NATIONAL WATER RESEARCH INSTITUTE

Final Report

of the February 18-19, 2014, Meeting of the

Independent Advisory Panel

for the

LOTT Clean Water Alliance
Reclaimed Water Infiltration Study

August 11, 2014
Fountain Valley, California

DISCLAIMER

This report was prepared by an NWRI Independent Advisory Panel, which is administered by the National Water Research Institute (NWRI). Any opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes.

ABOUT NWRI

A 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

For more information, please contact:

National Water Research Institute
18700 Ward Street
P.O. Box 8096
Fountain Valley, California 92728-8096 USA
Phone: (714) 378-3278
Fax: (714) 378-3375
www.nwri-usa.org

Jeffrey J. Mosher, Executive Director
Gina Melin Vartanian, Editor

Publication Number: NWRI-2014-03

CONTENTS

ACRONYMS

ADI	Acceptable daily intake
DWEL	Drinking water equivalent level
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
LOEL	Lowest observed effect level
MCL	Maximum contaminant level
mgd	Million gallons per day
NDMA	N-Nitrosodimethylamine
NOEL	No observed effect level
NRC	National Research Council
NWRI	National Water Research Institute
PFC	Perfluorinated compound
PPCP	Pharmaceuticals and personal care products
PTFE	Polytetrafluoroethylene
SAT	Soil aquifer treatment
TTC	Threshold of toxicological concern
WHO	World Health Organization
WRMP	Wastewater Resource Management Plan
WWTP	Wastewater treatment plant

1. PURPOSE AND HISTORY OF THE PANEL

In 2013, the National Water Research Institute (NWRI) of Fountain Valley, California, a 501c3 nonprofit, appointed local and national water industry experts to an Independent Advisory Panel (Panel) to provide a credible, third-party science-based review the "Reclaimed Water Infiltration Study" proposed by the LOTT Clean Water Alliance of Olympia, Washington.

The multi-year scientific study by LOTT will focus on determining potential human and/or ecological health risks from the infiltration of reclaimed water into local groundwater (particularly, the impacts of pharmaceuticals and personal care products [PPCPs]) and approaches to reduce those risks. The goal of the LOTT study and Panel review is to help policymakers make informed decisions about future reclaimed water treatment and uses.

1.1 Description of the Project

The LOTT Clean Water Alliance is a wastewater utility whose members include the Cities of Lacey, Olympia, and Tumwater, and Thurston County in Washington State. Currently, most of the wastewater is treated at the Budd Inlet Treatment Plant and discharged into the Budd Inlet at the southern tip of Puget Sound. As part of its long-range plan to manage wastewater, LOTT is engaged in increasing the production of Class A Reclaimed Water, the highest quality of reclaimed water as determined by the State Departments of Ecology and Health.

LOTT has built a Reclaimed Water Satellite System to produce 2 million gallons per day (mgd) of reclaimed water. The system includes the Martin Way Reclaimed Water Plant, which employs a membrane bioreactor for primary, secondary, and tertiary treatment. The water is then piped to the Hawks Prairie Reclaimed Water Ponds and Recharge Basins, where it circulates through five constructed wetland ponds that also serve as a public park and ecosystem for local wildlife. Afterwards, the water flows into recharge basins to infiltrate into the aquifer.

LOTT also produces about 1 mgd of Class A Reclaimed Water at its Budd Inlet Treatment Plant using a sand filter technology. Most of this reclaimed water is currently used for irrigation, toilet flushing, water features, and process uses within the treatment plant. Additional infiltration sites, including the Henderson site, are currently planned for future application.

Recently, questions and concerns about the infiltration of reclaimed water have been raised. To address these questions, LOTT is beginning a multi-year scientific study to achieve the following:

1. Provide scientific data and community perspectives to help policymakers make informed decisions about future wastewater and reclaimed water treatment and uses.

2. Ensure that the scientific study and public involvement processes are credible, objective, transparent, responsive, and responsible.

3. Foster meaningful, community-wide dialogue about water quality, reclaimed water, groundwater recharge, risk assessment, and related watershed issues.

The primary study question is as follows: *What are the risks from infiltrating reclaimed water into groundwater because of chemicals that may remain in the water from products people use every day, and what can be done to reduce those risks?*

Environmental assessments, including surface water and groundwater sampling, geologic exploration and testing, and laboratory testing, will be completed during various study phases. The nature of these sampling programs, contaminants to be monitored, sampling locations, and sampling frequency will be developed through the study scoping effort as preliminary information, planning data, and study needs are assessed among key project stakeholders. The Hawks Prairie Reclaimed Water Ponds/Recharge Basins, which are already in operation using reclaimed water, will be used as the primary site to test the fate and transport questions.

The expert Panel was organized in 2013 by NWRI at the request of LOTT to review study efforts and advise the study team at specific milestones to ensure a credible, independent, transparent, and science-centered review of the scope, field work methods and results, modeling development, and study outcomes.

1.2 Panel Members

The Panel is made up of six experts in areas related to the infiltration of reclaimed water, including water reuse and public health criteria, toxicology, environmental geology, environmental health, and other relevant fields. Panel members include:

- *Panel Chair:* James Crook, Ph.D., P.E., Water Reuse and Environmental Engineering Consultant (Boston, MA)
- Richard Bull, Ph.D., MoBull Consulting (Richland, WA)
- Jennifer Field, Ph.D., Oregon State University (Corvallis, OR)
- Evan Gallagher, Ph.D., M.E.M., University of Washington (Seattle, WA)
- Roy Haggerty, Ph.D., R.G., Oregon State University (Corvallis, OR)
- David Stensel, Ph.D., P.E., University of Washington (Seattle, WA)

Background information about the NWRI Panel process can be found in Appendix A, and brief biographies of the Panel members can be found in Appendix B.

2. PANEL MEETING

A 2-day meeting of the Panel was held on February 18-19, 2014, at LOTT's administrative offices and WET Science Center in Olympia, Washington. This was the first time the Panel met to review LOTT's Reclaimed Water Infiltration Study.

