NatVal Road Map Report

The road map to a national validation framework for water recycling schemes

Michael Muston
Muston & Associates

David Halliwell
Water Quality Research Australia

WQRA water quality research australia
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WSAA WATER SERVICES ASSOCIATION OF AUSTRALIA
Australian Water Recycling Centre of Excellence

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Location:

WQRA Head Office

Level 3, 250 Victoria Square, Adelaide SA 5000

Postal Address:

GPO BOX 1751, Adelaide SA 5001

For more information about WQRA visit the website www.wqra.com.au

NatVal - The Map to a National Validation Framework for Water Recycling Schemes

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FOREWORD

Research Report Title: NatVal - The Map to a National Validation Framework for Water Recycling Schemes

Project Leader: Dr David Halliwell

Research Officers: Principal Investigators are detailed in Section 1.5 of this report

WQRA Project No. 3009-10: NatVal - The Map to an Accepted Workable National Validation Framework for Water Recycling Schemes

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ABBREVIATIONS

ADWG	Australian Drinking Water Guidelines
AGWR	Australian Guidelines for Water Recycling
AWRCoE	Australian Water Recycling Centre of Excellence
BOM	Bureau of Meteorology
COAG	Council of Australian Governments
DAF	Dissolved Air Flotation
DALY	Disability Adjusted Life Years
ETV	Environmental Technology Verification program
EU	European Union
IP	Intellectual Property
IPART	Independent Pricing and Regulatory Tribunal
IPCS	International Programme on Chemical Safety
JAS-ANZ	Joint Accreditation System of Australia & New Zealand
LRV	Log Reduction Value
MAR	Managed Aquifer Recharge
MBR	Membrane Bioreactor
MF	Microfiltration
MOU	Memorandum of Understanding
NATA	National Association of Testing Authorities, Australia.
NatVal	The map to an acceptable, workable national validation framework for water recycling schemes
NF	Nanofiltration
NHMRC	National Health and Medical Research Council
NRWRF	National Recycled Water Regulators Forum
NSF	United States National Science Foundation
Validation Framework	National Validation Framework for Treatment Technologies
NWC	National Water Commission
OBP	Office of Best Regulatory Practice
PDT	Pressure Decay Test
PI	Principal Investigator
PSC	Project Steering Committee
RIS	Regulatory Impact Statement
RABQSA	RABQSA International (previously known as the Quality Society of Australasia) Registrar Accreditation Board by Australia-based Quality Society of Australasia
RO	Reverse Osmosis
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
TEF	Toxic Equivalency Factor

UF	Ultrafiltration
UV	Ultraviolet Disinfection
WHO	World Health Organisation
WQRA	Water Quality Research Australia
WSAA	Water Services Association of Australia

EXECUTIVE SUMMARY

The 'NatVal: The Map to an Accepted Workable National Validation Framework for Water Recycling Schemes' project was submitted to the Australian Water Recycling Centre of Excellence (AWRCoE) for funding consideration by a national collaborative research team led by Water Quality Research Australia in response to a need identified by Goal 2 of the AWRCoE Strategic Research Plan. The project was awarded to the project team through a competitive, request for proposal process.

The aim of the NatVal project was to deliver a Road Map for the development of a national validation framework for water recycling schemes in Australia, consistent with the 2006 Australian Guidelines for Water Recycling (AGWR). After significant stakeholder consultation, a National Validation Framework for Treatment Systems (Validation Framework) was developed and is outlined in this Road Map Report. The NatVal project has been staged in 2 parts, with Stage 1 NatVal delivering the Road Map as outlined in this document, while Stage 2 NatVal will implement the findings from the Road Map report to work towards implementation of the Validation Framework.

During the development of the Validation Framework, a significant number of knowledge gaps were identified. The majority of gaps fall into a few general areas, including:

- The absence of current rules or guidelines to validate specific technologies,
- Lack of shared knowledge on existing schemes and validation undertaken,
- Insufficient available data to assess the feasibility of an approach, and
- A lack of quality assurance programs for measurement requirements within validation programs.

While there were surprisingly few knowledge gaps identified that would prevent the implementation of a Validation Framework, addressing each of these gaps over the longer term would result in more efficient and effective implementation.

The project team is currently preparing the Stage 2 NatVal submission for funding consideration by the AWRCoE and other stakeholders. The intent of this submission is to articulate the project plan that will work towards the implementation of the proposed Validation Framework for recycled water schemes. Some proposed activities may be conducted separately to the NatVal Stage 2 project.

Overall, the project team recommended the following:

- That the Validation Framework as outlined in Figure 1 is supported by the AWRCoE to deliver against the AWRCoE's Goal 2, pending the outcome of the development of the full business plan,
- The development of a full business plan as a matter of priority be undertaken to fully articulate all the costs and benefits of the proposed Validation Framework,
- That a Regulatory Impact Statement be undertaken to investigate the impact of the Validation Framework on the regulatory environment, and
- That the AWRCoE consider a Stage 2 NatVal submission to address the knowledge gaps and barriers outlined in this Stage 1 NatVal report with the aim of moving towards full implementation of a Validation Framework.

1 INTRODUCTION

1.1 Background

The Australian Guidelines for Water Recycling (AGWR) are based on the principle of preventive risk management. Health and environmental risk based targets are used to calculate the “performance targets” for water recycling schemes which define the minimum performance that must be achieved by the treatment process and preventive measures. The AGWR requires treatment processes to be validated prior to operation of the water recycling scheme. This approach shifts the focus from end point monitoring, which in the case of pathogens is expensive and does not identify water quality issues until potentially well after the public have been exposed to the water, to process barriers and the operational monitoring of those barriers.

At present there is no process for national recognition of validation studies undertaken either overseas or as part of approval processes within Australia. There is also limited information or agreement on validation requirements for treatment processes or schemes. The AGWR describes the concept of and need for validation but doesn’t provide specific guidelines. As there is currently no consistent approach to technology validation across Australia, validation testing is often undertaken that replicates work on similar or identical technologies in other jurisdictions. This results in duplication of effort, additional cost and time delays in commissioning of schemes, unnecessary duplication of work by regulators in reviewing detailed validation reports and potential inconsistent application of the results across jurisdictions. These costs and delays can be a barrier to implementation, particularly for small regional utilities and private scheme operators.

Following extensive industry consultation by the Australian Water Recycling Centre of Excellence (AWRCoE) there was a strong call for a national validation framework for recycled water schemes to demonstrate compliance with the AGWR (2006).

The AWRCoE attributed such high importance to the development of a validation framework for recycled water schemes that this activity was designated one of four high priority goals to be delivered by the AWRCoE. The AWRCoE in August 2010 called for Expressions of Interest to address this goal followed by a selective tender for the project. The issues to be addressed included:

- Context of Validation,
- Acceptance, Implementation and Revision,
- Validation Logistics, and
- Impact Assessment.

The NatVal project was submitted to the AWRCoE by a national collaborative research team led by Water Quality Research Australia (WQRA) in response to the need identified in Goal 2 of the AWRCoE Strategic Research Plan. The aim of the project is to help deliver a framework for the validation of individual treatment process barriers and preventive measures used in recycled water as part of a multiple barrier approach to protect public health and the environment.

WQRA, supported by a team of researchers, industry specialists and regulators were successful in being awarded this project by the AWRCoE, and this report outlines the findings from the collaborative team.

1.2 NatVal Stages 1 and 2

Stage 1 of the NatVal project is the development of the Validation Framework, and was to include industry consultation with urban and regional utilities, State and Territory regulators, technical experts from a range of fields and institutions, and technology suppliers. A key component of NatVal was to conduct a knowledge gap analysis for validation of water recycling schemes utilising the experience and expertise of academics, research centres, regulators and technology providers all of whom will be involved with some aspect of the development, communication, endorsement, implementation or management of the Validation Framework.

Stage 1 outlines the Validation Framework that has been developed after significant consultation, including identifying the next steps required for implementation. At a high level, Stage 1 NatVal outlines broad business benefits and costs, associated with the existing system and the potential savings under the Validation Framework approach. As an important first step towards the development of a 'National Validation Framework for Recycled Water Schemes', significant emphasis has been placed on a national approach to the validation of individual treatment technologies, a key component of the validation of recycled water schemes. There are also additional state based requirements (e.g., completion of risk management plans) that form part of the overall validation for recycled water schemes. The proposed Validation Framework outlined in Figure 1, incorporates these additional elements under the 'State Based Regulator' section on the right of the diagram and has the flexibility to incorporate State based requirements at the national level if required in future.

Stage 2 NatVal is the execution of the outcomes of Stage 1, which will lead to the implementation of the Validation Framework, including progression of a range of supporting activities that will increase the efficiency and or effectiveness of the Validation Framework implementation. These supporting activities include delivery of new research projects, policy development and various State, Federal and Industry level negotiations to enable its implementation. Commitment to Stage 2 NatVal will be dependent on wide ranging support for the Validation Framework and the proposed implementation pathway as outlined in this report. The support of key industry, government and regulatory sectors is essential for successful implementation of the Validation Framework.

1.3 Project Aim

The aims of NatVal Stage 1 were to assess the current status of validation in Australia, benchmark this against international experience and propose a national Validation Framework for treatment technologies. The NatVal project will address and enhance the issues raised in the AWRCoE Discussion Paper Theme 2: Risk Management and Validation published by the AWRCoE in March 2010.

The AGWR (2006) describes validation as "...evaluating available scientific and technical information (including historical data and operational experience) and, where necessary, undertaking investigations to validate system-specific operational procedures, critical limits and target criteria. The aim of process validation is to ensure effective operation and control of the recycled water system".

Specifically, page 72 of the AGWR states that, "validation is particularly important for innovative hazard-control processes and for schemes involving relatively high exposures" (e.g. residential use). Validation also ensures performance reliability and

consistency. The AGWR recognises the need for technologies used in the treatment process to be validated when they operate with different operating parameters and environmental conditions (AGWR 2008). At present however, there is no central, coordinated information base available to regulators to avoid replication of technologies already validated under the same operating and environmental conditions.

1.4 Outline of NatVal Process

The NatVal Project team includes the Project Manager (Mr Michael Muston), Project Leader (Dr David Halliwell) and the Principal Investigators (PI) who led the detailed project activities. The majority of the PI's have significant experience across most jurisdictions and scales of operation. Project activities were conducted through work blocks called 'Street Maps'. The Street Map topics and associated PI's are listed in Table 1. Where relevant to the Street Map activity, the PI's engaged key stakeholders. This included state based regulators (both through the National Recycled Water Regulators Forum and individually), water utilities (through WSAA and individually), suppliers, consultants (including but not restricted to those that are identified partners to our bid) and local and international researchers through partner research institutions (universities, research centres and CSIRO). The project team was guided by an internal Project Steering Committee (PSC) and externally by the AWRCoE's Project Advisory Committee (PAC) (NB. refer to Appendix 2 for a list of advisory committee representatives).

The Stage 1 Street Map work packages provided a focused assessment of a subject area, the collective sum of which, contributed to the proposed Validation Framework as outlined in this Road Map report.

The 'Street Maps' undertook a range of activities including:

- Review of current and newly emerging techniques for validation of treatment processes from the literature and stakeholder interviews,
- Identified the relevant guidelines and other similar documents in Australia and globally,
- Documented outcomes from interviews with partners and stakeholder consultation workshops,
- Identified existing case studies, research projects and industry initiatives,
- Identified key industry, regulator and emerging research concerns and expectations,
- Investigated appropriate validation processes for the range of different treated water sources and qualities, treatment technologies and end uses,
- Benchmarked the current and proposed Australian validation frameworks against international experience and identified innovative and practical approaches to validation,
- Identified knowledge gaps and research needs as well as institutional, policy and governance issues that need to be overcome,
- Provided recommendations for research and for institutional framework and policy change, and
- Identified potential additional partners and funding or commercial opportunities and case studies that will be mutually beneficial to the implementation of the framework.

A compendium of Street Map reports has been published as a supplementary document to this Road Map report and is available from the AWRCoE website (http://www.australianwaterrecycling.com.au/coe/).

NatVal Stage 1 comprised of two workshops. The first 'inception' workshop aimed to finalise the scope of the Street Map topics listed in Table 1 and develop a draft Validation Framework for consideration while preparing the Street Map reports. Subsequently, a two-day workshop was convened to enable Street Map PI's to present the outcomes of each Street Map for discussion with key stakeholders, including the PSC and PAC. This process enabled each PI to receive direct feedback on their Street Map activity, prior to incorporation of this information into the Road Map Report. At the conclusion of the workshop the project team and invited stakeholders had reached consensus on the Validation Framework. Although the Validation Framework was refined following the workshop, the core elements of the Validation Framework remain unchanged.

