the State of California. The plan can be used as a model nationally and internationally for regions considering DPR.

What is DPR?

DPR is the introduction of highly treated reclaimed water *directly* into the raw water supply immediately upstream of a water treatment plant, or into the distribution system downstream of a water treatment plant. To date, proposals have been to introduce DPR water into a water treatment plant intake rather than into the distribution system. While identical in many aspects to indirect potable reuse (IPR) with full advanced treatment, DPR eliminates the passage of the treated water through an environmental buffer—such as a groundwater aquifer or a reservoir (*below*). The direct passage of treated water to the drinking water system is the main characteristic distinguishing it from the indirect path of IPR.



Despite the similarities between the two systems, DPR presents significant new benefits and challenges. By eliminating the environmental buffer, DPR can significantly reduce the energy and cost requirements, maintain the high water quality of the advanced treated water, and remove the need for a suitable aquifer or reservoir, which are not available in all locations. Eliminating the buffer also poses important new challenges. DPR loses the benefits from the environmental buffer, namely (1) decreased contaminant removal, (2) decreased blending and dilution, and (3) shortened time period to detect and respond to treatment failures. Determining how to design and operate DPR systems to overcome these challenges represents an important technical and regulatory hurdle. The public health risks from DPR may differ from IPR, and the system must adapt to meet these differences. Beyond health considerations, DPR must also be cost-effective and acceptable to the public, the ultimate consumers of DPR.

These issues become more complex when considering the fact that DPR also exists in various forms. DPR product water can either be added to the influent of a drinking water treatment plant or pumped directly into a treated water distribution system. Given that these two scenarios provide different levels of treatment, the requirements for different DPR configurations should also be appropriately adjusted.

For DPR to move forward, research must address the needs of the three main groups of stakeholders: (1) regulators, (2) utilities, and (3) communities. Each group (and its consultants) has its own set of issues, though significant overlap exists between the groups. For regulators, the key concern is ensuring that DPR regulations are protective of public health. In their presentations, the California Department of Public Health (CDPH) has discussed two paths to achieving safe DPR systems. In Path 1, they discuss the use of (1) multiple barriers to minimize the chance of a complete treatment failure and (2) infallible treatment verification monitoring. In Path 2, they discuss the use of redundant barriers to provide supernumerary (i.e., above the minimum) log reduction capacity to compensate for any lack of reliability in the treatment, monitoring, or failure response component of the scheme so that the risk of inadequate treatment is miniscule. In both cases, the end goal is the same—a reliable DPR system, i.e., one that protects public health. Reliability is therefore the key concept for regulators.

Of the three groups, the utilities need to address the broadest range of concerns for DPR. Not only are they beholden to regulatory requirements, but they must ensure that DPR can be accomplished in a cost-effective manner while also being acceptable to the communities that they serve. Research needs for the utilities therefore spans regulatory issues, economics, and public acceptance.

Finally, the consumers of DPR water—the communities—must also be involved for the success of DPR. Communities are aware of the wastewater origin of DPR water, and are rightfully concerned about safety. Research is also needed therefore to understand what obstacles communities face in accepting DPR as a new drinking water resource.

Drivers for California DPR Initiative

The California DPR Initiative was developed to address the obstacles to DPR and to move it forward as a viable means to expand our water supply. The Initiative sees that DPR has the

potential to provide a sustainable and cost-competitive water supply option that is less energy-intensive than many alternative options. This new path forward is very timely given the decline in traditional water supply sources along with growing demand.

Another main driver for DPR is legislative action. The State of California's Recycled Water Policy established aggressive goals to increase recycled water production in order to help meet the State's overall water supply goal (by 2020, increase recycled water use by 1 million acre-feet per year over 2002 levels). Initially, the main tool to achieve this goal was the expansion of non-potable reuse, though it has become clear that the goal cannot be met through non-potable reuse alone. IPR has also provided a new opportunity for achieving this goal, though IPR itself has limitations that preclude its use in certain situations. Many communities without suitable groundwater aquifers or reservoirs, communities who have maximized their non-potable options, and communities that have exhausted all other water supply options could benefit from DPR.

The most significant legislation pushing DPR forward has been SB 918. In addition to advancing regulations for IPR, SB 918 also requires the State to evaluate the feasibility of DPR by the end of 2016. The California DPR Initiative aims to contribute to this movement by providing information for regulators, utilities and communities as they consider the implementation of potable reuse in the State of California.

The Initiative has identified seven strategies to achieve this goal:

1. Define the agenda for needed DPR research
2. Raise funds to support the research program
3. Commission DPR research studies
4. Use research findings to develop communication, education, and awareness programs
5. Recruit partners to disseminate the message and coalesce DPR support
6. Develop and education and outreach agenda and programs for key stakeholders
7. Establish practice and technical recommendations for utilities to adapt and adopt DPR

The focus of this document is on the first of the seven strategies: defining the agenda for DPR research. The following sections provide a framework for meeting the research needs of the three main DPR stakeholders: regulators, utilities, and communities.

Key Participants in DPR Initiative

The WRRF and WRCA launched the California DPR Initiative in 2012 to provide leadership and direction in the field of DPR, a practical solution to water scarcity and water stewardship. The Initiative strives to provide needed information through both research and education & outreach.

WRRF – Research

The research side of the initiative is led by WRRF, whose mission is to conduct and promote applied research on the reclamation, recycling, reuse, and desalination of water. The

Research Foundation is an educational, nonprofit public benefit 501(c)(3) corporation that conducts applied research on behalf of the water and wastewater community for the purpose of advancing the science of water reuse, recycling, reclamation, and desalination. The Foundation's research covers a broad spectrum of issues, including chemical contaminants, microbiological agents, treatment technologies, salinity management, public perception, economics and marketing. The Foundation's research supports communities across the United States and abroad in their efforts to create new sources of high quality water while protecting public health and the environment. In the context of the DPR Initiative, the main goal of WRRF is to support the Panel's evaluation of DPR feasibility per SB 918, and to support possible future draft regulations as appropriate.

The selection and management of research projects, including those in the DPR program, in addition to the organization of the Foundation, are described in detail in the Foundation's Operating Plan (http://www.watereuse.org/sites/default/files/u8/Operating_Plan_2010.pdf). In summary, research projects are determined on an annual basis by the Research Advisory Committee (RAC) and are approved by the Board of Directors. The RAC, comprised of 32 technical experts from around the world, meets in the beginning of each year to select and/or develop proposed research projects that reflect priority issues from the Foundation's research agenda. The RAC reviews a summary, completed by staff, of the collected information to date from research needs workshops (e.g. DPR workshop 12/12/12), Subscriber surveys/workshops, the Board, and other sources including the RAC members themselves. A list of priority projects for funding consideration under the Solicited Research Program is created and presented for approval by the Board.