2.1 Background Material

Prior to the meeting, LOTT provided the following background material and reports to the Panel:

- *Scope of Services for the LOTT Clean Water Alliance Reclaimed Water Infiltration Study: Phase III – Study Implementation* (draft dated January 28, 2014)
  The scope of services includes:
  - Water Quality Characterization
  - Treatment Effectiveness Evaluation
  - Risk Assessment
  - Cost/Benefit Analysis
  - Public Involvement
  - Project Report
  - Interim Project Meetings and Presentations
  - Peer Review
  - Project Management

- *Groundwater Recharge Scientific Study- Phase 1 (Technical Data Review), Technical Memorandum – "State of the Science"* (dated May 31, 2013).
  The technical memorandum includes the following sections:
  - Major Classes of Contaminants Present in Wastewater, Treated Wastewater, and Reclaimed Water
  - Contaminant Removal through Wastewater Treatment and Water Reclamation (In Plant) Processes
  - Contaminant Removal through Soil Aquifer Treatment
  - Relative Risks Associated with Reclaimed Water

- *LOTT Clean Water Alliance Reclaimed Water Infiltration Study Phase 1 (Technical Data Review), Technical Memorandum – Case Study Summary* (dated July 26, 2013)

- *Two-page document titled, "Questions for Peer Review: LOTT Clean Water Alliance Reclaimed Water Infiltration Study"* (dated Feb. 14, 2014, and updated Feb. 19, 2014)

2.2 Meeting Agenda

Staff from NWRI, LOTT, and the consultant team collaborated on the development of an agenda for the 2-day Panel meeting, which is included in Appendix C. The agenda was based on meeting the following objectives:

1. Provide an overview of the LOTT Clean Water Alliance mission, Wastewater Resource Management Plan (WRMP), and Reclaimed Water Program.

2. Present the structure, concept, and efforts to date of the Reclaimed Water Infiltration Study.

3. Tour LOTT's Martin Way Reclaimed Water Plant and Hawks Prairie Recharge Facility.

4. Review the draft scope of work for Phase 3 of the study with the consultant team.

During the first day of the meeting, LOTT staff members provided brief introductions and background information about LOTT and its reclaimed water program before hosting a tour of relevant sites, including Martin Way Reclaimed Water Plant and the Hawks Prairie Recharge Facility. Upon returning from the tour, the consultant team gave an overview of the study's draft scope of work.

Presentations included:

- Introduction to LOTT
- Cleaning and Restoring Water for Our Communities: LOTT's Reclaimed Water Program
- LOTT Treatment Facilities and the Reclaimed Water Infiltration Study
- Advisory Groups, Surveys, and Other Public Outreach Associated with the Study
- Overview of the Proposed Study Scope of Work

Time was allowed for questions and discussion between LOTT staff, the consultant team, and Panel members following each presentation. On the second day of the meeting, additional members of the consultant team were made available to answer questions from the Panel. The Panel then met in a closed session to develop a draft report outline, which is expanded upon in this report.

2.3 Meeting Attendees

All Panel members attended this meeting with the exception of Dr. Richard Bull. Other attendees included NWRI staff, LOTT staff, and consultant team members. A complete list of Panel meeting attendees is included in Appendix D.

3. FINDINGS AND RECOMMENDATIONS

The principal findings and recommendations derived from the material presented and discussed during the meeting are provided below. The findings and recommendations are organized under the following categories:

- General Comments
- Site Characterization
- Tracer Tests
- Ecological Health Risk
- Human Health Risk
- Monitoring (Analytes, Methods, Locations, etc.)
- Panel Response to Study Questions

3.1 General Comments

- LOTT and the communities it serves are to be commended for their care of the environment, water conservation efforts, and significant efforts in addressing wastewater management.

- LOTT is to be commended for adopting a scientific approach to investigating the fate of reclaimed water following aquifer recharge and for working to ensure that the scientific investigation is credible, objective, and transparent.

- It was clear to the Panel that LOTT's outreach program is an integrated element in the wastewater treatment operation and is important to the public in the communities that LOTT serves.

- The Panel commends LOTT and the project team for excellent work with the meeting preparation, presentations, and site tour.

- A site assessment at a secondary site (such as the Henderson site) would be useful. Regarding the Henderson site:

    - The Henderson site was characterized as having permeable sand lenses and gravels, as well as fractured flow with no appreciable soil development. The depth of the vadose zone at the Henderson site is less than that at the Hawks Prairie site. Contaminant attenuation may be different at the Henderson site than at the Hawks Prairie site, and waters reintroduced at the Henderson site are closer to potential downgradient supply wells and the Deschutes River.

    - The reclaimed water infiltrated at the Henderson site would be from a different wastewater treatment plant (WWTP) than that used for infiltration at the Hawks Prairie site; thus, it may contain different constituents of concern.

- Because the site characteristics at the Henderson site may differ from those at the Hawks Prairie site, one cannot extrapolate the conditions from the Hawks Prairie site to the Henderson site.

- Initial studies aimed at understanding a site's ability to accept infiltrated water is needed, but it is important to know if contaminants are able to transport more rapidly to downgradient wells at the Henderson site due to sediment/soil characteristics and aquifer properties.

- If the goal of LOTT's studies is to determine the risk associated with using reclaimed wastewater for groundwater recharge, it is important to establish whether the aquifer system at a proposed site is contaminated by septic system discharges or other sources prior to the introduction of LOTT reclaimed wastewater.

- The Panel suggests that LOTT encourage its academic partners to publish peer-reviewed scientific papers of results from the Reclaimed Water Infiltration Study. The study goals included ensuring that the process is "credible, objective, and transparent." Because the study appears to be planned with sufficient attention to scientific protocols and questions and represents a significant scientific opportunity, peer-reviewed publication of some of the results should be possible. Publication will increase the transparency and credibility of the study and is likely to increase public trust.