Subsequent to the second workshop the proposed Validation Framework was reviewed by the PSC and the PAC, and has since undergone additional stakeholder review. Key stakeholder groups including the National Recycled Water Regulators Forum (NRWRF) and the Water Services Association of Australia (WSAA) have documented their in principle support for the proposed Validation Framework, as outlined in Section 4.

1.5 Street Map Reports

The Street Map topics outlined in Table 1 were investigated as part of the NatVal Project and have been compiled in the Supplementary Street Map Report. The Street Map Topics were reviewed internally by the PI's, the NatVal PSC and key industry stakeholders to ensure they addressed the aims of the project.

Table 1 Street Map titles and principal investigators

Street Map 1. Natural treatment systems	Dr Declan Page, CSIRO Prof Ana Deletic, Monash University Dr Simon Toze, CSIRO
Street Map 2. Membrane treatment systems: Existing and potential validation techniques	Dr Alice Antony, UNSW A/Prof. Greg L. Leslie, UNSW Dr Pierre Le-Clech, UNSW Dr Marlene Cran, Victoria University Prof Stephen Gray, Victoria University
Street Map 3. Chemical and photochemical disinfection/oxidation systems: Existing and potential validation techniques	Dr Alexandra Keegan, AWQC Dr Wolfgang Gernjak, University of Queensland
Street Map 4. Biological treatment systems	Dr Helen Stratton, Griffith University Dr Amanda Ind, Griffith University
Street Map 5. Adsorptive treatment systems: Existing and potential validation techniques	Dr Wee Hong Chin, RMIT University Prof Felicity Roddick, RMIT University Dr. Linhua Fan, RMIT University Dr. Thang Nguyen, RMIT University
Street Maps 6. Establishment of a national validation framework for water recycling	Dr Kaye Power (IPART NSW), Dr Dan Deere (Water Futures)
Street Map 7. Proponent Perspective on a National Validation Framework for Water Recycling	Ms Palenque Blair, Water Corporation WA Mr Graeme Watkins, Mid Coast Water
Street Map 8. Validation of water recycling schemes: Technology supplier perspectives	Mr Eddy Ostarcevic, Integrated Elements Dr Marlene Cran, Victoria University Prof Stephen Gray, Victoria University
Street Map 9. Multiple barrier validation: General approach, indicators and surrogate measures for pathogens, chemical contaminants and pollutants	Dr Stuart Khan, UNSW Dr Rita Henderson, UNSW Dr Ben ven den Akker, UNSW Dr Fred Leusch, Griffith University Prof Beate Escher, The University of Queensland
Street Map 10. Validation of non-treatment related barriers and preventive measures throughout the life of the scheme	Dr David Cunliffe, SA Health
Street Map 11. Capacity Building	Mr Chris Davis, UTS
Street Map 12. Performance criteria for instrumentation and associated methodologies for water quality assessment	Dr Cheryl Lim, National Measurement Institute

2 NATIONAL VALIDATION FRAMEWORK FOR WATER RECYCLING SCHEMES

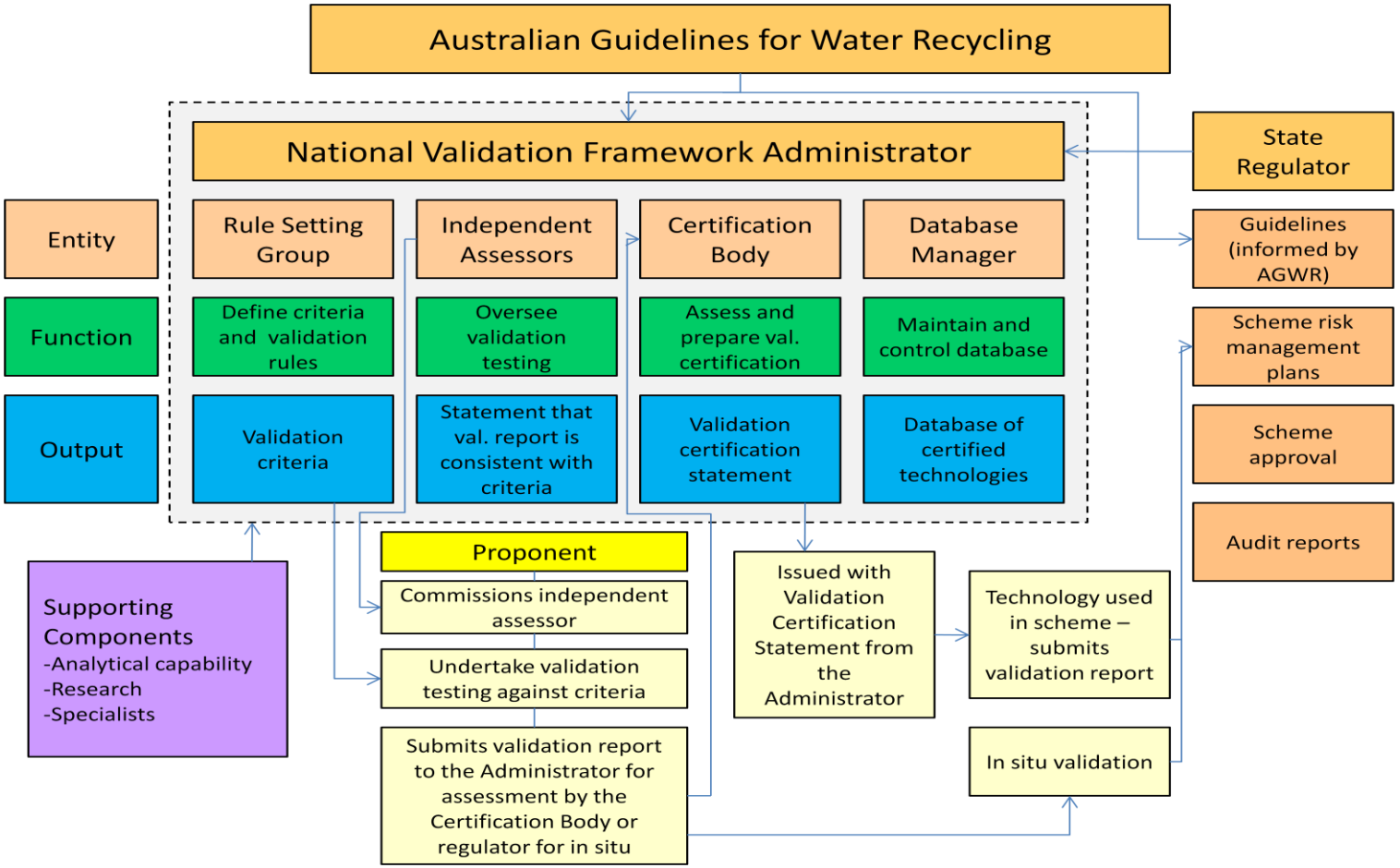
2.1 Objectives of the Framework

To ensure the development of the Validation Framework is relevant to industry and regulators the objectives need to be clearly defined. The objectives were to:

- Protect public health and the environment,
- Support Element 9 of the AGWR,
- Provide independent endorsement of technologies and processes,
- Ensure consistency between jurisdictions within Australia,
- Ensure a transparent and independent process, and
- Provide a mechanism for the recognition of international validation or technology certification programs.

The proposed Validation Framework is summarised in Figure 1 and shows each entity, its function and output, and the flow of information between processes. The Framework Administrator is seen as over arching, while the key components of the Validation Framework are enclosed by a dashed line. The processes and groups which sit outside the Validation Framework are grouped by colour and their relationship between each other is indicated by a line.

Figure 1 National Validation Framework for Treatment Technologies (Validation Framework)



2.2 Key Components of the Validation Framework

The following sections describe the roles and relationships for entities or functions identified in the Validation Framework. It should be noted that Stage 1 NatVal was to develop the Validation Framework. The allocation of functions to agencies was not an outcome of Stage 1. However, options for which agencies could fulfil a specific role have been identified, where there was a good alignment with the agency and the desired role/function, although this in no way implies that the specified agency has agreed to or are likely to perform the proposed function.

2.2.1 National Validation Framework Administrator

Entity	Role for these organisations	Potential agencies for this function

National Validation Framework Administrator	• Maintain/administer the Validation Framework
	• Develop Validation Guidelines and Standards (co-ordinate the Rule Setting Group)
	  ○ Overarching
	  ○ Technology-specific
		Lead role within one organisation, e.g.
		• NHMRC
		• SEWPaC
		• AWRCoE
		• NWC

The Framework Administrator provides a central point of coordination and is responsible for implementing the Validation Framework. There is a need for technical literacy within the Framework Administrator but there is also an administrative component. The Framework Administrator could be an existing government organisation, such as the National Health and Medical Research Council (NHMRC) or the Department of Sustainability, Environment, Water, Populations and Communities (SEWPaC), the National Water Commission (NWC) or there is scope for an organisation such as the AWRCoE to fulfil this role. This organisation would ideally be within Federal government or federally supported to accord the process national recognition.

The Framework Administrator maintains the Validation Framework and this includes the development of relevant guidelines and standards. The role includes overarching governance arrangements and technology-specific and *in situ* process guidelines. The Framework Administrator will draw from technical specialists and working committees (see below).

The Framework Administrator will Chair and coordinate the 'Rule Setting Group' (see below) and maintain an up to date register of Independent Assessors and Testing Laboratories (see below). The Framework Administrator may take on the roles of Certification Body and Database Manager or provide oversight and criteria setting for these entities only.

2.2.1.1 Rule Setting Group

The Framework Administrator will Chair and coordinate the 'Rule Setting Group', which would comprise a committee of national representatives, including industry, technical and regulatory specialists that are able to develop and approve validation guidelines. The process for selecting representatives for the Rule Setting Group should be transparent and include State regulators, utilities, suppliers and technical specialists. It is the responsibility of the Rule Setting Group to approve validation

guidelines for specific technologies. The Rule Setting Group may appoint any number of working committees to develop new guidelines and review existing guidelines (i.e. either local or international) and recommend their acceptance to the Rule Setting Group. Working Committees may be transient or permanent, depending on the need, they should represent an appropriate mix of stakeholders relevant to the guideline under development and contain the technical expertise required to deliver on the specified task.

2.2.2 Independent Assessors

Entity	Role for these organisations	Potential agencies for this function

Independent Assessor	• Review and/or prepare validation study designs prior to commencement
	• Endorse validation studies upon completion
	• Endorse and/or prepare validation reports for technology providers and scheme proponents
	  ○ Specific technologies
	  ○ *In situ* processes
		Individuals or organisations that are not associated with technology providers

The Independent Assessors will review and/or prepare validation study designs prior to scheme commencement, and endorse validation studies upon completion. They will also endorse and/or prepare verification schedules for whole treatment trains/schemes as part of the recycled water management plan (or equivalent) for scheme proponents to send to State and Territory Regulators. Their role may also include preparing validation reports for technology providers and scheme proponents covering specific technologies and *in situ* processes.

The Framework Administrator would set the requirements for a person to be considered an Independent Assessor and maintain a register, which can be accessed by regulators and proponents. The Framework Administrator would charge a registration fee and an annual renewal fee for Independent Assessors to cover the cost of initial assessment and to maintain a register of Independent Assessors.

2.2.3 Certification Body

Entity	Role for these organisations	Potential agencies for this function

Certification Body	• Certify treatment processes
	  ○ Specific technologies*
	  ○ *In situ* processes**
		Framework Administrator or organisations that are not associated with technology providers

*Specific technologies would include processes that could be validated at one location and then installed at other locations. Examples would include in-pipe UV systems or modular membrane treatment systems

***In situ* processes would include processes that would need to be validated on a case-by-case basis. Examples include maturation ponds, activated sludge plants, media filtration systems and natural treatment systems.

The Certification Body assesses validation reports and prepares a Validation Certification Statement. A Validation Certification Statement issued by the Certification Body is the recognition that the validation approach is accepted by the Framework Administrator. The outcome of this is a nationally recognised document

describing the defined operating conditions the specific treatment technology has been validated against, which would be accepted by State Regulators.

The certification of treatment technologies through the Certification Body and collation by the Framework Administrator would provide a mechanism to centralise information produced during validation in a centralised database. The database would contain information on certified technologies and *in situ* processes, including operating parameters and contaminant reduction values. The database could also be used as a resource for updating the AGWR.

While the certification role maybe carried out by the Framework Administrator it is presented as a defined entity in Figure 1. The role may be outsourced with the requirements for the certification body determined by the Framework Administrator.

Specific technologies would include processes that could be validated at one location and then installed at other locations. Examples would include in-pipe UV systems or modular membrane treatment systems.

In situ processes, such as lagoons and media filter beds, will require on site validation due to the variable nature of these processes in different operating environments. In such instances, the State regulator will need to review the validation data on a case by case basis.