Once approved, an assigned Project Manager (PM) forms a Project Advisory Committee (PAC) of 4-6 technical experts representing water and wastewater utilities, government agencies, consulting firms, etc. PACs are volunteers that provide expert peer review and technical oversight on Foundation research projects. The PM and PAC use the project description approved by the Board to develop a Request for Proposal (RFP). RFPs are posted for competitive bid on the Foundation's website and are promoted through news releases and by the WateReuse Association. PACs review proposals and come to a consensus recommendation for the project award. If there are any shortcomings of the selected proposal, award conditions are provided that the selected contractor must address in a revised scope of work.

Once a funding agreement is negotiated between The Foundation and the project team, the project commences. Quarterly progress reports are submitted to the Foundation and reviewed by the PAC to ensure the project progresses as expected. The contractor is responsible for addressing any of the PACs concerns during the project. The research team, PAC, and PM typically meet in person at least once during the project for a workshop, kickoff meeting, or at the end of the project to discuss project scope and conclusions. At the end of the project, the team submits a final report in addition to any other deliverables as stated in the RFP, which goes through several reviews prior to publication.

WRCA – Education and Outreach

Education and outreach activities are led by WRCA. The purpose of these activities is to provide information about DPR to support decision-making by stakeholders at State, regional and local level, and to develop information to support the education and outreach activities undertaken by the utilities. Phases II and III of the project WRRF-13-02 will take on the outreach activities in select communities and state wide.

Section 2: Research Path to achieve DPR Initiative's goal

To achieve the 2016 goal of SB 918, regulatory, scientific, technical, and attitudinal barriers to DPR need to be removed and/or addressed. Overcoming these hurdles requires undertaking three main tasks:

1. Conduct rigorous scientific research
2. Communicate the research findings through public awareness programs
3. Work with regulatory authorities to facilitate DPR implementation by local water utilities

To accomplish these tasks in the most effective manner, a research framework for ensuring the integration and complementarity of these tasks is needed. This framework is meant to provide a structure for determining important research focuses and to aid in assigning research priorities. All of the research must serve the principal goal of understanding the feasibility of the future of DPR in California. Given the varying needs of the main stakeholders, the research framework needs to be broad enough to cover the concerns of each group, while maintaining a global vision that allows the groups to achieve their shared goals.

Research Framework 1: Regulatory Concerns

To address the regulatory concerns, the research framework should focus on the ultimate goal of DPR systems – the provision of a safe and reliable potable supply. As stated above, **reliability** in the DPR setting is defined as the provision of a potable supply that is protective of public health at all times. To achieve reliability, a number of supporting concepts can be used including **redundancy**, **robustness**, and **resilience**. The DPR process (including source control, treatment, monitoring, operations, training, maintenance, etc.) can achieve reliability by incorporating these three factors into system design and operation. A reliable DPR process incorporates **r**edundancy (i.e., the use of multiple barriers to control acute risks) and **r**obustness (i.e., capacity to remove a wide range of contaminants) to control microbial and chemical risks under typical operation scenarios. In addition, DPR facilities must also be **r**esilient to ensure reliability even during rare failure events. A resilient system is not a system that never fails, but a system that fails safely, meaning that it responds to failure by preventing the distribution (and consumption) of all water that does not meet requirements. In ensuring the provision of safe DPR water, redundancy, robustness, and resilience all contribute to reliability.

The research plan can support the regulatory aspects of DPR by focusing on the reliability framework. Examples of specific research products that could be important guideposts toward this are raised in the following bullet points. It should be emphasized that this list of research products is not exhaustive.

Reliability

- *Develop concepts that draw upon the existing regulatory framework for drinking water to establish the definition of reliability in potable reuse*
- *Define treatment requirements for chemicals and pathogens of health significance*
- *Develop on-line monitoring strategies for each unit process and demonstrate application*

Redundancy

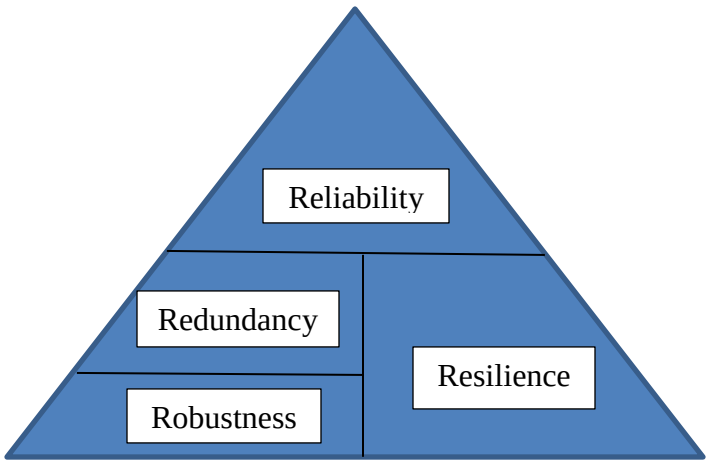
- *Define the benefits of the multi-barrier concept to ensure public health protection*
- *Describe the balance between redundancy, monitoring, and storage, and how they work together to ensure reliability*
- *Define what level of redundant (supernumerary) treatment is necessary to ensure reliability, particularly for CDPH Path 2*
- *Design of engineered buffers*

Robustness

- *Develop guidelines for an acceptable DPR source water*
- *Determine robust treatment schemes that are best suited to address unknown challenges*
- *Develop strategy to determine how to quantify the sense of the unknown with CECs*

Resilience

- *Determine appropriate resilient strategies to ensure reliability in extreme events*



Research Framework 2: Utility Concerns

The research needed to address utility concerns is the broadest of the three stakeholder groups, given their interaction with both regulatory issues (Framework 1) and community issues (Framework 3). Utilities also have a number of unique research needs that are specific to their issues, mainly focusing on the economic and technical feasibility of DPR systems. Research Framework 2 therefore focuses on overcoming the specific **technical** and **economic** obstacles that currently affect DPR implementation.

Examples of specific research products that could be important guideposts toward this are raised in the following bullet points. It should be emphasized that this list of research products is not exhaustive.

Economic and Technical

- *Identify methods to reduce the cost (and energy intensity) of DPR treatment*
- *Identify alternative treatment trains that meet public health criteria*
- *Identify non-RO DPR treatment options to eliminate need for brine disposal*
- *Develop DPR training and operational plans*
- *Product water aesthetics: taste and odor*

Research Framework 3: Community Concerns

Addressing community concerns represents a significant challenge in achieving the goal of widespread public acceptance for DPR. Research is needed to explore and assess the critical concerns among community members and survey attitudes about DPR. Activities would include gauging the general understanding of DPR, identifying the primary concerns, and developing educational and communication tools that support acceptance. Learning how members of the community respond to the idea of DPR — emotionally and objectively — and focusing in on their main concerns are key pieces in understanding public perception and developing the tools and messages that will support acceptance.