- The Panel recommends that LOTT archive the study data for future analysis, if needed. A secondary priority would be archiving a subset of water samples. Archived data should be accessible to the public. An archive of the data is important for several reasons. First, similar to the above recommendation to publish scientific results, a data archive will increase transparency and credibility. Second, the study results could be important to other wastewater treatment facilities in the U.S. and elsewhere. Third, the best scientific research makes data publicly available. Fourth, a data archive can be done cost effectively.

- Terminology can be an important component of the outreach effort. Therefore, the project team should be careful about the terminology used for chemicals.

3.2 Site Characterization

- The approach in the scope regarding soil characterization is adequate to meet the study goals. The Panel recommends taking some core samples when drilling new wells. As an enhancement to the project, core samples could be used to conduct controlled studies of the fate and transport of residual chemicals in the laboratory and to measure organic carbon content. As indicated in the *Groundwater Recharge Scientific Study Phase 1 (Technical Data Review) Technical Memorandum – "State of the Science"* (p. 18), soil organic carbon is a key parameter to determining the potential for contamination sorption. For this reason, organic carbon on soil and aquifer sediment is an important parameter for predicting contaminant transport at a site. It would be a further enhancement to the study to archive core samples for future use, but it may be beyond the

budget to do so. If core samples of aquifer sediment are archived, they could be used in the future to conduct column studies to verify estimates of contaminant sorption to site sediments.

- The approach proposed in the scope regarding aquifer permeability and storage is appropriate. The Panel notes that it will be useful to obtain the highest quality aquifer permeability and storage data possible. Recognizing that pump tests will not be possible on all wells because of constraints of budgets and well diameters, the Panel recommends doing slug tests where possible. As the LOTT team is aware, slug test data is not as accurate as production well aquifer tests, but can assist in determining aquifer parameters.

- The approach proposed in the scope regarding monitoring various aquifers is appropriate. The Panel notes that observations are needed to determine vertical head gradient in the shallow aquifer, confining layer, and deeper aquifer so that both horizontal and vertical migration of contaminants can be adequately monitored. Some migration into the lower aquifer might be possible; if so, that aquifer would need to be monitored. We recognize that multi-level samplers are not feasible. Nested monitoring wells completed at different depths should be sufficient.

- The proposed approach in the scope regarding groundwater movement is reasonable. However, the Panel recommends LOTT consider the potential for transient flow and transient gradients in the system. Groundwater movement is assumed to be at steady-state, but this may not be the case. Direction and rate of flow could change throughout the monitoring period, particularly with changes in aquifer recharge and seasonal changes in boundary conditions.

3.3 Tracer Tests

- The approach for the tracer test of up to 12 months in the proposed scope is reasonable. The Panel recommends that tracers be injected as long as possible and monitored for as long as 12 months. More than likely, the groundwater system is not pristine and is impacted by septic systems and other sources. Input of constituents to the groundwater from these sources could be transient and may not be detected by a tracer study that is short in duration.

- Reducing the field challenges of long-term injection is important. One option may be to inject the tracer at the WWTP. The proposed approach involving an automated pumping system to deliver the tracer in the discharge piping before it enters the basins is reasonable.

- Bromide and SF_6 are both excellent tracers, are conservative under most situations within groundwater, have been widely used, and are likely to produce useable results with the outlined study plan. As an enhancement to the project, LOTT may want to consider additional added tracers (reactive and non-reactive) that could be monitored using existing analytical techniques without additional costs to supplement the analysis.

- The sampling frequency and spatial resolution of wells for tracer monitoring is important. The maximum number of wells and the maximum sampling events in the scope are justified. The decisions about number of wells and sample frequency are reasonable, given that the study team has already considered higher sampling frequency and more wells, and that these numbers are similar to those used at other similar sites.

- The current focus of the tracer study is on two chemicals selected for their conservative behavior. The Panel agrees that bromide and SF_6 are among the best tracers. Both SF_6 and bromide do not biodegrade, nor do they sorb to aquifer sediments such that they are not retained. As indicated, SF_6 is volatile and losses are expected depending on how and at what depth SF_6 is introduced. Solutions of bromide are dense and may take a path in which the tracer cloud sinks. However, both chemicals are well suited to defining the flow path and arrival of water at downgradient sampling sites. They are not well suited for determining the behavior of potentially reactive or sorbing organic or inorganic contaminants. For this reason, intrinsic tracers (such as boron) that are present in the infiltrated reclaimed water should be considered. These intrinsic tracers can be evaluated by ratioing their concentration in the reclaimed water to that of the conservative tracers, SF_6 and bromide.

- As an enhancement to the study, LOTT could examine unique compounds in wastewater effluent (such as boron) as possible tracers. The compounds would need to be different than those from septic discharge. It may be possible to obtain water quality data of groundwater at monitoring wells that have not yet received any infiltrated reclaimed water, compare those data to reclaimed water quality data, and identify constituents in the reclaimed water that are not present in the existing groundwater (or present in much lower concentrations) that may be used as a tracer.

- The Panel would like to review where proposed wells will be located. A review of the detailed tracer and monitoring plan by the Panel may be useful to LOTT.

- If the layer of groundwater containing tracers/wastewater is small relative to a large screened interval of a well, sampling from a large screened interval may result in the dilution of groundwater containing tracer/contaminants with uncontaminated water. The result will be a lowering of concentrations in the sample, with the potential for dropping concentrations below the detection limit. Sampling narrower intervals potentially offers more information at the depth of the tracer cloud and minimizes the dilution of tracer/contaminant information.

- It would be useful to consider multi-level sampling of the groundwater, which would allow the study to develop vertical resolution within the subsurface.

- LOTT should consider high-frequency sampling of the wastewater effluent and archiving samples. Not all samples need to be analyzed immediately – many samples could be saved to add resolution where it is needed. It may be useful to be able to return to the sample archive and analyze additional samples within the timeframe of interest. To be more cost-effective, sub-compositing samples could be considered. The proper place to

do this sampling would be a location closest to the addition where the tracer is well mixed.