2.2.4 Database Manager

Entity	Role for these organisations	Potential agencies for this function

Database manager	• Maintain a Database of certified processes
	  ○ Maintains a record of validation guidelines
	  ○ Maintains validation reports
		• Bureau of Meteorology (BOM)

The centralised database provides access to validation data for specific technologies. This removes duplication for scheme proponents who wish to utilise pre-validated technologies. In such cases, shorter and less costly verification is required by proponents to confirm that the pre-validated technology installed in the scheme operating within conditions as defined in the certificate, and is achieving treated water that meets the required guideline contaminant concentration.

The overarching responsibility of maintaining a database function within the Validation Framework resides with the Framework Administrator; however, the database management function is likely to be outsourced to an organisation with database management expertise. For example, the Bureau of Meteorology (BOM) has significant expertise in water-related data management and may be a suitable option. Alternatively, there is a pre-existing database that is currently maintained by the Queensland Water Directorate, which provides a model for the establishment of a national database. Other entities that manage water quality databases such as analytical laboratories could also potentially play a role.

2.3 Supporting Components of the Framework

2.3.1 Analytical Capability

Entity	Role for these organisations	Potential agencies for this function

Analytical facilities	• Conduct analytical tests
	  ○ *Ex situ* for specific technologies
	  ○ *In situ* for other processes
	• Prepare analytical reports
	• Prepare validation reports
		Must be a certified facility (based on criteria set by the independent oversight agency, e.g. must have NATA accreditation), could be any of:
		• Commercial or Government laboratories
		• University facilities

The Framework Administrator sets the requirements for independent analytical facilities and maintains a register of certified facilities that proponents can access. The analytical facility would be charged a registration fee and an annual renewal fee by the Framework Administrator to cover costs of the initial assessment and to maintain a list of accredited analytical facilities. The laboratory accreditation, certification of technologies and accreditation of independent assessors by the Framework Administrator could be outsourced to private organisations such as JASANZ, NATA or RABQSA.

The analytical laboratories and testing facilities would conduct testing in accordance with the validation guidelines for the treatment technology or process. In conjunction with an Independent Assessor, they may also prepare validation reports to be forwarded to the Framework Administrator or Certification Body to certify a new treatment technology or to the regulator for approval of *in situ* treatment processes.

2.3.2 Research & Specialists

Entity	Role for these organisations	Potential agencies for this function
Research Specialist	• Support the development of guidelines via involvement in working groups • Undertake research and development to support validation of recycled water	• Working group for each specialist area including representation of technology providers, proponents and technical specialists. • Core technical specialist and technical writers (currently the NATVAL Street Map PI's)

As indicated above, the Framework Administrator will coordinate the 'Rule Setting Group', which would comprise a committee of national representatives, including industry, technical and regulatory specialists that are able to review and approve validation guidelines for use. This group would call upon a wide range of researchers and specialists to form working parties to address technology issues. Working parties would be tasked with detailed technical writing or reviewing of validation guidelines, including testing protocols and requirements for the testing facility. Working parties would also provide advice on the application of overseas validation information in an Australian context. Working parties may be appointed for an indefinite period to continue to provide expert input into a technology area, scientific developments for treatment processes and provide feedback to the broader research community on emerging issues of concern. Alternatively, the Framework Administrator, through their

'Rule Setting Group' may appoint a temporary working party for a defined period of time to complete a specific outcome.

2.4 Proponents

2.4.1 Scheme Proponents

Entity	Role for these organisations	Potential agencies for this function

Scheme proponents	• Choose a treatment train that is amenable to validation
	  ○ Select validated technologies and/or
	  ○ Undertake new validation studies
	• Develop and/or commission a Validation Schedule for each specific treatment technology as part of the recycled water management plan
	• Complete verification testing
	  ○ Intensive post-commissioning
	  ○ Ongoing routine
	• Conduct re-validation if/when required by guidelines for the technology
		Any of:
		• Water utilities
		• Third party access entities
		• Private schemes
		• Frontline representatives of schemes

For scheme proponents, the Validation Framework will provide greater clarity for validation of technologies, including *in situ* processes and the opportunity for selection of pre-validated technologies from the database. Proponents would be required to develop and/or commission a validation schedule for each specific treatment train/scheme as part of the recycled water management plan. Verification of the scheme when operational will still be required, however the Validation Framework will reduce the cost and time burden of validation for proponents. Additionally, the rules will be nationally applicable, negating the complication of different validation approaches across jurisdictions. The scheme proponent would be required to conduct re-validation as necessary such as following a change in treatment technology. The proponent will need to comply with the regulatory requirements for each jurisdiction.

2.4.2 Technology Proponents

Entity	Role for these organisations	Potential agencies for this function
Technology proponent	• Commission new validation studies • Engage analytical facilities to conduct validation testing • Commission independent validation reports • Submit validated technologies to the oversight entity for certification • Provide advice to committees • Involvement in technical working party	Any of: • Manufacturers • Resellers

The Validation Framework permits technology suppliers to have their treatment technologies undergo 3rd party validation and certification. The technology providers can engage Independent Assessors to design and implement a validation study. The results would be sent to the Framework Administrator for certification. In cases where previous validation has been carried out, either overseas or within Australia, the technology provider could commission a validation report from an Independent Assessor.

The advantage to the technology provider for this process is that it provides a competitive advantage for their technology. The costs of doing this could be added to the development or marketing costs of the technology. Validation data relevant to the technology including the operational conditions will be available on the database. This will avoid repetition of the validation testing provided the operating conditions are within the certified operating conditions.

2.5 State and Territory Regulators

Entity	Role for these organisations	Potential agencies for this function

State and Territory Regulators	• Provide the final endorsement the validation schedule for each scheme
	  ○ Defer to the national oversight agency for technology endorsement
	  ○ Endorse and/or arrange for the endorsement of any on site validation
	• Undertake/oversee ongoing audit of all schemes
	• Maintain a representation through a MOU with the oversight entity
		Any of:
		• Federal government
		• State government
		• Territory government
		• Local government

The State, Territory or Local Council Regulators will remain responsible for scheme approval. The benefit to Regulators adopting a Validation Framework is the removal of duplication of effort across jurisdictions. Additionally the regulators may call upon the database of validated technologies to identify pre-existing validated technologies as well as guidelines for validation of specific technologies that have been agreed by the Framework Administrator. The Validation Framework also presents a structured approach to the development of new validation guidelines.

Regulators will have representation at the 'Rule Setting Group' which is overseen by the Framework Administrator. Primarily through this forum, but also potentially through a Memorandum of Understanding approach, the regulators will accept the outputs from the Framework Administrator, such as certified technologies and validation rules. The Regulators will also have representation on 'Working Parties' that are established by the 'Rule Setting Group' to review and agree on technology specific validation rules, whether they have been locally generated or whether they arise from international entities.

The Regulators would set conditions for the ongoing auditing of any scheme under jurisdictional regulatory requirements. The verification and ongoing operational monitoring would be approved by the regulator as part of the recycled water management plans.

3 PRELIMINARY BUSINESS CASE

3.1 Benefits of a Validation Framework

The benefits of adopting the Validation Framework include:

- providing national consistency for validation requirements for proponents, regulators and technology providers,
- provision of a national process for consideration of overseas testing within Australia's requirements,
- reduction in the cost of validation for specific treatment technologies as once certified, validation would not require repeating unless significant changes in the process occurred,
- collation of validation data for *in situ* treatment technologies would provide data to support the updating of the AGWR,
- streamlining of the process of recycled water scheme design in that proponents could chose a validated treatment technology and know the confirmed LRV to be used in design,
- development of a framework which could be applied to drinking water technologies in the future, and
- development of a framework which could be extended to environmental treatment technologies.

3.2 Challenges for Implementing the Validation Framework

The potential challenges for implementing the Validation Framework include:

- Ensuring that an appropriate home can be found for each of the identified entities,
- Ensuring that a financially sustainable model for the Validation Framework is developed,
- Ensuring that the Validation Framework can accommodate small systems, which due to their economies of scale (or lack thereof) are expensive to validate under most regimes, and
- Ensuring that it can be implemented within the current regulatory frameworks within each jurisdiction.

3.3 The Need for a Business Case

As part of NatVal Stage 1, preliminary case study information has been gathered to assess the historical validation costs under existing systems and therefore highlight areas for potential savings under the Validation Framework. Several truncated case studies have been outlined below. These case studies highlight the significant costs that are incurred during scheme validation. The Validation Framework approach could significantly reduce some of these costs, particularly if it succeeds with generating national agreement for validation guidelines for specific treatment technologies and agreement that treatment technologies once validated, may be transferred to new jurisdictions and only require a much less onerous verification process. Although the preliminary case study and anecdotal data suggests that the benefits of the Validation Framework could far outweigh the costs, a strong recommendation from the project team is for a full business case to be conducted as

one of the first elements of Stage 2 NatVal. Alongside this business case, or perhaps even as a subset within it, is the need for a Regulatory Impact Statement.

3.4 Case Studies

The details of a number of case studies are outlined in the Supplementary Street Map Report. Understandably, it was difficult to obtain specific data with regards to costs incurred during recycled water scheme validation. In part this was due to concern regarding data being exploited out of context, but perhaps a more significant explanation is that it can be difficult to separate scheme validation costs from other operational costs for recycled water schemes. The data presented below presents only direct costs of sampling and analysis along with some indication of staff time. There would be a number of additional plant operational costs associated with recycling plant operation and instrumentation and potentially online monitoring during the period of operation when water cannot be provided to the intended user.

Several utilities kindly supplied high level costs for individual scheme validation, which have been included in Table 2. The scheme and utility names have been removed, although they are all Australian. This data indicates that significant costs are incurred under the various validation regimes operating nationally.

Table 2 Indicative high level costs for existing scheme validation

Scheme	Utility Size	End Use	Analytical Cost ($)*	Cost/ML/day ($)	Staff Time
A	Large	IPR**	$665,000	$133,000	2 Senior FTE for 2 years
B	Large	IPR	$1,330,000	$17,733	unknown
C	Large	IPR	unknown	unknown	unknown
D	Large	Irrigation	$150,000	$1,744	0.3 Senior FTE
E	Large	Industrial	$340,000	$2,833	0.3 Senior FTE
F	Small	Irrigation	$23,200	$11,600	unknown
G	Large	Environmental	$150,000	$3,000	0.3 Senior FTE
H	Large	Class A (residential)	$200,000	$6,536	0.3 Senior FTE

* NB. includes sampling costs for some schemes but not all

** IPR = indirect potable reuse

In addition to the time and costs incurred by utilities, regulators also contribute a significant portion of their time on scheme validation (refer Table 3). The proposed Validation Framework could significantly reduce the current duplication of effort by all parties by providing a mechanism for technology validation, which would not require repetition across jurisdictions.

Table 3 Regulator time input for validation

SCHEME TYPE	ENTITY	VALIDATION COSTS ESTIMATES	
		TIME IN MEETINGS HRS	TIME REVIEWING DOCUMENTATION HRS
Existing Class A+ scheme	Qld Health Regulator	1	70
Existing Class A+ scheme	Qld Health Regulator	6	70
New Class A+ scheme	Qld Health Regulator	10	350
Existing Class A	Qld Health Regulator	1	28
Western Corridor	Qld Health Regulator		210
Proponent with limited experience with the department's validation requirements	Victoria DOH	8-10	80 – 100
Proponent with extensive experience with the department's validation requirements	Victoria DOH	2 - 4	15 - 30
Large or novel scheme such as the returns flow scheme	Victoria DOH	20 – 40	120 - 200
Proponent with limited experience with the department's validation requirements	NSW Office of Water and NSW DOH	14 – 20	154 - 230
Proponent with extensive experience with the department's validation requirements	NSW Office of Water and NSW DOH	8 – 14	48 - 94
Large or novel scheme such as the returns flow scheme	NSW Office of Water and NSW DOH	16 - 20	140 - 285
Proponent with limited experience with the department's validation requirements	WA DOH	10	14
Proponent with extensive experience with the department's validation requirements	WA DOH	6	10
Large or novel scheme such as the returns flow scheme	WA DOH	18	30
Proponent with limited experience with the department's validation requirements (Small -moderate size scheme - proponents used an expert consultant to verify/certify validation data provided to the Department	SA Health	15	45
Proponent with limited-some experience with the department's validation requirements but extensive experience with the Department's quality assurance requirements (Large scheme - dual reticulation).	SA Health	**First occasion** 12	**First occasion** 50
Proponent with increasing experience with the department's validation requirements (same proponent as above)	SA Health	**Second occasion** 3	**Second occasion** **4**
Large or novel scheme	SA Health	35	56

3.5 Regulatory Impact Statement

A national (and potentially State/Territory) Regulatory Impact Statement (RIS) is required, which would include stakeholder consultation to assess one or more final options. This would follow guidelines developed by the Office of Best Regulatory Practice (OBRP). The business case should be presented to the Ministerial Councils and enHealth.