The emphasis of Research Framework 3 should be Awareness, Education and Acceptance. Research in this area would include various assessment, in-depth interviews, surveying, focus groups, and communication research (message testing and evaluation). The areas of research could include:

- *Identify and clarify health and safety concerns related DPR*
- *Identify concerns about reliability (What happens if something goes wrong?)*
- *Develop communication tools to address emotional and intellectual concerns*
- *Develop a public outreach framework and messages that can be adapted by utilities for a variety of community audiences.*

Section 3: Current WateReuse Research Foundation DPR Research Projects

In 2011, WRRF began its program specifically geared towards DPR with funding research identified by WateReuse's *Direct Potable Reuse: A Path Forward*, the 2012 NRC report on potable reuse, and the investors of the California DPR Initiative. These six projects (WRRF-11-01, 11-02, 11-05, 11-10, 12-06, and 12-07), representing over $3.8 million in research, created a solid foundation exploring the viability of DPR. Significant findings and conclusions will arise from these initial DPR projects and will help steer future DPR research.

In the meantime, WRRF and WRCA hosted a DPR Research Needs Workshop at West Basin's Edward C. Little Water Recycling Facility in December 2012 to identify research gaps to be addressed in new research. Attended by more than 50 (Appendix A) international leaders in potable reuse, the workshop divided the experts in industry, academics, consulting, and regulators into four strategic breakout groups (Operations, Quality Assurance, Treatment Technology, and Public Acceptance). Descriptions for 22 projects resulted and were ranked by the workshop attendees.

This ranked list was submitted to the Foundation's Research Advisory Committee (RAC) for review and selection at their January 2013 meeting. The RAC further developed four projects addressing regulatory, utility, and community concerns. This 2013 DPR research approved by the Board (WRRF-13-02, 13-03, 13-12, 13-13) totals $1,000,000 and is funded by the CA DPR Initiative donors as well as Metropolitan Water District of Southern California. This program is further enhanced by collaboration with the Water Research Foundation (WRF), who is funding and managing an additional two projects (WRF4506 and 4536) at $600,000.

The RAC again met in January 2014 and added more important research to address remaining gaps in DPR. The RAC built off of existing projects and recommended research to develop four new solicited research projects to be started in 2014. Those 2014 projects along with 3 additional Tailored Collaboration DPR projects add another $4.5 million to the DPR program to address technical and public acceptance concerns with DPR.

The Foundation's 19 DPR projects initiated in 2014 or before total $10.4 million in research to evaluate and demonstrate the feasibility of DPR (Table 1). A detailed description of the current DPR research portfolio is presented in Appendix B.

Table 1. WRRF DPR Research Program 2011 - 2014

Project #	Research Project Title	Principal Investigator	Research Focus	Expected Publication	WRRF contribution	In Kind Contribution
WRRF-11-01	Monitoring for Reliability and Process Control of Potable Reuse Applications	Ian Pepper, University of Arizona	Regulatory - Process Reliability, Utility	Nov-15	$400,000	$1,298,817
WRRF-11-02	Equivalency of Advanced Treatment Trains for Potable Reuse	Rhodes Trussell, Trussell Technologies	Regulatory - Treatment, Utility	Sep-15	$375,000	$868,000
WRRF-11-05	Demonstrating the Benefits of Engineered DPR versus Unintentional Indirect Potable Reuse Systems	Glen Boyd, The Cadmus Group Inc	Community, Regulatory	published May-2014	$49,558	$10,000
WRRF-11-10	Risk Reduction Principles for DPR	Andy Salveson, Carollo	Regulatory - Treatment	published Jul-2014	$73,407	$71,555
WRRF-12-06	Guidelines for Engineered Storage for Direct Potable Reuse	Andy Salveson, Carollo	Regulatory - Treatment, Community, Utility	May-15	$100,000	$111,788
WRRF-12-07	Methods for Integrity Testing of NF and RO Membranes	Joe Jacangelo, MWH	Regulatory - Process Reliability	Dec-16	$300,000	$296,965
WRRF-13-02	Model Public Communication Plan for Advancing DPR Acceptance	Mark Millan, Data Instincts	Community	Jan-15	$337,125	$272,606
WRRF-13-03	Critical Control Point assessment to quantify robustness and reliability of multiple treatment barriers of DPR scheme	Troy Walker, Hazen & Sawyer	Regulatory - Process Reliability, Utility	Apr-16	$300,000	$238,969
WRRF-13-12	Evaluation of Source Water Control Options and the Impact of Selected Strategies on DPR	Alan Rimer, Black & Veatch	Utility, Regulatory	Jun-16	$150,000	$81,150
WRRF-13-13	Development of Operation and Maintenance Plan and Training and Certification Framework for Direct Potable Reuse (DPR) Systems	Troy Walker, Hazen & Sawyer	Utility	Apr-16	$250,000	$85,000
WRRF-13-14 (WRF4508)	Assessment of Techniques to Evaluate and Demonstrate the Safety of Water from DPR Treatment Facilities	Channah Rock, University of Arizona	Utility, Regulatory	Dec-16	$275,000	$144,177
WRRF-13-15 (WRF4536)	Blending Requirements for Water from Direct Potable Reuse Treatment Facilities	Andy Salveson, Carollo Engineers	Utility	Dec-16	$325,000	$403,310
WRRF-14-01	Integrated Management of Sensor Data for Real Time Decision Making and Response	TBD	Regulatory - Process Reliability, Utility	TBD in 2017	$300,000	TBD
WRRF-14-02	Establishing additional log reduction credits for WWTPs	TBD	Regulatory - Treatment	TBD in 2017	$400,000	TBD

WRRF-14-03	Develop Methodology of comprehensive (fiscal/triple bottom line) analysis of alternative water supply projects compared to DPR	TBD	Utility	TBD in 2017	$250,000	TBD
WRRF-14-08	Economics of DPR	Bob Raucher, Stratus Consulting	Utility	Sep-14	$25,000	0
WRRF-14-10	Enhanced Pathogen and Pollutant Monitoring of the Colorado River Municipal Water District Raw Water Production Facility at Big Spring Texas	Eva Steinle-Darling, Carollo	Regulatory	Aug-16	$100,000	$561,755
WRRF-14-12	Failsafe Potable Reuse Project at the City of San Diego's Advanced Water Purification Demonstration Facility	Shane Trussell, Trussell Technologies	Utility, Regulatory	Apr-17	n/a	$3,088,313
WRA-14-01	Developing Direct Potable Reuse Guidelines	Jeff Mosher, NWRI	Regulatory	Dec-14	$53,120	0

The DPR research projects in Table 1 are identified into the three main research focuses, displayed graphically in the Venn diagram in Figure 2. All of this DPR research is highly complementary of each other and must be closely coordinated to share approach and results throughout the duration of the project work. WRRF coordinates biannual meetings with the project teams of these DPR projects to encourage communication and avoid duplication. Figure 3 shows the project duration of the 19 DPR projects underway (green is expected).