3.4 Ecological Health Risk

- In general, the approach and deliverables for ecological health risk seem reasonable given the scope and overall budget of the project. It will be important to characterize any potential effects from persistent chemical constituents (e.g., sucralose), which are resistant to degradation and may be used as surrogates for other residual chemicals, even though they themselves may not present a health concern. Although some aquatic toxicology studies exist indicating that sucralose does not alter the survival, growth, and reproduction of certain aquatic organisms, compounds such as these have not been extensively tested in species (e.g., salmonids) that may potentially receive exposures from such chemicals. Reviewing constituents after the Tier 1 (screening) assessment for the aquatic ecotoxicology effort is reasonable.

- In addition to the ECOTOX database, the Panel recommends a thorough review of other literature for sub-lethal effects of residual chemicals because the sub-lethal effects (i.e., those that occur at concentrations below those that elicit mortality) will be more relevant than lethal exposures. These sub-lethal effects include such endpoints as behavior and reproduction, which have been shown to affect the survival of aquatic wildlife. In this regard, for the "no observed effect levels" (NOELs) and "lowest observed effect levels" (LOELs), it will be important to discriminate the endpoints that these metrics are based on (i.e., growth, reproduction, behavior, etc.).

- The Panel is uncertain of the value of assessing ecological risk related to the use of reclaimed water for landscape irrigation.

3.5 Human Health Risk

- A complete human risk assessment of potable reuse projects cannot be quantitative because of a large number of unknowns that are typically not addressed in the risk analyses. One reason is the presence of unknown compounds (largely trace organic chemicals). Another reason is the lack of appropriate toxicological data in humans or experimental animals suitable for estimating the risks they might pose. The absence of data does not translate into a lack of risk. Therefore, the emphasis of risk assessments in the area of potable reuse should focus on information that speaks broadly to the overall risk rather than the minutiae of the assessment of risk for individual chemicals. Assessing individual contaminants of the water, especially active ingredients of PPCPs, is more useful as illustrations of how effective the treatment processes are in removing chemicals than providing reliable estimates of overall risk. If done systematically, the effectiveness of treatment could allow for predicting whether other unidentified related chemicals are removed. Uncertainties in the risk assessment will remain, but examining a broad database will allow this uncertainty to be narrowed based upon the performance of the treatment train.

- The specific question with the scope is that it addresses a narrow group of contaminants. Many of the analytes chosen were selected because they could be detected with a single method of analysis. They were not necessarily chosen because of a higher probability of occurrence than related compounds (e.g., in the same pharmacological class or mode of action). The relative potency of the chemicals has not been used in the selection. The selection also did not necessarily include analytes that act as surrogates that will reflect the removal of other chemicals. Therefore, the risk assessment can be used to see if there is a problem with one of the measured compounds, but it will not necessarily provide a basis of comparing the abilities of different treatment processes to diminish overall risk. The scope of the project could be narrowed to reflect what can be accomplished with the analyses that are proposed.

- The risk model proposed could be designed to address chemicals that are found in local wastewater. The major concern related to the potable reuse of municipal wastewater remains the potential that unknown trace organics may present hazards to human health. Consequently, it is important that efforts be made to identify chemicals present in the system being studied. The most efficient means of identifying such chemicals is a source control program that actively identifies and monitors non-domestic waste discharges to the wastewater collection system.

- Data were not provided related to the occurrence of contaminants in the wastewater being treated for current water reuse applications. Reference is made to some analysis of three systems (one of which was LOTT) published by the Washington State Department of Ecology. The list of chemicals appears to be largely confined to pharmaceuticals. As demonstrated in the 2012 National Research Council (NRC) report on *Water Reuse*,[1] these compounds are likely not of concern.

- Demonstrating due diligence will help gain public confidence. The present effort should characterize the performance at the recharge site(s) under consideration. Chemicals with maximum contaminant levels (MCLs) and state action levels should be addressed in this analysis.

- There are some challenges in the proposed analysis of risk that will prevent the risk analysis from being quantitative. These are:

    - Characterization of unknown compounds, as described above.

    - The methods used for arriving at points of departure are not equivalent. Traditional methods, based on risk assessment paradigms of the U.S. Environmental Protection Agency (EPA), World Health Organization (WHO), and U.S. Food and Drug Administration (FDA), use human and/or animal data that are acceptable methods for estimating risk quantitatively (not necessarily failsafe). These can extend to other methods that indirectly use human data as a gauge of human sensitivity with some confidence. However, screening methods

[1] National Research Council (2012). *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater*, National Academies Press, Washington, D.C.

based on loose analogies to structural and functional groups are not intended to be risk assessment tools, but rather methods of triage (e.g., thresholds of toxicological concern [TTCs] to identify chemicals for which new toxicological data are necessary). These methods were developed primarily to address the likelihood that minor contaminants of various commercial products are of sufficient concern. While there is no objection to utilizing these methods for their intended purposes, they should not be used to generate acceptable daily intakes (ADIs). As long as the chemical occurs at concentrations below its TTC, it should be eliminated from the risk assessment. A compound above its TTC should be identified, but it should not be concluded that this compound presents a significant health risk.

- The estimates generated by the variety of methods proposed must always be identified with the method of derivation. These are not equivalent indicators of risk.

3.6 Monitoring (Analytes, Methods, Locations, etc.)

- The Panel agrees that lysimeters are useful as part of the study as planned.

- The January 28, 2014, *Scope of Services Phase III – Study Implementation* report includes information regarding monitoring for pathogens or indicator organisms, including total and fecal coliform organisms and coliphage to characterize WWTP effectiveness. The Panel recommends that LOTT also sample WWTP water for *Cryptosporidium*.

- The selection of chemical analytes is reasonable given budgetary constraints, notwithstanding the discussion of the risk assessment approach in Section 3.5. To support the risk assessment goals, other specific compounds that should be analyzed may need to be identified.