A sound business case needs to be developed supporting the Validation Framework and the proposed business model, including long term funding requirements and scheme viability. The conduct of an RIS could consider additional but related elements, including:

- Certification of on-site sewage treatment systems and recycled water systems;
- Treatment technologies for drinking water;
- Long-term development of an Environmental Technology Verification program similar to the ETV in the EU with the same objectives; and
- Review the capacity to link into international establishments that already have been set up as verification centres.

The anticipated timeframe for the RIS is 4-6 months. Major time impacts on this timeframe are the stakeholder consultation and OBRP for acceptance of the final draft report. The initial cost estimate for the conduct of the RIS is approximately $300,000.

4 STAKEHOLDER CONSULTATION

Stakeholder consultation is pivotal for the development and implementation of the Validation Framework. There is a requirement to maintain an ongoing dialogue with stakeholders throughout the framework development process, during its implementation and beyond, to ensure that it is workable, acceptable and remains current.

The project team has endeavoured to consult widely during the 6 month development phase of NatVal Stage 1. Although a significant number of key groups and individuals have been consulted to date, including regulators, utilities, suppliers and various technical experts, there is still further work to be done to ensure effective consultation across a wide range of stakeholders to ensure successful implementation. In some cases, the requirement to engage additional stakeholders has arisen as the Validation Framework has taken shape. Further consultation with key stakeholders is envisaged as a key component during the development and execution of NatVal Stage 2.

The stakeholder groups that have been consulted to date are listed in the following sections. Relevant feedback that either supports or contravenes the needs for the Validation Framework has also been included under the subheadings below.

4.1 National Bodies

There are at least 2 levels of engagement required at the national level, including strategic discussions as to how best the Validation Framework can be implemented and the various roles that agencies will play, and technical discussions regarding the Validation Framework itself. In the former case, these discussions have only just commenced with the government and non-government entities that may have a role in the implementation of the Validation Framework. This is due to NatVal Stage 1 utilising the stakeholder consultation to develop and define the proposed Validation Framework.

Primarily through the AWRCoE, there have been various high level briefings to outline the project intent in the absence of technical detail. At a technical level, there have been several federal government agencies involved in Stage 1 NatVal, most notably the CSIRO and the National Measurement Institute.

As the details for the Validation Framework have emerged, it has become increasing apparent that the role of ‘Framework Administrator’ would be best served by a federal government agency, and if not, an agency that has strong federal backing with a national mandate. A separate process led by the AWRCoE to inform relevant agencies in Canberra regarding NatVal and its implementation, its need and potential benefits has commenced and will likely continue into the Stage 2 NatVal project.

4.2 Regulators

There has been significant and on-going dialogue with state and territory based regulators at multiple levels during the development of the Validation Framework. A consultation paper outlining the roles of the proposed elements and the possible organisational structure of the Validation Framework was sent to all the representatives of the NRWRF with a request for feedback. This was followed by a

phone call to officers within those agencies known to have a direct regulatory role in the approval of recycled water schemes, in particular high exposure schemes, within their jurisdictions.

A presentation was made to the NRWRF on the 15th August 2011 in Hobart on the proposed Validation Framework during the latter stages of NatVal Stage 1 when the framework was well developed. After extensive discussion the members expressed their agreement for the proposed Validation Framework and the following statement was accepted at the meeting as a statement of the NRWRF position on the framework:

"NRWRF recognises the need for a National Validation Framework for water recycling to protect public health and the environment. We support the conceptual draft model of the National Validation framework as presented by WQRA. The NRWRF does not have the delegation to endorse the framework, however is committed to working with WQRA and AWRCoE to further develop a nationally acceptable validation framework."

4.3 Supply Industry

A range of technology suppliers were invited to contribute to the early development of the Validation Framework through a survey including small Australian owned and operated companies to major international suppliers. In most cases, respondents were aware of the project but had limited knowledge of the potential implications to their specific technology and this was perceived as a concern. Overall, the views on working towards a National Validation Framework were positive with most respondents expressing support for a Validation Framework. The responses outlined below were received during the initial development of the Validation Framework, and thus do not necessarily reflect supplier opinions on the completed Validation Framework.

The respondents expressed many advantages to the introduction of a Validation Framework including:

- Providing a level playing field in terms of product capabilities,
- Validation to internationally recognised standard would offer treatment guarantees to operators, resulting in greater community benefits,
- It would enable companies to compete with imported technologies that have internationally recognised validation,
- Beneficial to have technologies validated prior to design and construction of plants,
- Money saving benefits and more open competition on the market for different providers,
- Currently, most Australian regulators accept external validation certificates, and
- Provide an established target for industry so that all proponents have a clear understanding of the requirements for successful validation and implementation of technologies.

The major concern with the Validation Framework from nearly all respondents was the potential for increased costs associated with:

- Maintaining system validations,
- Extending project timelines, and
- The potential impact on small market companies.

Most respondents expressed interest in further involvement with requests for more detailed discussions, which have now occurred. Some of the general comments, suggestions and questions from technology suppliers include:

- The Validation Framework would require international recognition to have a high value,
- Validation is a grey area that can be manipulated to the advantage of some technology suppliers to the detriment of the industry,
- Pleased with the proposed framework as it may help clarify current uncertainties with validation,
- Any proposed framework should be aimed to serve regulatory needs for at least 10 years, and
- Is the proposed scheme based on established testing protocols or is this the push for external funding to help establish them over the next decade or so?

For some suppliers, local validation is not possible with validation services not currently offered in Australia. The costs of validation may vary significantly depending on technology type with costs in excess of AU$100,000 not uncommon.

A lack of Australian standards for UV validation, full-scale validation of treatment plant performance and virus testing was also noted in stakeholder feedback.

Data collection and storage is a potential issue of concern for suppliers. Most suppliers provide proof of validation as required and some suppliers have data hosted by third parties that is available electronically or in hard copy on request. The issue of collecting and storing validation data with a Framework Administrator was a concern to many respondents who consider their raw data as confidential. In some cases respondents suggested that access to data should be restricted.

SUPPLIERS CONSULTED	
Aquagenics	Koch Membrane Systems
Australian Ultra Violet Services (Operations) Pty Ltd	Melbourne Water
CRS Industrial Water Treatment Systems Pty Ltd	Orica Watercare
Dow Chemical (Australia) Ltd	Osmoflo Pty Ltd
Environmental Water Services	Prominent Fluid Controls Chlorine Dioxide
GE Water & Process Technologies	SA Water
Grundfos	Siemens Ltd
Hydramet Australia	Tenix
Hydranautics	Toray Membrane Australia
ITT Flygt	Veolia Water Solutions & Technologies
John Holland Water	Westwater Enterprises Pty Ltd
KBR	

4.4 Utilities

A background paper was developed along with a survey regarding the proposed Validation Framework, and distributed to water utilities and other proponent or operator stakeholders for completion. Twenty seven responses were received as well as a combined response from the WSAA.

The main concerns of proponents are summarised below:

- The need to be risk-based but practical,
- The need to have State and Territory health regulator endorsement,
- The Framework Administrator needs to be able to draw on the best available technical expertise for guideline creation and maintenance, but retain independence,
- It is vital that consideration is given to international certifications to minimise re-work by technology suppliers,
- Funding for the Validation Framework should be whole of government, as the benefits will be to the community, however it is reasonable to charge for certification of technologies and auditing,
- A water recycling database of previous treatment validation and verification data and certifications would provide benefit to the whole water industry including regulators, but it's scope and management to ensure data verification would need careful consideration, and
- Clear identification of requirements for re-validation should be provided in the validation guidelines for each technology.

The Water Services Association of Australia (WSAA) who represent the largest utilities in Australia, comprising the bulk of water and wastewater services provided to Australian, are involved in NatVal on multiple levels. They have been extensively consulted during the development of the Validation Framework, and have provided the following statement in support of the Validation Framework:

"WSAA recognises the need for a national validation framework for water recycling to protect public health and the environment. We support the conceptual draft model of the National Validation framework as presented by WQRA. WSAA in principle agrees with the proposed framework and supports the further development of this framework with a view to implementation."

UTILITIES AND OTHER ORGANISATIONS CONSULTED	
ActewAGL,	Parkes Shire Council
Australian Groundwater Technologies *	Queensland Water
Ballina Shire Council	South East Water
Byron Shire Council	Sydney Olympic Park Authority
City West Water	Sydney Water
Coliban Water	Tamworth Regional Council
East Gippsland Water	Toowoomba Regional Council
Eurobodalla Shire Council	Tumbarumba Shire Council
Gosford City Council	Unitywater
Harden Shire Council	Veolia Water Australia (x2)
Hydroscience Consulting	Water Conservation Group
Lismore City Council	Water Corporation (WA)
Melbourne Water	Western Water
Nubian Water Systems	

* previously United Water Wastewater Operations – involved in UF membrane challenge testing

5 FUNDING AND ADMINISTRATIVE SUPPORT

Critical to the success of the Validation Framework is the development of a viable funding model for its implementation. Several existing overseas and local schemes were investigated to explore their relevance to an Australian Validation Framework, including the funding mechanism currently used in existing schemes. These included the water efficiency labelling scheme (WELS) and the European Union (EU) and the United States Environmental Protection Authority (US EPA) Environmental Technology Verification Program (ETV) funding arrangements. Based on these case studies and discussions with various stakeholders, suggestions for funding the core elements of the Validation Framework detailed in Section 2 are outlined in Table 4. These approaches will be further assessed during NatVal Stage 2.

Table 4 Funding options for the Validation Framework

FRAMEWORK ELEMENT	PROPOSED FUNDING APPROACH(ES)
National Validation Framework Administrator	Government funding the core staff, development of guidelines and maintenance of database
Independent Assessor	Charge technology providers or proponents to undertake independent assessments Pay fee to be an approved Independent Assessor
Certification Body	Charge fees for certification services (technology, personnel and research) and access to information
Database Manager	Charge levied for database access by proponents
Analytical Facilities	Charge for conducting validation testing Charged a fee by the Framework Administrator for their certification
Guideline Development Technical Committee	Working group would be voluntary Core technical specialists would be either paid by the oversight committee or donated as true in-kind (seconded)
Scheme Proponents	Could be charged to access the services provided by the oversight agency Scheme proponents would pay for testing for *in situ* technologies and final verification of scheme
Technology Proponent	Fees levied by the oversight agency for certifying a technology Pay analytical facilities or Independent Assessors for validation studies
State and Territory Regulators	Free access the service provided by the Framework Administrator

6 POTENTIAL BARRIERS TO IMPLEMENTATION

Implementation of the proposed Validation Framework requires the resolution of several major barriers and potentially some minor barriers. Of significance are issues such as acceptance of the proposed Validation Framework by regulators, management of intellectual property (IP), mechanisms for consideration and acceptance of international validation data and approaches, establishment and management of a database that captures validated technologies, approaches to validation and validation data (at least at a high level). The following subsections describe these areas in further detail.

6.1 Acceptance of Validation Framework by Regulators

Crucial to the success of the Validation Framework is acceptance by regulators. To achieve this regulators have been included on the project team and its advisory committees. There has also been significant consultation with individual regulators and through the National Recycled Water Regulators Forum.

6.2 Intellectual Property Management

The careful management of IP will be a core component to the success of the Validation Framework. For participants to fully benefit from prior work a level of validation data will need to be captured in the database and available for use in new schemes and upgrades. Most suppliers provide proof of validation when required in the form of validation letters, certificates or reports. Some suppliers have data hosted by third parties that is available electronically or in hard copies on request. The issue of collecting and storing validation data with the Framework Administrator was a concern to many technology industry respondents during the consultation phase of this project. In most cases, companies consider the raw data confidential but would provide access to validation certificates. Access to data should be restricted as this could raise legal issues. At this stage it is envisaged that suppliers would provide data at an executive summary level, which is consistent with current industry practice. Some international providers already distribute validation data as required.

6.3 Recognition of International Data and Validation Approaches

Given the relatively small size of the Australian water recycling marketplace, it is likely that most water recycling technology developments will be derived internationally. Consequently, the Validation Framework requires the flexibility to assess and where appropriate adopt non-Australian derived guidelines, standards or validation data for specific technologies. To duplicate testing in Australia for internationally validated technologies, is inefficient and poses additional and potentially significant expense on industry to the extent that it may constitute a barrier to entry for specific technologies, which would place the Australian industry at a disadvantage to its international peers.

Validation data should only be accepted from organisations with a level of accreditation or quality assurance consistent with or higher than that specified by the data quality objectives agreed by the Framework Administrator. The minimum

requirements for quality assurance procedures should be those specified for facility accreditation of testing laboratories in Australia.

The implications of accepting the results of validation tests performed against guidelines/documentary standards other than those adopted by Australian jurisdictions should be thoroughly investigated in consultation with stakeholders. This would ideally happen during the treatment technology guideline development stage.