Figure 2. Venn Diagram of Reliability Framework

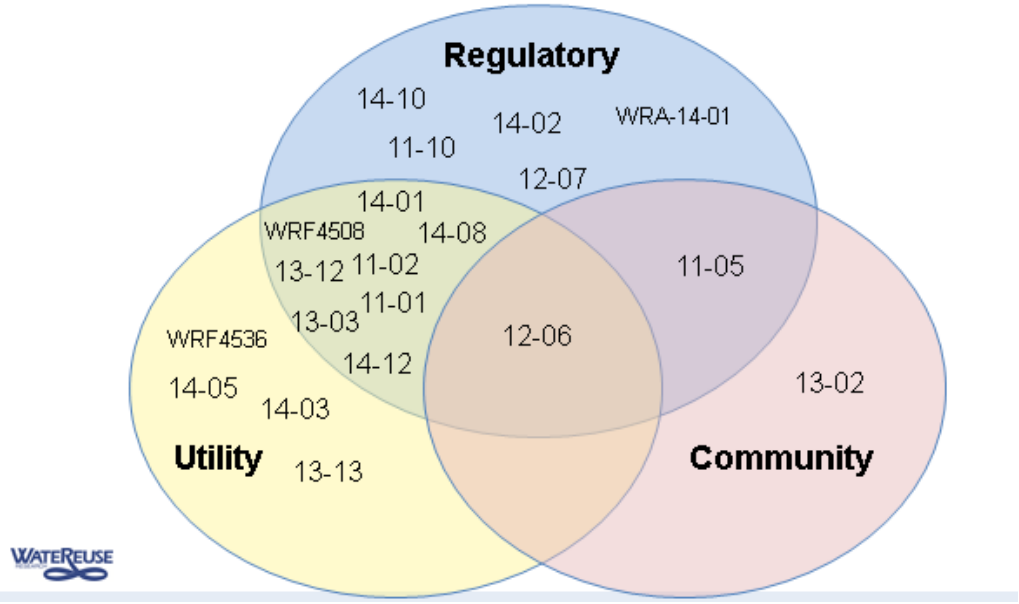
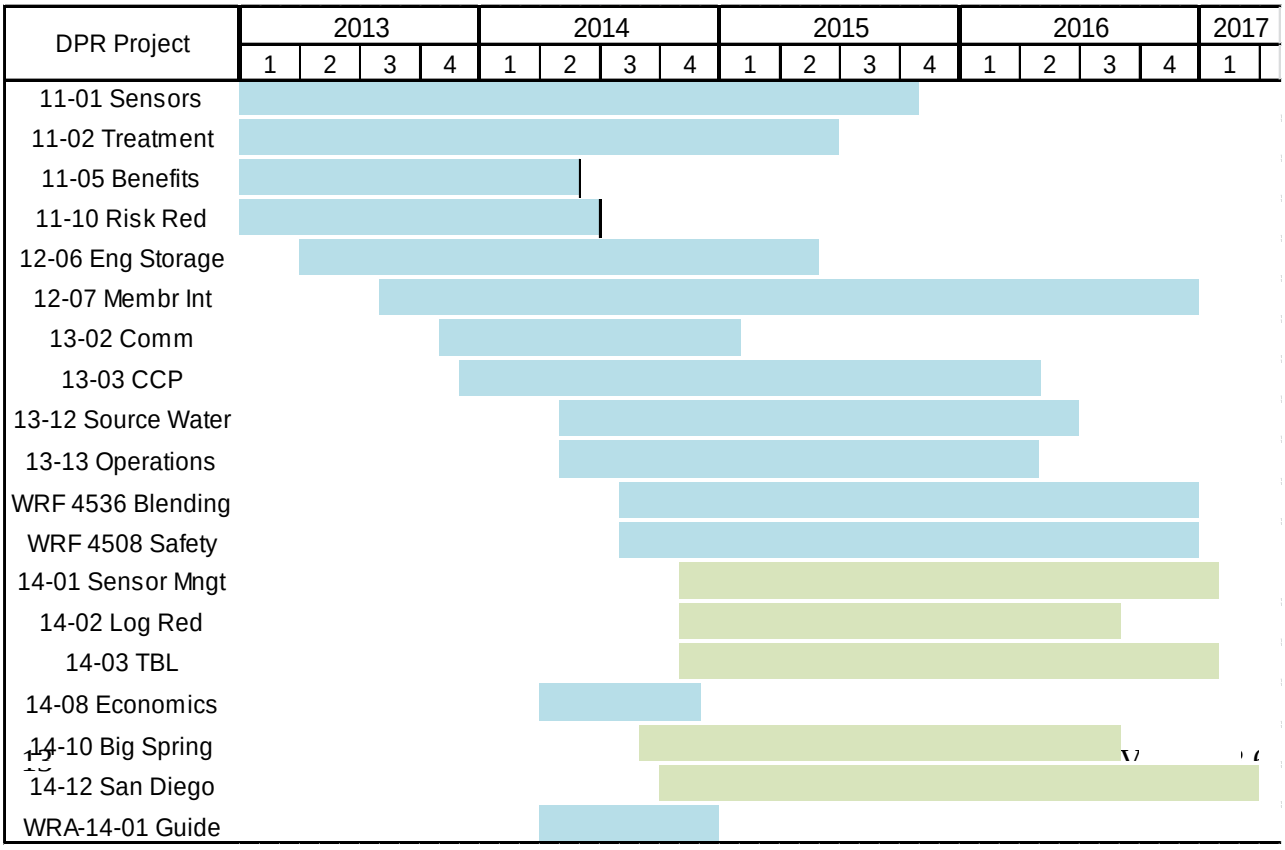


Figure 3: Current DPR Research Timelines



Section 4: Future Research and Next Steps

New DPR research will be initiated in the end of 2014 and beyond to ensure gaps are filled to illustrate the feasibility of DPR. Several sources will be considered for this new research, most importantly recommendations from the expert panel. After funding six projects in 2013 and four in 2014 and incorporating/combining descriptions, four out of the original 22 research projects proposed at the 12/12/12 DPR Workshop remain (Table 2). These will be candidate projects for the RAC in their consideration of research to fund. Additionally, the recommendations of the current 19 projects underway will come into clearer focus and will be considered. To take advantage of the evolving knowledge, future DPR Research Needs (through survey, panels, workshops, etc) will be considered to assess progress and redirect research priorities towards promising paths. Input from the Expert Panel's June 12, 2014 report will be utilized to develop new research at the September 6, 2014 RAC meeting.