- The Panel agrees that perfluorinated compounds (PFCs) should be included in the study. These compounds are under scrutiny due to their wide-scale production and uncertainties regarding their toxicity to humans and aquatic organisms. The EPA's Unregulated Contaminant Monitoring Rule 3[2] lists six PFCs and offers an explanation of their potential health effects.

    - If perfluoroalkyl substances are added to the monitoring list, precautions need to be taken at the time of any well installation or sampling to avoid materials containing polytetrafluoroethylene (PTFE) (e.g., Teflon).

- LOTT should consider including constituents with drinking water MCLs as part of the monitoring plan. In addition, LOTT should provide the rationale as to why some contaminants are included in the monitoring plan and others are not.

[2] http://water.epa.gov/lawsregs/rulesregs/sdwa/ucmr/ucmr3/index.cfm

3.7 Panel Response to Study Questions

As the study scope of work has been developed, LOTT has compiled a list of questions from several sources. Selected questions that seemed most appropriate for the Panel to address were provided to the Panel at their first meeting. Those questions came from members of the Community Advisory Group, members of the public, public workshops, and members of the study's Science Task Force and/or LOTT Technical Sub-Committee. The Panel's responses are provided below. In some cases, additional clarification was needed.

3.7.1 Study Methodology Questions

- *Question 1 – Are the analytical methods to be used by Eurofins Analytical going to be comparable to PPCP study results from Ecology (and potentially the University of Washington) and the Case Studies provided by HDR? Are any of the constituents typically found to remain after SAT (like sulfamethoxazole) more likely to present problems with comparability?*

  The PPCP analytical method used by Eurofins-Eaton Analytical is capable of providing results at the low levels (i.e., in the nanogram per liter level) and, therefore, would be comparable to other studies.

  A number of chemicals are less amenable to removal through soil aquifer treatment (SAT) (including, but not limited to, sulfamethoxazole). In general, levels found in municipal wastewater are below levels of concern. However, the Panel cannot make definite statements in response to this question without reviewing the appropriate monitoring data.

- *Question 2 – For evaluating SAT effectiveness, is it more important to establish site selection criteria based on estimated time of travel, distance from the infiltration location, or some combination of both? Which would give us the most information for the proposed level of effort (i.e., 12 offsite wells), and do you have recommendations for locating the wells?*

  Of the two site selection criteria mentioned in the question, it would be more important to establish criteria based on the time of travel (time is important for pathogen reduction in the underground and attenuation/degradation of chemical constituents). However, site selection should include a range of criteria, including site geology, geochemistry, hydrology, and so forth.

- *Question 3 – Can the results from the Hawks Prairie analysis be used to develop a template that can be applied to other future sites?*

  Assuming the additional sites undergo a site assessment as characterized in the scope, it is reasonable that the work at Hawks Prairie can later be applied to future sites, such as Henderson. As long as the site assessments characterize soils, hydrogeology, geochemical conditions (e.g., redox conditions, organic matter content), and other site-

specific parameters, the results could be transferrable. A minimum travel time before infiltrated reclaimed water reaches a drinking water well is reasonable.

- *Question 4 – How important would it be to have a second site as part of the study?*

  It will be necessary to evaluate the effectiveness of SAT and other conditions at each individual site. The value of a second site is to gain some understanding of the variability in effectiveness of SAT from one LOTT site to another. Clearly, there is some value in a second site, provided that basic site characterization can be done and that measurements of attenuation of residual chemicals can be made.

- *Question 5 – Are the sampling locations, frequencies, and intensities appropriate to achieve 95-percent accuracy?*

  Although if may not possible to achieve a specified accuracy for all the constituents, the information collected in this study will be able to provide important information in characterizing and understanding the role of the SAT in attenuating chemical constituents.

- *Question 6 – Is the proposed duration of tracer study monitoring (6 months) sufficient? Why not extend beyond 6 months?*

  The tracer study approach in the scope (i.e., up to 12 months for the tracer study) is reasonable. The actual monitoring period will be adapted to the data. If early breakthrough occurs, then prolonged observation will be less valuable.

- *Question 7 – Can full-scale contaminant loading be accurately accounted for/simulated with the proposed methodology of installing a berm in Basin 4 at the Hawks Prairie site?*

  The berm at the Hawks Prairie site will help create a loading rate similar to the full-scale operation. This is a reasonable approach. The only limitation is caused by site heterogeneity. If the section of the basin where the test occurs is different than the larger basin, then results may be skewed. However, in the estimation of the Panel, it is more valuable to use a fraction of the basin at full recharge rate and have more uncertainty about heterogeneity, than to have a smaller recharge rate with less uncertainty about heterogeneity.

- *Question 8 – Is it acceptable to eliminate background characterization of the deeper aquifer at Hawks Prairie?*

  The project scope mentions that several deep monitoring wells will be completed at both sites and that some of these will be used to create piezometer nests to measure and monitor vertical gradient. This is adequate for monitoring the hydrology. It would be useful to include a small number of samples before, during, and after the tracer test to monitor tracer and residual chemicals. The deeper wells could also be monitored periodically in the long term for residual chemicals.

3.7.2 Background Sampling

- *Question 1 – What level of effort is appropriate for background sampling at Hawks Prairie and in other areas?*

  Some background monitoring has been previously conducted that provides some information on background groundwater quality. The approach proposed in the scope will evaluate reclaimed water loading over background loads. Now that reclaimed water in infiltrating at Hawks Prairie, more background sampling is not possible.

- *Question 2 – For background sampling, isn't it important to characterize groundwater at various times of year/seasons to account for seasonal variations in precipitation/groundwater levels?*

  In general, it would be useful to characterize groundwater at various times of the year. However, given a limited amount of available resources, there is a trade-off between seasonal sampling and sampling a larger number wells. Obtaining one sample at a larger number of wells may provide a greater benefit than multiple (seasonal) sampling at fewer wells. A separate study would be needed to characterize the specific benefits for seasonal sampling versus sampling a larger number of wells. Sampling a larger number of wells would support the study objectives.