The possibility of implementing a formal mechanism for influencing the development of international guidelines/documentary standards for recycled water validation should be explored, and is best led by the Framework Administrator.

6.4 Database Establishment and Management

The purpose of the database is to provide a central location for the collection and access of the list of technologies that have been validated and associated validation data to remove the duplication of effort from scheme proponents who wish to utilise pre-validated technologies. In such cases, a much shorter and less costly 'verification' process is all that is required by scheme proponents to confirm that the pre-validated technology is operating within its predefined parameters, contained on the database.

The Queensland Water Directorate maintains a centralised database for collection of data from member water service providers including small water utilities throughout Queensland. This database is called SWIM (http://www.swim.qldwater.com.au/) and is a joint initiative of Qld Water and the Local Government Association of Queensland with the Queensland Government. The database allows local government water service providers to submit data as requested by the State and Commonwealth governments to the database. The database manager keeps up to date with reporting requirements of government departments and then provides this data directly to the government agencies when required.

The types of data collected into the SWIM database include: drinking water guideline compliance data and sewage discharge environmental compliance information along with many other metrics of operation, such as financial, assets performance, water sources and usage and customer service. The SWIM database may provide a model on which development of a national validation database could be based.

The Framework Administrator is responsible for the management of the database, although the database function may be subcontracted to a suitable group with database management expertise. As previously mentioned, this could include organisations such as the Bureau of Meteorology, who have a specialist Water Division under the Water Act 2007 and have significant experience in database management. Alternatively, it could be through other 3rd party providers. To ensure that efficiency gains through the implementation of the Validation Framework are fully captured, the establishment of a suitable database is vital.

6.5 Industry Capacity Building

The proposed Validation Framework requires a minimum level of technical expertise for the staff employed by the entities outlined in Section 2. There may be a requirement to upskill segments of the workforce to ensure they are capable of

interpreting and implementing their responsibilities as outlined in the proposed framework. A related potential barrier is the ability of key staff from responsible entities to remain aware of, comprehend and utilise the knowledge from new research, to ensure that it is quickly incorporated into the database, and more generally, utilised in the implementation of the Validation Framework.

7 RELATIONSHIP TO AGWR

The Validation Framework is designed to support the AGWR and to provide certainty to all stakeholders of consistent outcomes from the implementation of the requirements relevant to validation. The AGWR 2006 (Element 9) sets out validation processes and procedures for recycled water schemes to ensure effective operation and control of recycled water systems. This involves:

- Evaluating available scientific and technical information (including historical data and operational experience) and, where necessary; and
- Undertaking investigations to validate system-specific operational procedures, critical limits and target criteria.

The AGWR suggests that the focus of validation is for innovative hazard-control processes and for high exposure schemes (e.g. residential use). In these cases, validation may be divided into:

- Evaluation of existing information;
- Pilot trials and pre-commissioning testing of full-scale plants;
- In some cases, evaluation of specific end-use restrictions for human health or environmental protection; and
- Seasonal variations should be considered in designing validation programs.

The Validation Framework is consistent with the AGWR, delivering a national process in an efficient, effective and consistent manner. The Validation Framework will result in a consistent approach to validation. This provides a significant improvement on current practice by avoiding the need to carry out validation in each jurisdiction.

8 CURRENT STATE OF KNOWLEDGE

NatVal Stage 1 included international review of equivalent validation procedures and guidelines in use or in development for a range of treatment technologies and processes. The full details of these results have been published in the Supplementary Street Maps Report. The current state of knowledge for validation procedures and associated analytical techniques in use or under development has been synthesised for this Road Map Report as outlined in Table 5. Many of these approaches are still in the developmental stage and this has been noted against each specific technology in the table.

Table 5 outlines specific approaches for technology validation and Table 6 summarises the relevant international guidelines and related documents. This information is important as it provides the local context under which various validation techniques have been developed and adopted.

Although it is not a precondition that every treatment technology or process has a defined validation guideline prior to implementation of the Validation Framework, it is important to have a mechanism within the Validation Framework whereby validation approaches can be assessed, modified if required, and adopted as a nationally agreed and consistent process. The proposed framework enables this through the 'Rule Setting Group' and its various 'Working Parties' under the auspices of the 'Framework Administrator'. It is likely that an ongoing support activity during framework implementation and beyond will be the continued development of agreed validation guidelines for specific technologies.

Table 5 Treatment technologies and validation procedures

Technology	Validation Procedure	Description	Source	Generally Accepted in Australia (Yes / No)
Membrane Treatment System Technologies	Pressure Decay Test (PDT)	For low pressure systems, for detecting breaches monitoring and control of defects greater than about 1 to 2 um (sensitivity approx 5 LRV)	Membrane filtration guidance manual (USEPA 2005), ASTM standard D6908-06 (Johnson, 1998, ASTM 2006)	Yes, but not regulated by Departments of Health. Often specified in tenders.
	Vacuum Hold Test (VHT) otherwise known as the San Diego Protocol (SDP)	Performed before membrane installation in high pressure systems. Typically only vacuum decay rate is reported and a pass/fail is assigned to the membrane element based on the rate over 1 min.	Montgomery Watson (year) as part of an overall study conducted by the City of San Diego. ASTM standard D6908-06 (ASTM 2006)	Yes, but not regulated by Departments of Health. Often specified in tenders.
	Pulse Integrity Test (PIT)	For high pressure systems. An integrity monitoring test where a short pulse of 5-40s of a highly rejected challenge species like magnesium sulphate or sodium sulphate is applied across a membrane module.	Developed by Steven et al. 2005	No, not generally accepted or practiced as an on-site integrity test.
	Bacteriophage Challenge Testing	For low and high pressure systems. A systematic performance testing protocol and specification for MF and UF membranes relating to the removal of viral and submicron bacterial pathogens (sensitivity – 4.5 LRV)	AWWARF report (Jacangelo et al. 2006)	Yes
	Fluorescent dye tracers (Rhodamine WT) and bromide tracers	For low and high pressure systems. A non-toxic fluorescent dye that is widely used as a water flow tracer in fresh or highly saline waters.	ASTM standard D6908-06 (ASTM 2006), Arcoumanis et al. 1990; Sutton et al. 2001; Magal et al. 2008	Yes
	Nanoscale Probes	In line with the challenge tests, monodispersed tracer particles have been introduced for integrity testing of UF membranes, capable of monitoring virus sized particles.	Gitis et al. 2006b; Gitis et al. 2006a	Not validated in full scale plant. Not often practiced but should be accepted.
	Magnetically Susceptible Particles or magnetic nanoparticles	With the concept of SIM , spiking the magnetically susceptible particles or magnetic nanoparticles and measuring the intensity of magnetic field	Rajagopalan et al. 2006; Deluhery et al. 2008; Guo et al., 2010	Not validated in full scale plant Not generally known by industry.
	Spiked integrity monitoring (SIM)	Spiking powdered activated carbon particles in the feed and measuring their concentration in the permeate (sensitivity – 6 LRV). For low pressure membrane systems.	Kruithof,et al., 2001; Van Hoof et al., 2003	Not validated in full scale plant.
Chemical & Photochemical Disinfection / Oxidation Technologies	Computational Fluid Dynamics	Dose distribution estimates developed based on numerical (computational) representations of UV reactor behaviour. This has utilised computational fluid dynamics (CFD) simulations and modelling.	Blatchley et al., 2008.	No

Technology	Validation Procedure	Description	Source	Generally Accepted in Australia (Yes / No)
	Dyed Microspheres.	A new method for validation of UV reactor systems. Dyed microspheres allow measurement of the UV dose distribution delivered by a photochemical reactor for given operating conditions	Blatchley et al., 2006, 2008	No
	Actinometric Methods	Monitor the H_2O_2, consumption as it is directly correlated to the amount of radicals generated and therefore to the extent of reaction occurring inside the reactor.		No
	Measurement of chemical indicators and surrogates	Indicators and surrogates requires only a limited set of analytes to be measured to assess and monitor treatment processes for an assumed much larger group of chemicals. Surrogates currently used as microbial indicators include Clostridia (e.g. C. perfringens, C sporogenes), bacteriophage, vegetative bacteria, particle profiling, Fluorescence dyes and microspheres.	The general approach has been outlined by Drewes et al., 2008	No
	Biodosimetry and collimated beam testing (accepted practice for UV disinfection)	UV reactors are validated to a range of operating conditions including flow, transmittance and lamp output power to determine the reduction equivalent dose (RED) or Log10 inactivation, and RED bias to establish the safety factor required. An empirical measure of microbial inactivation in a UV reactor is provided, but much of the physical behaviour of these systems including the combined effects of the irradiance field, fluid mechanics and microbial dose-response behaviour is not quantified well.	US EPA Ultraviolet disinfection guidance manual for the final long term 2 enhanced surface water treatment rule' (2006)	Yes
	Determination of contact time	Contact time is determined by measuring residuals of chemical disinfectants (e.g. chlorine, chloramine, ozone) by on-line measurement.		Yes
Biological Treatment System Technologies	Automated Image Analysis	Images of fresh mixed liquor samples are analysed by specific programs to give information on potential problem forming filamentous bacteria in Activated Sludge	da Motta et al., 2011	No
	Modelling	Activated Sludge Models (ASM1; ASM2d; ASM3; ASM3 + Bio-P; ASM2d + TUD; New General; UCTPHO+) are used to asses system design and performance using a variety of inputs	Hauduc et al., 2010	Yes
	Principle Components Regression	Emerging Technique. Combined with neural nets to give a predictive tool used to validate pathogen reduction in activated sludge	Flapper et al., 2010	No

Technology	Validation Procedure	Description	Source	Generally Accepted in Australia (Yes / No)
	Palisade's Neural	Emerging Technique. Software used to log results of online independent physico-chemical data within activated sludge systems. The variables are deposited automatically into a spreadsheet that is continuously plotting and predictive tools automatically plot continuous log removal rates for each pathogen and indicator.	Palisade Corporation, 2009	No
Adsorptive Treatment System Technologies	Measurement of chemical indicators and surrogates	Use of a limited set of chemical indicators and surrogates (DOC, COD, BOD, UVA, colour, fluorescence, hydrophilicity/hydrophobicity) to assess treatment processes.	Drewes et al., 2008	Sometimes
	Measurement of pathogen indicators and surrogates	Use of microbiological indicators (Norovirus, E. coli, Coliforms, Enterococci and Protozoa such as Cryptosporidium, Giardia) and surrogates (such as particle profiling or volume of particles) to assess treatment processes.	Keegan et al., 2009	Sometimes
Natural Treatment System Technologies	Residence time calculation	Residence time in the aquifer, reservoir, wetland or stormwater WSUD systems are determined by modelling.	Kremer et al., 2009; Deletic, 2001; Linter et al., submitted	No
	Tracer studies	Use of natural and applied tracers to determine the residence time of water in the aquifer during MAR and stormwater biofilters and wetlands.	Kremer et al., 2009; as per challenge test currently undertaken within Cities as Water Supply Research Program	No
	Measurement of chemical indicators and surrogates	Indicators and surrogates requires only a limited set of analytes to be measured to assess and monitor treatment processes for an assumed much larger group of chemicals. Surrogates currently used as microbial indicators include Clostridia (e.g. C. perfringens, C sporogenes), bacteriophage, vegetative bacteria, particle profiling, Fluorescence dyes and microspheres.	The general approach has been outlined by Drewes et al., 2008; as per challenge test currently undertaken within Cities as Water Supply Research Program	No
	Measurement of *in situ* pathogen decay	Use of pathogen diffusion chambers for measurement of in situ decay rates in groundwater (for aquifers and biofilters) and surface waters (for reservoirs and wetlands).	Toze et al., 2010; Sidhu et al., 2010	No
	Assessment of pathogen inactivation in aquifers and WSUD filters using colloid filtration theory (CFT)	Use of modelling to determine removal efficiency based on attachment and removal. Biological decay still required to be determined separately by use of diffusion chambers.	Schjiven et al., 2010	No
	Assessment of total attenuation based on CFT	A similar method as described above based on theoretical and empirical attenuation of pathogens (described as a log10 / m decay rate).	Liping et al., 2008	No