Table 2. Remaining (unfunded) DPR Projects

Future Research Project Title	Source	Budget
Evaluation of Policies Integrating DPR and other Reuse Strategies into Comprehensive Water Supply Planning	2014 RAC B list	$200,000
Project to support CA DPR Initiative Effort document 'process', concerns, etc as learning document	2014 RAC B list	$50,000
White Paper: State of the Science Report on Antibiotic Resistance in potable reuse applications	2014 RAC B list	$25,000
Develop concepts that draw upon the existing regulatory framework for drinking water to establish the definition of reliability in potable reuse	NRC/DPR Path Forward	TBD
Identify non-RO DPR treatment options to eliminate need for brine disposal	NRC/DPR Path Forward	TBD
WRRF-11-01 *Monitoring for Reliability and Process Control of Potable Reuse Applications Expansion*: Real-time Detection of Viruses in Water	Extension of current project	$60,600
WRRF-11-01 *Monitoring for Reliability and Process Control of Potable Reuse Applications Expansion*: Real-time Detection of Fluorescence	Extension of current project	$98,475
WRRF-11-02 *Equivalency of Advanced Treatment Trains for Potable Reuse Expansion*: Additional in vitro bioassay suite	Extension of current project	$200,000
WRRF-12-06 *Guidelines for Engineered Storage Systems Expansion*: Performing real-time emergency response to treatment process or water quality failures	Extension of current project	$40,000
Performance Testing of the Colorado Municipal Water District's Raw Water Production Facility in Big Spring, TX	proposed to 2014 TC program, TBD	$80,000
Dealing with reverse osmosis brine in applications with non-ocean discharge	12/12/12 DPR Workshop (DPR-OP-12-01)	TBD
Reducing Energy Intensity of Advanced Treatment Methods for Recycling Water	12/12/12 DPR Workshop (DPR-TT-	$1,000,000

	12-01)	
Establishment of QA Requirements for Alternative DPR Treatment Schemes	12/12/12 DPR Workshop (DPR-QA-12-03)	$300,000 - $350,0000
Evaluate the Feasibility of Using Odor compounds as surrogates for monitoring low molecular weight particles that may pass through MF & RO and Using Flavor Profile Analysis (FPA)as part of this feasibility analysis.	12/12/12 DPR Workshop (DPR-QA-12-01)	TBD

Appendix A: Attendees of 12/12/12 DPR Workshop held at West Basin Municipal Water District

Last Name	First Name	Affiliation
Bardowell	Phylyp	Office of Congresswoman Napolitano
Barnard	Randy	CA Department of Public Health
Bernados	Brian	CA Department of Public Health
Bishop	Jonathan	SWRCB
Brown	Garry	Orange County Coastkeeper
Bunts	Don	Santa Margarita Water District
Campos	Carlos	Suez Environment
Cline	Shonnie	Water Research Foundation
Cook	Paul	Irvine Ranch Water District
Cotruvo	Joseph	Joseph Cotruvo & Associates, LLC
Crozes	Gil	Carollo
Drewes	Jorg	Colorado School of Mines
Festger	Adam	Trojan Technologies
Fiedler	Jim	Santa Clara Valley Water District
Ghirelli	Bob	Orange County Sanitation District
Haddad	Brent	University of California, Santa Cruz
Hultquist	Robert	CA Department of Public Health
Infurnari	Mike	WateReuse Research Foundation
Jacangelo	Joe	MWH
Jones	Paul	Eastern Municipal Water District
LeChevallier	Mark	American Water
Lovell	Adam	Water Services Association of Australia
Macpherson	Linda	CH2M Hill
McDonald	Ellen	Alan Plummer & Associates
Millan	Mark	Data Instincts, Public Outreach Consultants
Miller	Wade	WateReuse Association
Minton	Julie	WateReuse Research Foundation
Mosher	Jeff	National Water Research Institute
Nagel	Richard	West Basin Municipal Water District
Nellor	Margie	Nellor Environmental Associates, Inc.
Owen	Doug	Malcolm Pirnie, ARCADIS
Pettijohn	Dave	LADWP
Price	Kevin	USBR
Provencher	Lisette	United Water
Rayburn	Chris	Water Research Foundation
Richardson	Tom	RMC Water and Environment
Rossi	John	Western Municipal Water District

Ruiz	Hector	Trabuco Canyon Water District
Salveson	Andrew	Carollo
Smith	David	WateReuse California
Snyder	Shane	University of Arizona
Spivy-Weber	Fran	California State Water Resources Control Board
Steele	Bill	USBR
Trejo	Reymundo	Upper San Gabriel Valley MWD
Tremblay	Ray	Los Angeles County Sanitation District
Trussell	Rhodes	Trussell Technologies
Trussell	Shane	Trussell Technologies
Wehner	Michael	Orange County Water District
Whitaker	Robb	Water Replenishment District of Southern CA
Wildermuth	Ron	West Basin Municipal Water District
Yamamoto	Gary	CA Department of Public Health
Zornes	Greta	ConocoPhillips

Appendix B. DPR Research Project Details

1. WRRF-11-01, *Monitoring for Reliability and Process Control of Potable Reuse Applications* (Contractor: University of Arizona)

The objective of this project is to identify, evaluate, test, and validate monitoring systems that can be used to assure the public safety of potable reuse. The project is specifically focused on real-time or near real-time monitoring for the removal of trace organics and biological contaminants.

The project is comprised of three tasks: 1) state of knowledge and initial workshop, 2) laboratory evaluation of monitoring control systems and 3) pilot and full-scale evaluations.

Status: The project is on track; the team submitted their sixth progress report in January 2014 and will be submitting their seventh progress report in March 2014.

Notable Update:

Task 2 is is currently 85% complete. The purpose of this task is to identify correlations between treatment performance and sensor response. As part of this task the following will be performed:

- Treatment train development: The following treatment trains will be evaluated at the lab-scale. The treatment trains were selected in consistence with project WRRF11-02.

  From secondary treatment → MF/UF → RO → UV/AOP → To reuse application

  From secondary/ tertiary treatment → *MF/UF* → O_3 → *GAC/BAC* → *From surface/groundwater augmentation*

- Use of surrogates to predict trace organic compound (TOrc) removal by granular activated carbon: The purpose of this subtask is to develop correlations between bulk organic parameters (e.g. color, total organic carbon, UV absorbance and fluorescence excitation/emission spectroscopy) and TOrC removal during oxidation processes. Some preliminary testing has been performed. The project team is evaluating and analyzing the data.

- Data Acquisition Software Development: The purpose of this sub-task is to develop a SCADA system for monitoring and controlling the water quality throughout the treatment train for water reuse

- On-line Sensors for Real-Time Monitoring of Water Quality: As part of this sub-task, 10 different online sensors were installed in the lab and are currently being evaluated (see Table 3). These sensors are capable of measuring 13 different surrogate parameters of water quality which can be divided into four categories: i) general (pH, temperature, conductivity, turbidity); ii) organic (UVT254, UVA254, TOC, DOC, fluorescence); iii) inorganic (chlorine, NO_3-N); and iv) microbial parameters (total cell count, microbial toxicity

Table 3: Surrogate parameters and online sensors that will be analyzed as part of WRRF-11-01 Task 2

General parameters	Organic parameters	Inorganic parameters	Microbial parameters
pH	UVT 254 (%)	Chlorine (mg/L)	Total cell count (counts/100mL)
Temperature (°C)	UVA 254 (cm^{-1})	NO_3-N (mg/L)	Toxicity (%)
Conductivity (µS/cm)	DOC (mg/L)		
Turbidity (NTU)	TOC (mg/L)		
	Fluorescence (A.U.)		