- *Question 3 – Surface water characterization – why collect at "first flush" and high-flow inter [sic]? Are these really the best times to collect if the point is to characterize as relates to reclaimed water infiltration?*

  Phenomena other than wastewater in the watershed are more likely to impact first flush signatures.

3.7.3 Risk Assessment Questions

- *Question 1 – Is the risk model proposed appropriate for this project and protective of human health?*

  The proposed risk assessment model involving assessment of individual contaminants in the water is sufficient for illustrating the effectiveness of the treatment processes for removing the chemicals. At the level of detail implied by the analyses that are to be performed, the Panel believes the study team should confine their risk analyses to relative risks of specific chemicals found in the percolated water with that observed in the wastewater being applied. The Panel discussed aspects of the risk assessment and risk model component of the study in Section 3.5.

- *Question 2 – Is the risk assessment approach objective and credible?*

  The proposed risk assessment approach is objective and credible within the limitations discussed in Question 1 above and in Section 3.5.

- *Question 3 – Are there other more vigorous approaches that are more protective of public health that should be considered?*

  See the response to Question 1 above. In addition to the risk assessment, it will be useful to characterize the wastewater and reclaimed water after treatment (including after SAT).

- *Question 4 - Is the initial list of Tier 1 residual chemicals sufficient?*

  In an initial characterization of a new drinking water source, the Tier 1 analyses (i.e., a first analysis) should include frequent contaminants of drinking water, such as the group of chemicals that have MCLs and Health Advisories. It is assumed that Tier 2 analyses are to be directed towards derivation of more precise estimates of risk if such data are not available. The list of chemicals being assessed in the proposed analysis include active ingredients of PPCPs which, as demonstrated in the 2012 NRC report, are likely not of significant health concern at concentrations usually encountered in treated wastewater. The January 28, 2014, *Scope of Services Phase III – Study Implementation* report indicates that some additional residual chemicals (e.g., NDMA, 1,4-dioxane, nitrate, and metals) will be included. These fit into a similar category as the chemicals having MCLs or Health Advisories. If the study scope includes the proposed list of residual chemicals, along with the additions recommended by the Panel (e.g., MCLs, Health Advisories, PFCs, and *Cryptosporidium*), it would be sufficient and in keeping with other studies of this nature.

- *Question 5 – Are the data reduction methods which generate the Tier 2 list of chemicals appropriate?*

  The distinction between Tier I and Tier II needs to be well defined. The transition between Tier 1 and Tier II is based upon the frequency of a contaminant's occurrence and its probability of exceeding some reference risk level (defined in the context of cancer and non-cancer risk). A variety of methods are used, but their grounding in the available toxicological literature is different. Nevertheless, the intent seems to combine (or integrate) the outputs from these different analyses into a combined estimate of risk without distinction among the methodologies used. An explicit description of the two-tiered approach would be useful.

- *Question 6 – Is the Tier 2 Human Health risk assessment approach appropriate?*

  The Tier II assessment apparently relies on further examination of the health effects data, plus some consideration of interactive and additive effects among contaminants. However, the methods of risk assessment in Tier I and Tier II are not clearly distinguished between the two tiers. Also, some of the modes of action identified with the measured chemicals are found among more common contaminants of water that are not included in the chemical analyses of the waters in question. Consequently, the Panel would like to have an additional review of the implementation of the health effects risk

assessment approach, including the scientific justification for combining estimates arrived at by different methodologies.

- *Question 7 – Does the proposed approach for the ecological risk assessment seem complete?*

  In general, the deliverables for ecological health risks seem reasonable (with some caveats) given the scope and overall budget of the project. These are mostly associated with the state of ecological risk assessment and include the limitations of performing extrapolations of literature studies using fish (e.g., fathead minnows, rainbow trout) that are not the actual aquatic species of concern that may receive chemical exposures in this scenario. There also exists a high level of uncertainty associated with extrapolations from the laboratory data to the field situation, as well as the probability of a lack of scientific data on sublethal injuries to the target ecological receptors (e.g., Chinook or Coho salmon). Furthermore, it is unlikely that any trace organic chemicals at levels of ecological health concern would be present in the groundwater after SAT; therefore, the Panel suggests studies in this area be limited to metals. In addition, unless background sampling of the receiving waters is conducted, it would be difficult to prove chemicals detected in fish originate from the groundwater inputs or are of sufficient magnitude to elicit adverse biological effects. Additional Panel comments on the ecological risk assessment are provided in Section 3.4 of this report.

APPENDIX A: Panel Background

About NWRI

For over 20 years, NWRI – a science-based 501c3 nonprofit located in Fountain Valley, California – has sponsored projects and programs to improve water quality, protect public health and the environment, and create safe, new sources of water. NWRI specializes in working with researchers across the country, such as laboratories at universities and water agencies, and are guided by a Research Advisory Board (representing national expertise in water, wastewater, and water reuse) and a six-member Board of Directors (representing water and wastewater agencies in Southern California).

Through NWRI's research program, NWRI supports multi-disciplinary research projects with partners and collaborators that pertain to treatment and monitoring, water quality assessment, knowledge management, and exploratory research. Altogether, NWRI's research program has produced over 300 publications and conference presentations.

NWRI also promotes better science and technology through extensive outreach and educational activities, which includes facilitating workshops and conferences and publishing White Papers, guidance manuals, and other informational material.

More information on NWRI can be found online at www.nwri-usa.org.

About NWRI Panels

NWRI also specializes in facilitating Independent Advisory Panels on behalf of water and wastewater utilities, as well as local, county, and state government agencies, to provide credible, objective review of scientific studies and projects in the water industry. NWRI Panels consist of academics, industry professionals, government representatives, and independent consultants who are experts in their fields.

The NWRI Panel process provides numerous benefits, including:

- Third-party review and evaluation.
- Scientific and technical advice by leading experts.
- Assistance with challenging scientific questions and regulatory requirements.
- Validation of proposed project objectives.
- Increased credibility with stakeholders and the public.
- Support of sound public-policy decisions.