Table 6 Australian and International Guidelines and key measurement techniques

Guideline	Origin / Description	Reference
US EPA Membrane Filtration Guidance Manual (MFGM)	Developed in the context of LT2ESWTR to assist the water treatment society to execute membrane filtration to ensure regulatory compliance	USEPA 2005
NSF International – ETV	Developed in collaboration with USEPA, NSF established the Environmental Verification Program and assigned the testing of membrane systems to be performed by them.	available in the official website of NSF
Victorian Draft Guidelines for Validating Treatment Processes for Pathogen Reduction	Designed to support water recycling schemes in Victoria that produce Class A water. Guidelines for validating Class A recycled water schemes, treatment validation steps and validation requirements for specific treatment process units. Microbial quality objectives are presented in terms of LRV's for a range of bacteria, viruses and protozoa that may be present in the feed water. Validation of the various available treatment process units is outlined including validation for: • biological treatment, media filtration and membrane bioreactors • membrane filtration (MF, UF, NF & RO) • disinfection processes (UV, ozonation, chlorination, chloramination, chlorine dioxide).	Department of Health Victoria 2010
ISO/IEC 17043:2010	Conformity Assessment – General Requirements for Proficiency Testing	ISO 2010
US EPA Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule' (2006)	Considered the appropriate guidance document for the validation of UV reactors, with the main pathogen of concern being the protozoan parasite *Cryptosporidium*	USEPA 2006
European standards (DVGW, ONORM),	Validated by third party	
Chemical Indicators	An important objective for a chemical validation program is to confirm that the water treatment processes are operating correctly and performing sufficiently to produce water of an acceptable quality. One approach that has recently been validated conceptually is the use of indicator compounds and surrogate measures to assess and monitor water treatment process performance	Drewes et al., 2008
Toxic Equivalency Factor approach	a special case of the concentration addition concept of mixture toxicity, has been proven to be very useful for risk assessment of chemicals with the same mode of toxic action. The International Programme on Chemical Safety (IPCS) of the World Health Organisation (WHO) has been instrumental in developing and supporting harmonized approaches to the risk assessment of mixtures for dioxin-like chemicals, where the Toxic Equivalency Factor (TEF) approach is applied	Van den Berg et al., 2006
Bioanalytical tools	Used to define the hazard potential of undefined complex mixtures in water	Escher et al., 2011
Probabilistic Assessment	Probabilistic techniques have been used for many decades for such diverse applications as nuclear physics and future stock option valuations Monte Carlo simulation is currently the most widely used method for probabilistic risk assessment	Boyle, 1977 Williams & Paustenbach 2002; Lester et al., 2007

9 KNOWLEDGE GAPS AND RESEARCH NEEDS

Another key objective of the Street Map activities was to identify knowledge gaps and research needs for delivery through NatVal Stage 2 or other mechanisms. This activity has provided an excellent summary of the current knowledge base and the future requirements to implement the Validation Framework for recycled water schemes and ensure its operation is efficient and effective.

A summary list of knowledge gaps has been prepared in Table 7, along with estimates of the time and cost required to address each gap. Many of these key knowledge gaps form the basis for the Validation Framework Road Map summarised in Figure 2.

Although there were a large number of knowledge gaps identified, the majority of gaps fall into a few general areas, including:

- The absence of current rules or guidelines to validate specific technologies,
- Lack of shared knowledge on existing schemes and validation undertaken,
- Insufficient available data to assess the feasibility of an approach, and
- A lack of quality assurance programs for measurement requirements within validation programs.

A key component of the execution of NatVal Stage 1 was the 2 workshops that provided an opportunity for stakeholder discussion while the draft framework was under construction. From workshop 2, a number of research gaps were raised as 'high priority' issues that although included in Table 7, have also been highlighted below:

- MBR validation approaches,
- Statistical treatment of validation data,
- Source characterisation (in general),
- Virus related knowledge gaps (measurement, inactivation etc.),
- Biological process validation,
- Analytical capability, measurement uncertainty and process variability, and
- An agreed tool box for *in situ* testing validation.

The key knowledge gaps and research needs as well as institutional, policy and governance issues that require attention to enable the Validation Framework to be adopted across jurisdictions and for the broad range of current treatment technologies have been identified and are listed in Table 7.

A detailed project plan that addressed the key research gaps outlined in Table 7 is under construction as a separate document by the project team for submission to the AWRCoE for their consideration for NatVal Stage 2.

9.1 *In Situ* Treatment Validation

There is a need to develop guidelines for the validation of *in situ* treatment processes. Guidelines for self assessment and provision of data for desk-top assessment and certification using clear criteria established by the 'Rule Setting Group' as part of the Validation Framework is the preferred approach.

Validation of natural treatment systems remains difficult due to the complexity and sheer size of some systems. While smaller systems such as engineered biofilters

could be validated using more traditional challenge testing, other systems are simply not amenable to conventional approaches.

A standardised suite of tools (a tool box) to assess natural treatment systems in the laboratory and at field scale is required. Considerations include hydraulic studies, measurement of pathogen decay and organic chemical degradation. Such tools need to link to a standardised modelling approach to assess the efficiency of natural treatment systems as well as verification and operational monitoring protocols (surrogates and indicators) for confirmation.

Table 7 Summarised knowledge gaps and research needs (refer to Appendix 3 for a detailed list)

Theme	Ref. No	Knowledge Gap / Need	Task	Outcome	Estimated Duration	Comments
Framework Implementation	1	Determine if the Validation Framework benefits outweigh the costs	Prepare a Business Plan for the Validation Framework	Sound business case outlining the costs, benefits and funding requirements for the framework. This will support the presentation of the Validation Framework to the Federal Government and passage through the COAG process.	3 - 6 months	Recommend this activity is led by the AWRCoE and executed as a separate project to NatVal Stage 2. Should also identify 'preferred' entities for delivering each component of the Validation Framework.
	2	Determine the Validation Framework impact on existing legislation	Conduct a Regulatory Impact Statement (RIS)	Defined impact of the Validation Framework on the regulatory process	3 - 6 months	
	3	Implement the Validation Framework	To seek adoption of the Validation Framework from State and Federal Government	Adoption of the Validation Framework	1 - 3 yrs	Business Plan and RIS activities must precede this item
Benchmarking Studies	4	Inefficient and/or inconsistent validation practice for existing recycle water schemes	Conduct a survey of current and planned recycled water treatment plants, including validation requirements	Provide an inventory of all recycled water projects in Australia and important international projects (e.g. NEWater Singapore, OCWD California)	3 months	Occurred to some extent at a high level in NatVal Stage 1, but all individual stakeholders have not been consulted
	5	Lack of water quality and technology benchmarking data using bioanalytical tools and traditional approaches for recycled water and stormwater	Conduct bioanalytical monitoring and traditional approaches (i.e. chemical testing) on a range of recycled water types (including stormwater) and reference against the AGWR	Link existing water quality guidelines, bioanalytical approaches and conventional (chemical) testing for a range of water types	3 yrs	
	6	Lack of suitable analytical reference standards	Assess reference standard needs and develop priority reference standards for validation of water recycling schemes	Reference standards needs identified and suitable reference standards available	1-3 yrs	
	7	Little data on the application of a range of measurement technologies	Evaluate suitability of measurement technologies to assess the range of	Clearly defined measurement technologies for use in recycled	3+ yrs	For example, particle counters to assess membrane performance, use

Theme	Ref. No	Knowledge Gap / Need	Task	Outcome	Estimated Duration	Comments
		for their use in recycled water systems	treatment technologies used in recycled water systems	water systems to evaluate treatment technologies in use		of molecular and culture based techniques for treatment barrier validation, etc.
Guideline & Policy Development	8	Lack of validation guidelines for a range of technologies	Develop validation guidelines for a range of technologies including: • MBR • Membrane systems (low & high pressure) • Natural treatment systems • Biological treatment systems • Ozonation	Clear and nationally accepted validation guidelines	3+ yrs	Will need to prioritise order to capture greatest need / impact first (NB. MBR rated high during the 2nd NatVal workshop).
	9	Ability to adopt international validation practice that meets minimum acceptable Australian requirements	Establish a formal scan and review mechanisms through the Framework Administrator	Efficient adoption of international validation approaches that comply with minimum acceptable Australian validation criteria	1 yr set up, ongoing review of international practice	
	10	Lack of suitable quality system policies for recycled water systems	Investigate policy requirements for accreditation, QA/QC, data and guideline management for the Validation Framework	Appropriately documented quality systems to support the Validation Framework	1 yr	
Monitoring Approaches and Challenge Testing	11	The need for cost effective, accurate and reliable microbial and chemical surrogates for validation and on-going monitoring purposes.	Identify and test a range of microbial and chemical surrogates using a range of conditions and technologies.	Cost effective, accurate and reliable chemical and microbial surrogates	3+ yrs	This knowledge gap is likely to contain a number of sub-projects.
	12	Lack of standardised testing approaches to assess treatment technology performance	Development of standardised testing approaches to assess treatment performance, including integrating 'hazardous event' conditions	Standardised testing approaches for assessing treatment technology performance	3+ yrs	

10 FRAMEWORK IMPLEMENTATION

The implementation of the Validation Framework for water recycling schemes will require significant cross jurisdictional cooperation. The Validation Framework outlined in this document is potentially 'acceptable' and 'workable', the two key goals of the project team. The proposed Validation Framework has received significant stakeholder support from regulators, industry, suppliers and academia; however, a concerted effort is now required from all stakeholders to move beyond in principle support to implementation.

The development of the Validation Framework will require resolving a range of knowledge gaps and addressing a number of barriers to implementation as outlined earlier in this report. Significantly, the execution of NatVal Stage 1 has dramatically improved the dialogue between diverse stakeholders on this topic, for our national benefit.

The aim of NatVal Stage 2 is to utilise the outcomes from Stage 1 to work towards implementation of the Validation Framework for recycled water schemes. There are numerous activities to be conducted, but there are relatively few that are fundamental to implementation of the Validation Framework.

To summarise the propose approach for the Validation Framework implementation, future activities have been divided into:

(i) Framework implementation activities – that are fundamental and essential to the Validation Framework implementation,
(ii) Benchmarking studies – to provide a consistent baseline for validation activities,
(iii) Guideline and policy development – for effective operation of the Validation Framework, and
(iv) Monitoring approaches & challenge testing.

The knowledge gaps and next steps identified during NatVal Stage 1 have been articulated in the 'Validation Framework Roadmap' outlined in Figure 2 This roadmap has incorporated the collective input of all 'street map' activities that have been synthesised in this 'Road Map report'. Although the project team acknowledges that there are likely multiple approaches that could deliver the intended outcome of the Validation Framework for recycled water schemes, the path outlined in Figure 2 is proposed as the most reasonable given the investigations conducted during NatVal Stage 1.

With regards to the implementation activities, the following points articulate the 'big ticket' items that should be progressed in the immediate term:

- Full business plan development,
- Conduct a regulatory impact statement (NB. could be a subset of the business plan), and
- Continue stakeholder dialogue, with particular emphasis on relevant Federal Government agencies.

With regards to the wide range of supporting activities identified during NatVal Stage 1 and fully articulated in Appendix 3, these activities will be developed into the Stage 2 NatVal project plan for funding consideration by the AWRCoE and other stakeholders.

Figure 2 National Validation Framework Road Map

		Year 1	Year 2	Year 3	Year 4 onwards
Framework Implementation					
1	Business Plan				
2	Regulatory Impact Statement				
3	Validation Framework Implementation				
Benchmarking Studies					
4	Survey existing schemes				
5	Generation of water quality data using appropriate tools				
6	Identifying and generating Reference Standards to support technology validation				
7	Document appropriate measurement technologies to generate validation data				
Guideline & Policy Development					
8	Validation guideline development				
9	Assess/adopt international approaches				
10	Develop suitable quality system policies				
Monitoring Approaches & Challenge Testing					
11	Chemical and microbiological surrogates				
12	Develop standardised testing approaches				

11 RECOMMENDATIONS

The project team is currently preparing the Stage 2 NatVal submission for funding consideration by the AWRCoE. The intent of this submission will articulate the project plan that will work towards implementation of the Validation Framework for recycled water schemes as outlined in this report. Some of the activities outlined in Figure 2, including the development of a full business plan and the conduct of the regulatory impact statement, may be conducted as discrete activities (i.e. independent of NatVal Stage 2), which will be determined after consultation with the AWRCoE.

Overall, the project team recommend the following:

- That the Validation Framework as outlined in Figure 1 is supported by the AWRCoE to deliver against the AWRCoE's Goal 2, pending the outcome of the development of the full business plan,
- The development of a full business plan as a matter of priority be undertaken to fully articulate all of the costs and benefits of the proposed Validation Framework,
- That a Regulatory Impact Statement be undertaken to investigate the impact of the Validation Framework on the regulatory environment (NB. this activity could be a subset of the Business Plan development process), and
- That the AWRCoE consider a Stage 2 NatVal submission to commence the initiation of addressing the knowledge gaps and barriers outlined by this report with the aim of moving towards full implementation of the Validation Framework.

12 ACKNOWLEDGEMENTS

The project team wish to acknowledge all of the investigators that have contributed to the Street Map Reports and attended the workshops or in other ways have had input into the NatVal Project.

We also acknowledge the input into the NatVal Project from the many stakeholders who have contributed their time, knowledge and experience through response to questionnaires and other consultation and through participation in the NatVal Workshops.