To date, the following has been accomplished:

- Two Reverse osmosis units built
- Development of treatment technologies for UV, O3, ± H_2O_2
- IQ SensorNet installed
- LabView Software system installed for data stream collection from all sensors simultaneously
- SAFire fluorescence online sensor evaluated as surrogate for dissolved organic matter
- Instant BioScan evaluated as a real-time microbial sensor
- Advanced oxidation via ozone evaluated for removal of contaminants

2. WRRF-11-02, *Equivalency of Advanced Treatment Trains for Potable Reuse* (Contractor: Trussell Technologies)

This project will clearly identify the benefits and tradeoffs of various treatment process trains for potable reuse. This project will consider and examine criteria needed to evaluate the adequacy of treatment for direct and indirect potable reuse. A model will be developed that can allow for comparisons of alternate treatment trains for potable reuse. At least one advanced treatment train will be tested for direct potable reuse at a scale large enough to give information on real operating conditions.

Status: The project is on track. The National Water Research Institute (NWRI) coordinated an Independent Advisory Panel (Panel) to lead a 2-day workshop to develop a set of criteria that are protective of public health to evaluate treatment technologies for DPR. This Panel Report entitled *Examining the Criteria for Direct Potable Reuse* has been released. Shane and Rhodes Trussell attended the DPR Collaboration Meeting on 5/6/13 in Phoenix. In addition, a two-part webcast was conducted by the project team briefing attendants on the preliminary results of this project. The team submitted their

sixth progress report in November 2013 and is expected to submit their seventh in February 2014.

Notable Update:

To date, the team has completed or nearly completed all of the work comprising Task 1 and has made significant progress on Tasks 2 and 3. Within Task 1, the project team completed Task 1A (Literature Review) and Task 1B (Review of Available Public Health Criteria). The deliverable from these tasks was a Literature Review document that was distributed to the Expert Panel and the PAC prior to the September workshop. To satisfy Task 1C (Develop Criteria that are Protective of Public Health to Evaluate Treatment Technologies for Direct Potable Reuse), the project team developed a set of "Strawman" criteria—in the form of PowerPoint presentations—that were distributed to the PAC and Expert Panel prior to the workshop. Task 1C also included the August 29, 2012 workshop that was co-run with NWRI at the LA Department of Water and Power. The Expert Panel then refined these criteria in their Expert Panel Report; these treatment goals will serve as the final equivalency criteria for the evaluation of DPR treatment technologies. The PAC provided comments on the draft Expert Panel Report, and these comments were incorporated into the revised version of the Expert Panel Report that was included with a previous progress report. Finally, the project team created a State of the Science (SoS) Report for Task 1E that incorporates all of the information compiled in Task 1, including the literature review (Tasks 1A and 1B), the final set of public health criteria (Task 1C), and the additional design criteria for potable reuse trains (Task 1D). The draft SoS Report was revised based on comments from the PAC and included in a previous progress report. New science in potable reuse and proposals for new potable reuse projects are released frequently. We recommend the SoS Report be published as an independent WateReuse Research Foundation Report so that the information it contains can be timely and so that its contents can contribute to this active and dynamic dialogue.

In Task 2, the project team has completed a draft of the digital Toolbox, which includes a wide range of treatment technologies and treatment performance. Toolbox users are now able to combine a series of technologies to meet specified levels of pathogen and pollutant treatment. Two further efforts are required on this toolbox: 1) costs of treatment must be assembled, and 2) modifications to the treatment credits will be implemented once pilot testing is complete.

In conjunction with the initial findings from the Toolbox, potential treatment trains for near-full-scale direct potable reuse testing have been identified. The project team has developed a draft test protocol based on these treatment trains and the availability of pilot equipment (Task 3). Pilot testing at San Luis Obispo Water Reclamation Plant (WRP) was completed in March and follow up testing will be completed in July. Site modifications, including the installation of secondary containment to prevent runoff from potential pilot plant leaks from entering storm drains, were made at LACSD's San Jose Creek Water Reclamation Plant (SJCWRP) to accommodate pilot equipment at that location. The WEDECO ozone system, Leopold BAC pilot unit, Econity MF pilot unit, LACSD RO skid, and GE UF skid have been delivered to SJCWRP. The WEDECO and Leopold systems began operating in June, and the Econity, GE and RO skids began

operating in September. All of those pilot units are currently operating as part of Phase 1 testing.

3. WRRF-11-05, *Demonstrating the Benefits of Engineered Direct Potable Reuse versus Unintentional Indirect Potable Reuse Systems* (Contractor: The Cadmus Group Inc)

   This project will obtain a more quantitative assessment of the water quality impacts associated with unintentional indirect potable reuse and demonstrate how more fully engineered approaches to direct potable reuse will result in water quality benefits.

   Status: The project has been completed and has been published.

   Conclusions: The findings of this study indicate that predicted concentrations at intakes were largely dependent on dilution, background concentrations of contaminants in surface water, ambient temperature, and the residence time of the contaminants in the system. However, the impacts of effluent discharges on water quality at intakes were considered negligible. The selected analytical approach was appropriate for understanding system behavior in the selected *Unintentional Indirect Potable Reuse (de facto reuse)* cases and allowed for a consistent comparison of water quality impacts among different systems where data were limited. This approach may be adapted by other utilities that are located only a short distance downstream from the nearest wastewater treatment discharge point, have a limited number of non-point source discharges in that distance, and have adequate data on trace organics to assess the concentrations at the water intake. However, conclusions from this study were restricted by older source water quality data, limited data on emerging contaminants of concern, and asynchronous data collection efforts by different entities.

4. WRRF-11-10, Evaluation of Risk Reduction Principles for Direct Potable Reuse (Contractor: Carollo Engineers)

   The goal of this project is to identify how fail-safe concepts developed in other industries (structural/bridge, aviation/NASA) can be adapted and applied to DPR systems. The resultant guidance and recommendations will be built in a stepwise fashion from the foundation of "what we know" up through "what we could do," to "the pros, cons, and costs of the identified DPR approach alternatives."

   Status: Project was submitted to the publication queue for copyediting. Anticipated publication date is May 1, 2014.

Conclusions: DPR is without an environmental buffer such as a groundwater basin or a surface water reservoir. Potable reuse of highly treated reclaimed water without an environmental buffer is worthy of consideration as an alternative water supply. Understanding and replacing the value of the environmental buffer is a key component of this project. Concepts central to this work include:

- Multi-barrier treatment. Treatment is provided by multiple unit processes so that no one process is responsible for providing the full level of public health protection. The

treatment provided by each unit can be partially or completely duplicative to another process (i.e., provide redundant treatment).