NWRI has extensive experience in developing, coordinating, facilitating, and managing expert Panels. Efforts include:

- Selecting individuals with the appropriate expertise, background, credibility, and level of commitment to serve as Panel members.
- Facilitating hands-on Panel meetings held at the project's site or location.

- Providing written report(s) prepared by the Panel that focus on findings and recommendations of various technical, scientific, and public health aspects of the project or study.

Over the past 5 years, NWRI has coordinated the efforts of over 20 Panels for water and wastewater utilities, city and state agencies, and consulting firms. Many of these Panels have dealt with projects or policies involving groundwater replenishment and potable (indirect and direct) reuse. Specifically, these Panels have provided peer review of a wide range of scientific and technical areas related water quality and monitoring, constituents of emerging concern, treatment technologies and operations, public health, hydrogeology, water reuse criteria and regulatory requirements, and outreach, among others.

Examples of recent NWRI Panels include:

- **Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse** for the State Water Resources Control Board's Division of Drinking Water (CA)
- **Advanced Purified Water Treatment Plant – Phase I** for El Paso Water Utilities (TX)
- **Developing Proposed Direct Potable Reuse Operational Procedures and Guidelines for New Mexico** for the New Mexico Environment Department (NM)
- **Monterey Peninsula Groundwater Replenishment Project** for the Monterey Regional Water Pollution Control Agency (CA)
- **Groundwater Recharge Scientific Study** for the LOTT Clean Water Alliance (WA)
- **Groundwater Replenishment System Program Review** for the Orange County Water District (CA)
- **Examining the Criteria for Direct Potable Reuse** for Trussell Technologies (CA) and WateReuse Research Foundation (VA)
- **Evaluating Potable Reuse** for the Santa Clara Valley Water District (CA)
- **Indirect Potable Reuse/Reservoir Augmentation Project Review** for the City of San Diego (CA)
- **BDOC as a Surrogate for Organics Removal in Groundwater Recharge** for the California Department of Public Health (CA)
- **Effluent Master Plan** for Tucson Water (AZ)
- **Groundwater Replenishment Project Review** for the Los Angeles Department of Water and Power (CA)

More information about the NWRI Independent Advisory Panel Program can be found on the NWRI website at http://nwri-usa.org/Panels.htm.

APPENDIX B: Panel Member Biographies

James Crook, Ph.D., P.E. (Panel Chair)
Water Reuse and Environmental Engineering Consultant (Boston, MA)

Jim Crook is an environmental engineer with more than 40 years of experience in state government and consulting engineering arenas, serving public and private sectors in the U.S. and abroad. He has authored more than 100 publications and is an internationally recognized expert in water reclamation and reuse. He has been involved in numerous projects and research activities involving public health, regulations and permitting, water quality, risk assessment, treatment technology, and all facets of water reuse. Crook spent 15 years directing the California Department of Health Services' water reuse program, during which time he developed California's first comprehensive water reuse criteria. He also spent 15 years with consulting firms overseeing water reuse activities and is now an independent consultant specializing in water reuse. He currently serves on several advisory panels and committees sponsored by NWRI and others. Among his honors, he was selected as the American Academy of Environmental Engineers' 2002 Kappe Lecturer and the WateReuse Association's 2005 Person of the Year. Crook received a B.S. in Civil Engineering from the University of Massachusetts and both an M.S. and Ph.D. in Environmental Engineering from the University of Cincinnati.

Richard Bull, Ph.D.
Consulting Toxicologist
MoBull Consulting (Richland, WA)

Since 2000, Richard Bull has been a Consulting Toxicologist with MoBull Consulting, where he conducts studies on the chemical problems encountered in water for water utilities, as well as federal, state, and local governments. Bull is a Professor Emeritus at Washington State University, where he maintains Adjunct Professor appointments in the College of Pharmacy and the Department of Environmental Science. Formerly, he served as a senior staff scientist at DOE's Pacific Northwest National Laboratory, Professor of Pharmacology/Toxicology at Washington State University, and Director of the Toxicology and Microbiology Division in the Cincinnati Laboratories for the U.S. Environmental Protection Agency. Bull has published extensively on research on central nervous system effects of heavy metals, the carcinogenic and toxicological effects of disinfectants and disinfection by-products, halogenated solvents, acrylamide, and other contaminants of drinking water. He has also served on many international scientific committees convened by the National Academy of Sciences, World Health Organization, and International Agency for Research on Cancer regarding various contaminants of drinking water. Bull received a B.S. in Pharmacy from the University of Washington and a Ph.D. in Pharmacology from the University of California, San Francisco.

Jennifer Field, Ph.D.
Professor of Environmental and Molecular Toxicology
Oregon State University (Corvallis, OR)

Jennifer Field is a professor of Environmental and Molecular Toxicology at Oregon State University and serves as an Associate Editor for Environmental Science and Technology. From 2004-2008, Field was an editor for Water Research. Her current research includes the development and application of quantitative analytical methods for organic micropollutants and their transformation products in natural and engineered systems. Early in her career, she focused on field-based research to investigate the fate and transport of surfactants in groundwater and wastewater treatment systems. She was a pioneer in the area of fluorochemical occurrence and behavior with a focus on groundwater contaminated by fire-fighting foams, municipal wastewater treatment systems, and in municipal landfill leachates. Field received her Ph.D. in 1990 from the Colorado School of Mines.

Evan Gallagher, Ph.D., M.E.M.
Professor of Environmental and Occupational Health Sciences
University of Washington (Seattle, WA)

Evan Gallagher is a professor of Environmental and Occupation Health Sciences at the University of Washington (UW), is the Deputy Director of the UW Superfund research program, and serves on the editorial boards of Toxicological Sciences and Environmental Research. He is also an active member of the UW Center for Ecogenetics and Environmental Heath. Gallagher was formerly an Associate Professor at the University of Florida were he also served as Director of the Aquatic Toxicology Laboratory in the College of Veterinary Medicine. His research includes molecular and biochemical toxicology, focusing on environmental toxicological issues that cross ecosystem and human health boundaries. Gallagher received a B.S. in Biology from Virginia Polytechnic Institute and State University, an M.E.M. in Ecotoxicology and Environmental Chemistry, and Ph.D. in Biochemical Toxicology, both from Duke University.