The project would not be possible without the funding available from the Australian Water Recycling Centre of Excellence and the generous support of the Water Services Association of Australia, Dow Chemical and Water Quality Research Australia. The generous in-kind support of all the Project Partners (as listed in Appendix 2) and other support organisations who willingly gave their time, knowledge and ongoing support is gratefully acknowledged.

13 REFERENCES

AGWR (2006) Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (phase 1). NRMMC, EPHC & NHMRC.

AGWR (2008) Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (phase 2): Augmentation of Drinking Water Supplies Canberra: NRMMC, EPHC & NHMRC.

Arcoumanis, C., McGuirk, J.J. and Palma, J.M.L.M. (1990). On the use of fluorescent dyes for concentration measurements in water flows. *Experiments in Fluids* 10(2-3): 177-180.

ARMCANZ, ANZECC, NHMRC (Agriculture and Resource Management Council of Australia and New Zealand, Australian and New Zealand Environment and Conservation Council, National Health and Medical Research Council) (2000) Guidelines for Sewerage Systems: Use of Reclaimed Water. Commonwealth of Australia, Canberra.

ASTM (2006) Standard Practice for Integrity Testing of Water Filtration Membrane Systems (D 6908 – 06).

Australian Government (2010) Best Practice Regulation, Handbook. Canberra (http://www.finance.gov.au/obpr/about/)

Blatchley III E.R., Shen, C., Scheible O.K., Robinson J.P., Ragheb K., Bergstrom D.E., and Rokjer D. (2008) Validation of large-scale, monochromatic UV disinfection systems for drinking water using dyes microspheres. *Water Research* 42: 677-688.

Boyle, P. P. (1977) Options: A Monte Carlo approach. *Journal of Financial Economics* 4(3), 323-338.

CDSS (2001) California Department of Social Services, California Health Laws Related to Recycled Water – June 2001. California Code of Regulations, Title 22.

Deletic, A. (2001) Modelling of water and sediment transport over grassed areas. *Journal of Hydrology* 248(1-4), 168-182.

Department of Health Victoria (2010) Draft guidelines for validating treatment processes for pathogen reduction - Supporting Class A water recycling schemes in Victoria. Draft for consultation 3 September 2010.

Drewes, J. E., Sedlak, D. L., Snyder, S. and Dickenson, E. (2008) Development of Indicators and Surrogates for Chemical Contaminant Removal during Wastewater Treatment and Reclamation - Final Report, WateReuse Research Foundation, Alexandra, VA.

Escher, B.I., Leusch, F.D.L., with contributions by Chapman, H. and Poulsen, A. (2011) Bioanalytical tools in water quality assessment. IWA Publishing, London, UK (in press).

Gitis, V., Haught, R.C., Clark, R.M., Gun, J. and Lev, O. (2006a) Application of nanoscale probes for the evaluation of the integrity of ultrafiltration membranes. *Journal of Membrane Science* 276(1-2): 185-192.

Gitis, V., Haught, R.C., Clark, R.M., Gun, J. and Lev, O. (2006b) Nanoscale probes for the evaluation of the integrity of ultrafiltration membranes. *Journal of Membrane Science* 276(1-2): 199-207.

Gogate, P.R. and Pandit, A.B. (2004a) A review of imperative technologies for wastewater treatment I: Oxidation technologies at ambient conditions. *Advances in Environmental Research* 8(3-4), 501-551.

Gogate, P.R. and Pandit, A.B. (2004b) A review of imperative technologies for wastewater treatment II: Hybrid methods. *Advances in Environmental Research* 8 (3-4), 553-597.

Guo, H., Y. Wyart, et al. (2010) Application of magnetic nanoparticles for UF membrane integrity monitoring at low-pressure operation. *Journal of Membrane Science* 350(1-2): 172-179.

ISO/IEC (2010) Conformity Assessment – General Requirements for Proficiency Testing, ISO/IEC 17043:2010

Jacangelo, J.G., Brown, N.L.P., Madec, A., Schwab, K., Huffman, D., Amy, G., Mysore, C., Leparc, J. and Prescott, A. (2006) Micro- and ultrafiltration performance specifications based on microbial removal, Sponsored by AWWA Research Foundation, Published by American Water Works Association.

Johnson, W. T. (1998) Predicting log removal performance of membrane systems using in-situ integrity testing. *Filtration & Separation* 35(1): 26-29.

Kruithof, J. C., P. C. Kamp, et al. (2001) Development of a membrane integrity monitoring strategy for the UF/RO Heemskerk drinking water treatment plant. *Water Science and Technology: Water Supply* 1: 261-271.

Lintern, A., Daly, E., Brown, D., Hatt, B.E., Fletcher, T.D., Wong, T.H.D. and Deletic, A. (submitted) Development of a stormwater biofiltration model. *Journal of Hydrology*.

Magal, E., Weisbrod, N., Yakirevich, A. and Yechieli, Y. (2008) The use of fluorescent dyes as tracers in highly saline groundwater. *Journal of Hydrology* 358(1-2): 124-133.

Sethi, S., Crozes, G., Hugaboom, D., Mi, B. and Curl, J.M. (2004) Assessment and development of low-pressure membrane integrity monitoring tools, American Water Works Association.

Steven, J., Tom, H. and James, N. (2005) Sensitive Integrity Test for RO/NF Elements, PAPER: IWC-05-16. Proceedings of International Water Conference Orlando, Florida.

Sutton, D.J., Kabala, Z.J., Francisco, A. and Vasudevan, D. (2001) Limitations and potential of commercially available rhodamine WT as a groundwater tracer. *Water Resources Research* 37(6): 1641-1656.

USEPA (2006) Ultraviolet disinfection guidance manual for the final long term 2 enhanced surface water treatment rule. Washington, DC.

USEPA (2005) Membrane Filtration Guidance Manual. EPA.815-R-09-009.

USEPA (2004) Guidelines for Water Reuse. EPA/625/R-04/108.

Van den Berg, M., Birnbaum, L. S., Denison, M., De Vito, M., Farland, W., Feeley, M., Fiedler, H., Hakansson, H., Hanberg, A., Haws, L., Rose, M., Safe, S., Schrenk, D., Tohyama, C., Tritscher, A., Tuomisto, J., Tysklind, M., Walker, N. and Peterson, R. E. (2006) The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol Sci. 93(2), 223-241.

Van Hoof, S. C. J. M., L. Broens, et al. (2003) Development of a new integrity testing system. *Water Science and Technology: Water Supply* 3(5-6): 101-108.

WHO (2004) Guidelines for Drinking Water Quality, World Health Organization. Geneva.

Williams, P. R. D. and Paustenbach, D. J. (2002) Risk characterization: Principles and practice. *J. Toxicol. Env. Heal. B.* 5(4), 337-406.

APPENDIX 1 - GLOSSARY

Chloramination	Use of chloramines (compounds formed by the reaction of hypochlorous acid or aqueous chlorine with ammonia) as a means of disinfection
Chlorination	Use of chlorine as a means of disinfection
Indicator compound	An individual chemical, occurring at a quantifiable level, which represents certain physicochemical and/or biodegradable characteristics of a larger group of trace constituents
Multiple Barriers	Use of more than one preventive measure as a barrier against hazards
Ozonation	The process by which ozone is produced when oxygen (O2) molecules are dissociated by an energy source into oxygen atoms and subsequently collide with an oxygen molecule to form an unstable gas, ozone (O3), which is used to disinfect water. The mechanisms of disinfection using ozone include: direct oxidation/destruction of the cell wall; with leakage of cellular constituents outside of the cell; reactions with radical by-products of ozone decomposition; and damage to the constituents of the nucleic acids.
Preventive Measures	Any planned action, activity or process that is used to prevent a hazard or reduce to an acceptable level.
Process Barriers	A treatment or process step used to reduce the concentration of a hazard
Recycled water	Water generated from sewage, greywater or stormwater systems and treated to a standard that is appropriate for its intended use.
Recycled Water Management Plan	Or State equivalent e.g. Recycle Water Management Plan (NSW), Health and Environment Management Plan (Vic) etc.
Stakeholder	A person or group (eg an industry, a government jurisdiction, a community group, the public, etc) that has an interest or concern in something.
Surrogate	A challenge organism (such as bacteriophage), particulate or chemical (such as rhodamine) that is a substitute for the target microorganism of interest. For a surrogate to be suitable it must be either: • reduced (removed or inactivated) by the treatment process unit to an equivalent or lesser extent than the target pathogen, or • possible to demonstrate a reproducible correlation from literature, laboratory or field trials between reduction of the surrogate and the target pathogen.
Technology	A particular piece of equipment or process that is used in a

	treatment plant to remove pathogens or to contribute to the improvement of water quality.
(Treatment) System	A combination of technologies or treatment barriers intended to reliably provide a target water quality suitable for recycled water end user. Systems may also include non-treatment barriers that provide additional barriers after a treatment plant to further reduce the exposure risk of the end users.
Validation (of process)	The substantiation by scientific evidence (investigative or experimental studies) of existing or new processes and the operational criteria to ensure capability to effectively control hazards.
Verification (of process)	The confirmation by measurement of key water quality and operating parameters that a treatment process or is operating within defined limits.
Water Recycling	A generic term for water reclamation and reuse. It can also be used to describe a specific type of 'reuse' where water is recycled and used again for the same purpose (eg recirculating systems for washing and cooling), with or without treatment in between.

APPENDIX 2 – PROJECT TEAM AND COMMITTEES

The Project Team comprised:

- Ben ven den Akker (UNSW)
- Alice Antony (UNSW)
- Palenque Blair (Water Corporation)
- Wee Hong Chin (RMIT University)
- Marlene Cran (Victoria University)
- David Cunliffe (SA Health)
- Chris Davis (UTS)
- Dan Deere (Water Futures)
- Ana Deletic (Monash University)
- Beate Escher (University of Queensland)
- Linhua Fan (RMIT University)
- Wolfgang Gernjak (University of Queensland)
- Stephen Gray (Victoria University)
- David Halliwell (WQRA)
- Rita Henderson (UNSW)
- Amanda Ind (Griffith University)
- Pierre Le-Clech (UNSW)
- Greg Leslie (UNSW)
- Fred Leusch (Griffith University)
- Cheryl Lim (NMI)
- Alex Keegan (AWQC)
- Stuart Khan (UNSW)
- Michael Muston (Muston & Associates)
- Thang Nguyen (RMIT University)
- Eddy Ostarcevic (Integrated Elements)
- Declan Page (CSIRO)
- Kaye Power (IPART NSW)
- Felicity Roddick (RMIT University)
- Helen Stratton (Griffith University)
- Simon Toze (CSIRO)
- Graeme Watkins (Mid Coast Water)

The project was steered by an internal Steering Committee, comprising the following people:

- Nanda Altavilla (NSW Metropolitan Water Directorate, Dept. of Finance & Services)
- David Halliwell, Chair (WQRA)
- Stuart Khan (UNSW)
- Michael Muston (Muston & Associates)
- Declan Page (CSIRO)
- Cedric Robillot (WSAA Representative, SeqWater)
- Graeme Watkins (Mid Coast Water)

The AWRCoE convened a Project Advisory Committee to provide advice to the Project Team through the Project Manager or Project Leader, to assess milestone reports and other project outputs, and to report back to the AWRCoE's Research Advisory Committee. The Project Advisory Committee comprised:

- Mark Angles (Sydney Water)
- Therese Flapper (GHD)
- Sarah Haydon (AWRCoE)
- Bob Hultquist (Independent)
- Clare McAuliffe (Melbourne Water)
- Yvan Poussade, Chair (Veolia Water Australia)
- Suzie Sarkis (Dept of Health, Victoria)
- Troy Walker (Veolia Water Australia)

APPENDIX 3 –KNOWLEDGE GAPS AND RESEARCH NEEDS IDENTIFIED THROUGH STREET MAP PROCESS

Activity / Project Title	Proposer Name & Organisation	Potential Collaborators	Outcome addressed	Expected Duration	Comments
Draft of guidelines for MBR validation for water recycling schemes	Pierre Le-Clech (UNSW), Stephen Gray (VU)	Dow, Koch, Siemens, Tenix, GE, AECOM, John Holland, DoH (Vic), NRWRF	Will deliver appropriate and practical method to assign, approve and monitor LRV in MBR, to be later updated by further research activities (see below). It is also expected that two levels of validation will be delivered, depending on the recycling class	6 months	Estimated costs: $55,000 (6 months postdoc at 100,000/year + meeting costs $5,000)
Draft of guidelines for validation of high-pressure membrane systems for water recycling schemes	Pierre Le-Clech (UNSW), Stephen Gray (VU)	Dow, Koch, Tenix, GE, AECOM, John Holland, DoH (Vic), NRWRF	Will deliver appropriate and practical method to assign, approve and monitor performances of high-pressure membrane systems, to be later updated by further research activities (see below).	6 months	Estimated costs: $55,000 (6 months postdoc at 100,000year + meeting costs $5,000)
Draft of guidelines for validation of low-pressure membrane systems for water recycling schemes	Pierre Le-Clech (UNSW), Stephen Gray (VU)	Dow, Koch, Siemens, Tenix, GE, AECOM, John Holland, DoH (Vic), NRWRF	Will deliver appropriate and practical method to assign, approve and monitor LRV in low-pressure membrane systems, to be later updated by further research activities (see below).	6 months	Estimated costs: $55,000 (6 months postdoc at $100,000/year + meeting costs $5,000)
Validation of biological wastewater treatment systems	Helen Stratton & Amanda Ind (GU)	Seqwater (Water Secure/Veolia), Melbourne Water,	Lack of data for validation of biological systems. Will investigate appropriate methods for validation of biological processes and deliver draft guidelines for validating recycled water schemes that use biological processes.	12-24 Months	Phase 1 identified a severe lack of information for the validation of biological systems - in fact some reports suggested it is impossible to achieve.
Survey of Current and Planned Recycled Water Treatment Plants	Helen Stratton & Amanda Ind (GU)	DERM QLD, DoH (Vic), Veolia, Orange County	Provide an inventory of all Australian and relevant international recycled water projects	3 months	Will ensure that all potential stakeholders are identified and benchmarking will avoid further gaps emerging. This was partially carried out in Phase 1 but individual stakeholders were not engaged.
Removal and disengagement of pathogens in packed bed processes	Felicity Roddick, Thang Nguyen and Linhua Fan (RMIT)	AWQC, DoH (Vic), Melbourne Water, Activated Carbon Technology P/L	Efficacy of pathogen removal in packed beds and their appearance in backwash streams	12 months	
Development of Business case for framework	AWRCoE led	National Water Commission/ AWRCoE	Sound business case with funding requirements for the framework. Support the presentation of the scheme to the Federal Government and passage through the COAG process.		