- Redundant treatment. Treatment that is provided in excess of the required minimum needed to maintain adequate public health protection. This is typically provided as a back-up in case another process fails to provide adequate treatment.
- Process reliability. A measure of how consistently a treatment system can be depended upon to perform to specifications.

The project team recognizes that this project represents the beginning of DPR guidance criteria. As such, a number of recommendations for setting treatment goals for *reclaimed water as source water or as a potable source* are suggested.

In the absence of the environmental buffer, treatment processes need accurate, robust real-time, online monitoring of effluent quality. This monitoring ideally ensures process performance and alarms when process effluent quality changes. These improved monitoring techniques should be sensitive enough to pick up small changes and trends in treatment performance that could have a significant impact on the safety of the finished water. The monitoring techniques would focus on both microbes and trace pollutants.

5. WRRF-12-06, *Guidelines for Engineered Storage for Direct Potable Reuse Systems* (Contractor: Carollo Engineers)

   The main objective of this project is to develop recommendations for optimizing engineered storage systems for direct potable reuse; this will be accomplished through examining current practices and existing research to generate a guidance document and report.

   Status: The second progress report was submitted during the quarter. The project is on schedule.

   Notable Update: Project Principal Investigator and Co-PIs have submitted several abstracts to present the work at conferences including ACE, WRRF Research Conference, and Texas Water. The public outreach work was also presented by Linda MacPherson as part of an NWRI workshop on Direct Potable Reuse Public Perception on February 25.

6. WRRF-12-07, *Standard Methods for Integrity Testing and On-line Monitoring of NF and RO Membranes* (Contractor: MWH)

   The main goal is to create scientifically-based method(s) for the integrity testing of high pressure membranes, including nanofiltration (NF) and reverse osmosis (RO) membranes. Once developed, the goal is to have the methods adopted as industry standards and approved for higher pathogen removal credits by regulatory agencies.

   Status: The second progress report from MWH will be submitted in the next weeks. The project team is behind with this report.

Notable Update: A project kick-off meeting was held on October 3rd, 2013 between the Foundation, project team, and PAC members. The literature review has been completed and reviewed by the PAC. A survey on NF and RO integrity monitoring utilized by water utilities, technology providers and membrane manufacturers has been sent to the project participants. The survey results will be discussed during two workshops in early 2014.

7. WRRF-13-02, *Model Public Communication Plan for Advancing DPR Acceptance* (Contractor: Data Instincts)

   The objective of this project is to establish a framework communication plan and develop an implementable, strategic communication plan to achieve DPR acceptance for the State of California.

   Status: The project was awarded to Data Instincts, and after negotiating the funding agreement, the project commenced on November 15, 2014.

   Notable updates: The work was presented by Mark Millan as part of an NWRI workshop on Direct Potable Reuse Public Perception on February 25.

8. WRRF-13-03, *Critical Control Point Assessment to Quantify Robustness and Reliability of Multiple Treatment Barriers of DPR Scheme* (Contractor: Hazen & Sawyer)

   Objectives:

   1. Conduct hazard assessment for key unit operations for two or more direct potable reuse (DPR) treatment trains, including the following:
      a. MF/UF – RO – UV/H_2O_2 – Cl_2 – Engineered Storage
      b. O_3 – BAC – GAC – UV – Cl_2 – Engineered Storage
   2. Develop best design, monitoring, and operational practices by evaluating critical process control points in each of the DPR treatment trains evaluated to meet overall system robustness and reliability.
   3. Develop standard design approaches and response strategies (i.e., operations plan and standard operating procedures) to mitigate upset events to strive towards 'fail-safe' operation of a DPR plant.

   Research Approach:

   1. Conduct hazard assessment for key unit operations and determine critical control points
   2. Conduct bench/pilot level challenge test studies
   3. Conduct Monte Carlo risk analysis and develop standard design approaches, operational procedures, and response strategies

Project Update: This project was awarded to Hazen & Sawyer in December 2013 with the project commencing shortly thereafter. The project team has assembled a multi-disciplinary Hazard Analysis and Critical Control Points (HACCP) team to assist in the delivery of project outcomes. The first of two workshops with the HACCP team has been scheduled for February 2014 to fully vet the water quality objectives, critical control points, and final list of chemical and microbial indicators and surrogates. The first progress report is due April 2014.

9. WRRF-13-12, *Evaluation of Source Water Control Options and the Impact of Selected Strategies on DPR* (Contractor: Black & Veatch)

   The goals are to evaluate upstream wastewater treatment impacts (e.g. N/dN-nitrification/denitrification, industrial source control) on DPR source water quality and DPR process, and to evaluate impact of hydraulic control mechanisms (e.g. flow equalization and source water storage buffers) on influent water quality and flow variations that "stress" the DPR process.

   Project Update: Black & Veatch (PI Alan Rimer) has been awarded and the project will start soon.

10. WRRF-13-13, *Operations Plan Development Standard* (Contractor Hazen & Sawyer)

    The object of this project is to develop a standard operations and maintenance plan for various DPR treatment processes, including appropriate portions of the upstream secondary wastewater treatment processes providing feedwater to the DPR processes. A DPR Training and Certification framework for DPR system operators will also be developed.

    Project Update: Hazen & Sawyer (PI Troy Walker) has been awarded and the project will start soon.

11. WRF 4508, *Assessment of techniques for evaluating and demonstrating safety of DPR product water* (Contractor: U of Arizona; funded and managed by Water Research Foundation)

    The objectives of this project are to evaluate known techniques/methodologies (and potentially develop new technologies) for the assessment of DPR water safety (work with public outreach group to identify key criteria by which public would evaluate safety); to evaluate the effectiveness of currently accepted and alternative treatment trains for the production of DPR water using the developed techniques; to perform benchmarking to other water sources (e.g. surface water, bottled water, etc.); and to develop tools and methods for utilities to demonstrate water safety to the public, elected officials, etc.

    Water Research Foundation will manage this project, through a process similar to WateReuse.

Project Update: The project was awarded to U of Arizona (Channah Rock, PI), and the project will begin soon.

12. WRF 4536, *Blending Requirements for Water from DPR Treatment Facilities* (Contractor: Carollo; funded and managed by Water Research Foundation)

The objective of this project is to optimize with respect to water quality, the blending of DPR water with existing water supplies based on existing information. Phase II will conduct case studies of selected blending strategies

Water Research Foundation will manage this project, through a process similar to WateReuse.

Project Update: The project was awarded to Carollo (Andrew Salveson, PI), and the project will begin soon.

13. WRRF-14-01, Integrated Management of Sensor Data for Real Time Decision Making and Response (Contractor: TBD)

The objectives of this project are as follows:

Develop an operation support tool that integrates diverse sensors within the treatment process for immediate feedback/alerts. Integrate existing sensors as an early warning system for a Direct Potable Reuse (DPR) treatment process to provide:

- Real time sensor network for tracking system performance and key quality parameters,
- A tool for early detection of system anomalies prior to any compromise in water quality.