Roy Haggerty, Ph.D., P.G.
Hollis M. Dole Professor of Environmental Geology
Oregon State University (Corvallis, OR)

Roy Haggerty is a professor of Environmental Geology at Oregon State University and serves as the Associate Director of the Water Resources Science program. Haggerty's research focuses on ground water-surface water interactions, flow and transport in surface and ground water, nutrient

transport, modeling, hyporheic exchange, and heat transport in streams. He has co-authored more than 50 publications since 1994. Haggerty received his B.S. in Geology from the University of Alberta, Canada, and both an M.S. and Ph.D. in Hydrogeology from Stanford University. He is also a registered geologist in the state of Oregon.

David Stensel, Ph.D., P.E.
Professor of Environmental Engineering
University of Washington (Seattle, WA)

David Stensel is a professor of Environmental Engineering at the University of Washington (UW). Before joining UW in 1984, Stensel taught in the Civil Engineering Department at University of Utah for 4 years and worked in the industry developing and applying process technology for municipal and industrial wastewater treatment for 10 years. His research includes biological treatment processes for nitrogen and phosphorus removal, biomethane production through anaerobic processing of industrial wastes and municipal wastewater treatment plant sludge, biodegradation of hazardous substances, membrane bioreactors, and biodegradation of micropollutants in activated sludge wastewater treatment. In 2003, Stensel coauthored the textbook *Wastewater Treatment Engineering: Treatment and Reuse*. He received his B.S. in Civil Engineering from Union College and both an M.E. and Ph.D. in Environmental Engineering from Cornell University.

APPENDIX C: Meeting Agenda

NATIONAL WATER RESEARCH INSTITUTE

Independent Peer Review Panel Meeting: Evaluating Reclaimed Water Infiltration Study Scope of Work for the LOTT Clean Water Alliance

PRELIMINARY Meeting Agenda

February 18-19, 2014

Location
LOTT Clean Water Alliance
500 Adams Street NE
Olympia, WA 98501
*****Board Room*****

Contacts:
Jeff Mosher (NWRI)
Cell: (714) 705-3722
Brandi Caskey (NWRI Office)
(714) 378-3278

Meeting Objectives:

- Provide an overview of the LOTT Clean Water Alliance mission, Wastewater Resource Management Plan (WRMP), and Reclaimed Water Program.
- Present the structure, concept and efforts to date of the Reclaimed Water Infiltration Study.
- Tour of LOTT's Hawk's Prairie Recharge Facility.
- Review the draft scope of work for phase 3 of the study with the consultant team.

Tuesday, February 18, 2014		**LOTT Board Room**
8:15 am	Welcome and Introductions - Panel purpose - Introductions	Jim Crook, Panel Chair
8:30 am	Overview of Panel Process	Jeff Mosher, NWRI
8:45 am	Welcome from LOTT	Cynthia Pratt, LOTT Board President
	Overview of LOTT - Mission and WRMP	Mike Strub, LOTT Executive Director
	- Drivers for Reclaimed Water Program	Karla Fowler, LOTT
9:35 am	*Open Panel Discussion and Questions*	
9:45 am	**BREAK**	

10:00 am	Overview of LOTT Treatment Facilities and Reclaimed Water Infiltration Study	Ben McConkey, LOTT
10:45 am	*Open Panel Discussion and Questions*	
11:15 am	LOTT Outreach Program	Lisa Dennis-Perez, LOTT
11:45 am	*Open Panel Discussion and Questions*	
12:00 noon	**LUNCH**	**All**
12:45 pm	Tour of the Hawks Prairie Recharge Facility	Ben McConkey, LOTT
2:45 pm	*Open Panel Discussion and Questions*	
3:00 pm	**BREAK**	
3:15 pm	Overview of Draft Scope of Work	Jeff Hansen, HDR
3:45 pm	Open Panel Discussion and Questions	
4:30 pm	**ADJOURN**	

Wednesday, February 19, 2014		**LOTT Board Room**
8:15 am	Q&A with HDR Team	
9:45 am	**BREAK**	
10:00 am	Q&A with HDR Team	
11:00 am	Closed Panel Session	Jim Crook
12:00 pm	**LUNCH**	
12:45 pm	Closed Session	Jim Crook
2:30 pm	Outgoing brief to LOTT	Jim Crook
2:45 pm	**ADJOURN**	

APPENDIX D: Meeting Attendees

Panel Members:

- *Panel Chair:* James Crook, Ph.D., P.E., Water Reuse and Environmental Engineering Consultant (Boston, MA)
- Richard Bull, Ph.D., MoBull Consulting (Richland, WA)
- Jennifer Field, Ph.D., Oregon State University (Corvallis, CA)
- Evan Gallagher, Ph.D., M.E.M., University of Washington (Seattle, WA)
- Roy Haggerty, Ph.D., R.G., Oregon State University (Corvallis, CA)
- David Stensel, Ph.D., P.E., University of Washington (Seattle, WA)

National Water Research Institute:

- Jeff Mosher, Executive Director
- Gina Vartanian, Outreach and Communications Manager

LOTT Clean Water Alliance:

- Lisa Dennis-Perez, Public Communications Manager
- Karla Fowler, Community Relations & Environmental Policy Director
- Ben McConkey, Public Facilities Coordinator and Project Manager
- Mike Strub, P.E., Executive Director

Consulting Team:

- Gretchen Bruce, DABT, Intertox
- Jordan F. Clark, Ph.D., University of California Santa Barbara (on phone)
- Peter Fox, Ph.D., Arizona State University
- Jeff Hansen, P.E., HDR Engineering, Inc.
- John Toll, Ph.D., Winward Environmental, LLC