Activity / Project Title	Proposer Name & Organisation	Potential Collaborators	Outcome addressed	Expected Duration	Comments
Correlation of LRV with pressure decay on new and aged membranes to assess long-term removal of viruses	Marlene Cran, Stephen Gray (VU), Eddy Ostarcevic (IE)	Koch, others to be confirmed	Deliver previously unavailable data on LRVs for aged membranes. To be used to assist onsite verification.	12 months	$80,000
Evaluation of full potential of LRVs for RO membranes by challenge tests, pressure decay etc.	Marlene Cran, Stephen Gray (VU), Eddy Ostarcevic (IE)	Koch, Dow Chemical, others to be confirmed	Assessment of the true potential of LRV credits for RO membranes, evaluation of membrane supplier data	12 months	$130,000 - Full-time post-doc
Assessment of Priority Reference Standards Needs for Validation of Water Recycling Schemes	Cheryl Lim (NMI)	AWQC, QHFSS, ALS	Detailed assessment of availability of reference standards for treatment technologies identified to be of highest priority	2 months	The list of potential collaborators consists of those who provided relevant feedback to the questionnaire; there may be more organisations interested.
Development of Policies on Quality Systems	Cheryl Lim (NMI)	NRWRF, SEWPaC	Investigation into and Stakeholder Consultation on Policies relating to Accreditation, QA/QC, Data and Guidelines for a Validation Framework for Water Recycling Schemes	6-12 months	(a) Stakeholder consultation can be integrated with any other stakeholder consultation steps to be done in Stage 2 to minimise costs. (b) The list of collaborators does not include all stakeholders potentially involved in the stakeholder consultation phase.
Development of an Integrated Testing Strategy in a multibarrier approach	Stuart Khan, Rita Henderson, Ben van den Akker (UNSW), Beate Escher (UQ) Fred Leusch (GU)	AWQC, CSIRO	A coherent and tiered framework for assurance of chemical and microbial water quality	2 yrs	While there exist many successful and viable components of validation and there quality guidelines for product water, a missing link is the assessment of individual components of different treatment barriers with a coherent framework that integrates chemical and microbial risks.
Benchmarking of water quality and of different technologies using bioanalytical tools	Beate Escher (UQ), Fred Leusch (GU)	AWQC, CSIRO, CAPIM	Water quality benchmarking needs to be linked with existing water quality guideline values: Technology benchmarking using chemical analysis shows the disappearance of the parent compound, but does not identify if (potentially more toxic) transformation products have formed.	3 yrs	While there is broad agreement that bioanalytical tools should be used to validate different technologies, it is unclear what the results mean in absolute values. The major hurdle to overcome before defining effect-based water quality criteria is to link toxic equivalent concentrations to existing water quality criteria for single chemicals. Once this validation has been achieved, bioanalytical tools should be used to validate and compare different technologies (benchmarking of treatment technologies)

Activity / Project Title	Proposer Name & Organisation	Potential Collaborators	Outcome addressed	Expected Duration	Comments
Development of a standardised approach for integrating "hazardous event" conditions into treatment performance assessment	Stuart Khan & Ben van den Akker (UNSW)	SA Health	The need to rigorously assess likelihoods and consequences of hazardous events in order to properly assess performance	1 yr	This project could be undertaken in collaboration with numerous other activities being undertaken for NatVal. It would not likely require additional consumable resources to complete.
In-situ verification and monitoring for MBRs	Pierre Le-Clech (UNSW), Stephen Gray (VU)	Dow, Koch, Siemens, Tenix, GE, AECOM, water utilities	Assessment of (1) correlations between online monitoring techniques (i.e. turbidity) with LRV - for easier operation monotoring and (2) relative impact of fouling on LRV - to potentially limit the requirements during in-situ validation	18 months	Estimated costs: $255,000 (18 months postdoc at 100k/year + Pilot scale rig ($30k) + Analysis ($15k) + PhD stipend (2x30k))
Effect of high pressure membrane ageing on integrity for chemicals and pathogens.	Marlene Cran, Stephen Gray (VU), Pierre Le Clech (UNSW)	Veolia/Degremont/Water Authorities/DoH (Vic)	An understanding of how membrane rejection of chemicals and pathogens varies with ageing of materials. Can we use TDS rejection as a surrogate for chemical rejection?	12 months	Assuming a focus on ageing and TDS rejection correlated to chemical rejection with ageing. Cost: $150,000. Potential to extend to field testing, data collection to confirm laboratory results (additional 12 months?).
Validation methods for ozonation	Wolfgang Gernjak, Julien Reungoat, Jurg Keller (UQ/AWMC)	Melbourne Water, Unity Water, Sydney Water, DCM Process Control, ITT Water & Wastewater	Validation/verification based on on-line spectrophotometric measurements and link operational verification monitoring with process control optimizing ozone dose	2.5 years	$400,000 Currently no widely accepted methodology for ozone available with Melbourne Water's Eastern Treatment Plant Upgrade being the only validated plant
Validation of models for adsorption of micropollutants in wastewater matrices	Felicity Roddick, Thang Nguyen and Linhua Fan (RMIT)	AWQC, DoH (Vic), Melbourne Water, Activated Carbon Technology P/L	Prediction of performance of adsorption systems	18-24 months	
Regulatory impact Statement	TBA	National Water Commission, WSAA	Impact of proposed framework on the current regulatory process	3-6 months	
Comparison of inter-locking membranes (fixed o-rings) with interconnecting membranes (free o-rings) to quantify potential for rolled o-rings and subsequent leaks and lower LRV credits	Marlene Cran & Stephen Gray (VU), Eddy Ostarcevic (IE)	Dow Chemical, others to be confirmed	Currently get more LRV credit for UF than RO, need to assess whether this a function of the connection type and other fittings	6 months	$50,000 - Research assistant with part-time post-doc supervision

Activity / Project Title	Proposer Name & Organisation	Potential Collaborators	Outcome addressed	Expected Duration	Comments
Development of Priority Reference Standards Needed for Validation of Water Recycling Schemes	Cheryl Lim (NMI)	AWQC, QHFSS, ALS	Development of new reference standards to fill the gaps where most needed (as identified in Activity 1)	Dependent on findings of Assessment of Priority Reference Standards Needs Project	The list of potential collaborators consists of those who provided relevant feedback to the questionnaire; there may be more organisations interested.
Comparison of the use of molecular and culture-based techniques for validation of water treatment barriers.	Ben van den Akker (UNSW)	AWQC, CSIRO	Would facilitate improved interpretation and comparison of validation studies undertaken by the two different approaches to microbial enumeration.	2 yrs	In contrast to culture-based techniques, the molecular-based protocols need to be improved and standardized. For example, there is a lack of standardized, well-validated DNA extraction techniques, which are widely applicable to different environmental samples
Lab-grown 'vs' indigenous strains of microbial organisms	Ben van den Akker (UNSW)	AWQC, CSIRO	A range of laboratory-grown strains of microorganisms are now available for validation processes such as challenge testing. However, there are indications that these strains may not be as robust as indigenous wastewater strains.	2 yrs	More research into the suitability of laboratory grown strains for the measurement water treatment barrier performance is required given that indigenous indicators and laboratory strains can have different resistance to environmental pressures.
Standardised methodology for virus isolation, culture and detection for recycled waters	Alex Keegan (AWQC)	AWQC/ SA Water, CSIRO, Sydney Water	Establish consistent method for evaluating virus removal/inactivation/ presence in recycled wasteaters	2 years	$300,000
In situ natural system validation tool box	Declan Page (CSIRO)	CSIRO Land and Water, Utilities, Local Governments, Monash University, State Governments		6 months	
Characterisation of water source (focusing on stormwater)	Ana Deletic (MU)	Local Government, Melbourne Water, CSIRO Land and Water, Water Utilities (e.g. Yarra Valley Water, City West Water, South East Water, SA Water, etc)		3 years	
Biological process surrogates and indicators	Declan Page (CSIRO)	CSIRO, Utilities, Monash University, State Governments		3 years	
WSUD validation trial	Ana Deletic (MU)	Local Government, Melbourne Water, Yarra Valley Water, City West Water, South East Water, SA Water, etc.		1 year	

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Cheaper methods for assessing UV RED, using actinometric methods	Alex Keegan (AWQC), Wolfgang Gernjak (UQ/AWMC)	AWQC, SA Water, Melbourne Water, Aquatech Maxcon, Orica WaterCare, Trojan,	Will deliver cheaper option to USEPA UVDGM validation of UV reactors	2 years,	$250,000
Evaluation of particle counters for on-line monitoring of membrane performance	Marlene Cran & Stephen Gray (VU), Eddy Ostarcevic (IE)	Koch Membrane Systems, others to be confirmed	Maximise the use of existing technologies to benefit verification performance studies	12 months	$80,000 - Research assistant with part-time post-doc supervision
Review of the capacity to link into international established schemes including those places which have already been established	TBA	Federal Government	Ongoing sustainability of the scheme	3 months	This can be carried out by the framework administrator as part of their ongoing refinement of business model
Review of the extension of the framework to incorporate certification of on-site treatment technologies, validation of drinking water technologies and other environmental treatment technologies as with the ETV programs	TBA	Federal Government	Ongoing sustainability of the scheme		This can be carried out by the framework administrator as part of their ongoing refinement of business model
Suitable chemical indicators for various treatment processes	Stuart Khan (UNSW)	TBA	Considerable knowledge and experience is required to fully assess and validate the performance of specific chemicals for monitoring the performance of most types of treatment processes	2 yrs	This project could be undertaken in collaboration with numerous other activities being undertaken for NatVal.
Enhanced surrogate measures for chemical treatment performance	Stuart Khan & Rita Henderson (UNSW)	TBA	A clear relationship between the treatment performance for existing surrogate measures and some specific groups of chemicals is not always apparent. Furthermore, the sensitivity of the online measures is not always sufficient to demonstrate the full degree of treatment performance of some chemicals.	2 yrs	Spectrophotometric techniques such as UV absorbance and fluorescence emission may provide enhanced specificity and sensitivity. However, the routine online use of these techniques for monitoring treatment performance is yet to be adopted for large scale treatment processes.
Transformation products	Beate Escher (UQ)	Curtin University	One chemical can have a variety of transformation products, for which there is usually no known toxicity data and which have generally not undergone risk assessment.	3 yrs	Bioanalytical tools could be useful to investigate the toxicity and occurrence of transformation products and serve as a potency-scaled sum parameter of all chemicals (parents and transformation products) present in a water sample. This topic is addressed in a Goal 1 project but outcomes need to be integrated into NatVal.

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Standardisation of pathogen concentration protocols	Ben van den Akker (UNSW)	AWQC, CSIRO	Protocols for the concentration of bacteriophage and viruses, need to be improved and standardised	1 yr	0
Understanding pathogen reduction mechanisms	Ben van den Akker (UNSW)	AWQC, CSIRO	More research is needed to better understand the mechanisms of pathogen reduction via some treatment processes used in the water recycling industry.	2 yrs	Molecular-based viability assays have been developed, but are yet to be used in validation type studies.