Build on criteria developed in WRRF-13-03 and 13-13 for decision making based on established critical control points.

Develop framework for sensor data integration based on above criteria.

Project Update: This project was developed by the RAC in their January 2014 meeting and approved by the Board in late March. A PAC is being formed and RFP is expected summer 2014.

14. WRRF-14-02, Establishing additional log reduction credits for WWTPs (Contractor: TBD)

The objectives are as follows:

- Obtain more accurate picture of the microbial treatment requirements by addressing the major source of uncertainty—the concentration of pathogens in raw wastewater and secondary effluent
- Establish if there is any correlation between the number of pathogens in raw wastewater and secondary effluent
- Establish removal credit for biological treatment provided (e.g., activated sludge) for protozoa, bacteria, and viruses

- Determine validity of pathogen log-removal requirements identified by CDPH for potable reuse projects.

  Project Update: This project was developed by the RAC in their January 2014 meeting and approved by the Board in late March. A PAC is being formed and RFP is expected summer 2014.

15. WRRF-14-03, Develop Methodology of comprehensive (fiscal/triple bottom line) analysis of alternative water supply projects compared to DPR

    The objective of this project is to develop and demonstrate an assessment method (spreadsheet, database, or other) to provide information to decision makers in considering the full economic, social, and environmental impacts of a DPR water supply versus other alternative supplies.

    Project Update: This project was developed by the RAC in their January 2014 meeting and approved by the Board in late March. A PAC is being formed and RFP is expected summer 2014.

16. WRRF-14-08, Economics of Direct Potable Reuse (Contractor: Stratus Consulting)

    The objective of this project is to estimate the capital costs of DPR using existing treatment technologies (including monitoring equipment) along with an estimate of the operating costs. These estimated costs and the energy requirements, including GHG emissions, will be compared to other sources of water including imported water, local surface and groundwater, brackish groundwater desalination, and seawater desalination. This will primarily focus on California. The potential cost savings from choosing DPR over alternatives will be estimated as well. In addition, the estimated total volume of "new water" that could be generated from DPR in California will be estimated.

    Project Update: This project was sole-sourced to Bob Raucher (Stratus Consulting) and began in April. The white paper is due to complete in July 2014.

17. WRRF-14-10, Enhanced Pathogen and Pollutant Monitoring of the Colorado River Municipal Water District Raw Water Production Facility at Big Spring Texas (Contractor: Carollo)

    The objective of this project is to create a DPR Monitoring Guidelines document that makes recommendations for long-term monitoring at facilities like the one at Big Spring. It will take into account the results of the in-depth sampling conducted during this study, and develop a robust monitoring approach to reduce risk to public health while keeping costs low through the use of appropriate process monitoring and surrogate measurements.

A team led by Carollo was recently awarded a grant funded by the Texas Water Development Board (TWDB) to study the water quality delivered by the RWPF. This team is in the process of developing a testing protocol to demonstrate the water quality produced by RWPF. As part of this testing, state of the art online monitoring approaches and surrogate testing are proposed to compliment analyses for pathogens (virus, protozoa, and bacteria) and trace pollutants (pharmaceuticals, endocrine disruptors, disinfection by products, flame retardants, perfluorinated compounds, and others).

The current study provides a detailed review of system performance in accordance with public health and Texas Commission on Environmental Quality (TCEQ) regulatory objectives. The additional funding from WRRF for this TC project allows a substantial expansion of project scope and value. This additional sampling and laboratory work would be done concurrent with funded efforts. This additional research will increase the breadth and statistical accuracy of the data set, which is necessary for this research to have national recognition.

Project Update: This project was accepted as part of the Tailored Collaboration Program in May 2014. A PAC is being formed and the project is expected to begin August 1, 2014.

18. WRRF-14-12, Failsafe Potable Reuse Project at the City of San Diego's Advanced Water Purification Demonstration Facility (Contractor: Trussell Technologies)

This project will develop and examine a conceptual framework for a direct potable reuse facility for the California Department of Public Health (CDPH) at the City of San Diego's newly upgraded Advanced Water Purification Demonstration Facility (AWPF). It is envisioned that the conceptual framework will address issues beyond the treatment plant, such as source control, required operator training and certification, product water delivery and mixing strategies/requirements, as well as a plan to provide an alternative potable water supply in emergency scenarios and to ensure that extreme events do not compromise public health. There could be other necessary components of this framework that have yet to be defined. However, these aspects of the framework are not the focus of the specific testing program of the project, which will focus on demonstrating that a proper combination of today's established treatment technologies and on-line monitors are capable of providing the backbone of a reliable potable reuse project. The AWPF treatment plant has been modified to incorporate redundancy, both in treatment processes and on-line monitors; so that it can be ensured that adequate barriers are always in place to protect public health. The AWPF also incorporates a robust treatment train with diverse processes that are able to address various contaminants at varying concentrations. The demonstration facility will be evaluated in a manner that aims to demonstrate that the environmental buffer used in today's potable reuse projects in California can be eliminated. The project will be highlighted by an expert panel workshop that will consider the knowledge base developed by the WateReuse Research Foundation to date in outlining specific guidelines that will better define the needs of a direct potable reuse facility. Per Senate Bill 918, the CDPH must report on the feasibility of direct potable reuse by the end of 2016 and a National Water Research Institute (NWRI) expert panel has been contracted with the State of California to, among many other things, evaluate the feasibility of direct potable reuse. The primary

goal of this project is to inform the panel discussion and engage the CDPH in concepts that will encourage direct potable reuse.

Project Update: This project should start fall 2014 after successful contract negotiation between SDCWA, City of San Diego, WRRF, and Trussell.

19. WRA-14-01, Developing Direct Potable Reuse Guidelines (Contractor: NWRI)

Project Duration:

- Project Start – April 2014
- Draft Report Due – November 2014
- Estimated Publication Date – December 2014

The project will develop a White Paper with the purpose of identifying topics and issues that need to be addressed in the development of future national potable reuse guidelines. Guidelines for potable reuse would focus on issues such as public health protection, sufficient multiple barriers, risk assessment, water quality monitoring, and operation management. At present, six U.S. states (i.e., California, Texas, New Mexico, Oregon, Florida, and Arizona) have standards and/or guidelines for potable reuse under development, while many more are interested in receiving guidance. Federal guidelines on potable reuse do not currently exist and are not expected to be forthcoming.

This White Paper will be developed by an Expert Panel conducted by NWRI. The panel will meet several times to develop a comprehensive source of information and expert judgment on DPR, eview current state standards and guidelines efforts, and review decision factors and public protection goals for DPR. The first expert panel meeting is expected to occur in August. In June, a conference call was conducted with the PAC, the Panel Chair (George Tchobanoglous), Joe Cotruvo (Panel member), and Jeff Mosher of NWRI.