Externalities in Sustainable Regional Water Strategies: Application of a Simple Methodology

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The Urban Water Security Research Alliance (UWSRA) is a $50 million partnership over five years between the Queensland Government, CSIRO's Water for a Healthy Country Flagship, Griffith University and The University of Queensland. The Alliance has been formed to address South East Queensland's emerging urban water issues with a focus on water security and recycling. The program will bring new research capacity to South East Queensland tailored to tackling existing and anticipated future issues to inform the implementation of the Water Strategy.

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FOREWORD

Water is fundamental to our quality of life, to economic growth and to the environment. With its booming economy and growing population, Australia's South East Queensland (SEQ) region faces increasing pressure on its water resources. These pressures are compounded by the impact of climate variability and accelerating climate change.

The Urban Water Security Research Alliance, through targeted, multidisciplinary research initiatives, has been formed to address the region's emerging urban water issues.

As the largest regionally focused urban water research program in Australia, the Alliance is focused on water security and recycling, but will align research where appropriate with other water research programs such as those of other SEQ water agencies, CSIRO's Water for a Healthy Country National Research Flagship, Water Quality Research Australia, eWater CRC and the Water Services Association of Australia (WSAA).

The Alliance is a partnership between the Queensland Government, CSIRO's Water for a Healthy Country National Research Flagship, The University of Queensland and Griffith University. It brings new research capacity to SEQ, tailored to tackling existing and anticipated future risks, assumptions and uncertainties facing water supply strategy. It is a $50 million partnership over five years.

Alliance research is examining fundamental issues necessary to deliver the region's water needs, including:

- ensuring the reliability and safety of recycled water systems.
- advising on infrastructure and technology for the recycling of wastewater and stormwater.
- building scientific knowledge into the management of health and safety risks in the water supply system.
- increasing community confidence in the future of water supply.

This report is part of a series summarising the output from the Urban Water Security Research Alliance. All reports and additional information about the Alliance can be found at http://www.urbanwateralliance.org.au/about.html.

Chris Davis
Chair, Urban Water Security Research Alliance

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LIST OF ACRONYMS

BNR	Biological Nutrient Removal
ABS	Australian Bureau of Statistics
CBA	Cost-benefit Analysis
CEA	Cost-Effectiveness Analysis
CSIRO	Commonwealth Scientific and Industrial Research Organisation
eWater CRC	eWater Cooperative Research Centre
GHG	Greenhouse Gases
GU	Griffith University
LCA-IM	Life Cycle Analysis – Integrated Modelling project of the UWSRA
MCA	Multi-Criteria Analysis
ML	1 megalitre or 1 million litres
QWC	Queensland Water Commission
SEQ	South East Queensland
SEQ-RP	South East Queensland Regional Plan
SEQWS	South East Queensland Water Strategy
SWM	Sustainable Water Management
TBL	Triple bottom line
TEV	Total Economic Value
UQ	University of Queensland
UWSRA	Urban Water Security Research Alliance
WGM	Water Grid Manager
WTP	Willingness to Pay
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

In view of the need for a practical, general approach to including externalities in strategic resource decision-making in the South East Queensland (SEQ) context, this report presents a relatively simple and practical structured methodology for the effective incorporation of triple bottom line (TBL) effects of (water) resource management options.

Given the background research context of the report, the externality analysis emphasises water supply scenarios based on seven options recently mooted for ensuring sustainable water services in the SEQ region. However, the general methodology could easily be extended and applied to other geographical and resource contexts (and demand-side management options).

Externalities comprise an essential component of analysis for effective TBL accounting and assessment for the design and selection of sustainable and regional and local strategies for water (and other key scarce natural resources).

Externalities are effects on people's welfare that are not taken into account directly in market-place transactions. They typically cover the impacts of costs and benefits on those not considered and/or involved in (and hence "external" to) the market transactions that generate them. Hence, they do not directly influence the dollar values in prices typically used to evaluate costs and benefits of goods and services (including major infrastructure and policies and regulations). Examples include the potential climate change effects of desalination or water quality implications of wastewater recycling. They can be costs or benefits, and often take the form of long-term or unknown outcomes upon community well-being and are part of complex cause-effect chains. Although externality effects are not included in direct market transactions, they can have very significant impacts that will strongly influence the net benefits of major water servicing projects. TBL accounting covers the full social costs and benefits of such actions (and hence economic or direct financial, social and environmental effects and their interconnections).

There are a number of existing frameworks and externality valuation databases that can be used for the analysis and incorporation of externalities in decision-making for water and other resources. However, the approaches currently available tend to be technical, discourage actual application, and are often fixed in terms of decision criteria and procedures (given the narrow disciplinary foundations of the approach concerned). The "simple externality analysis" (SEXTAN) method presented here is proposed as a useful and innovation contribution to water-related TBL assessments, in terms of its: (1) life cycle approach; (2) focus upon the detailed impacts of seven specific and practical example water supply options (rather than a generalised water management approach); (3) direct application to a regional case study in SEQ; and (4) joint provision of information on option externalities and valuation estimates.

The externality analysis methodology presented in this report is ideally suited to the TBL assessment required for effective total water cycle management (TWCM) planning and implementation at regional and sub-regional scales. This is a result of its ability to incorporate the extensive range of interconnected environmental, economic and social factors that must be considered in integrated total water cycle management approaches.

The methodology was devised from research implemented as a response to the need for regional planning in a time of severe drought in SEQ. There has been extensive rainfall since 2009 and, at the time of writing this report, water supply storages in the region are full or at near-capacity. Hence, whilst ensuring long-term supply and use efficiency and water balance remain as key priorities, the focus of the UWSRA research now includes a strong emphasis on sub-regional scale planning and analysing and identifying reliable water supply and demand options that minimise total social costs,

including energy, greenhouse gas (GHG), nutrient loads and water quality problems, within a TWCM perspective. Broader water quality issues are an integral part of this approach and play a central role in the current research priorities.

The externality analysis methodology outlined in this report and the valuation estimates provided in a companion report (Daniels *et al.*, 2012) are provided as a general information base, and are left *open-ended* in terms of how they are applied in decision-making. However, the report has reviewed several major decision-making frameworks to demonstrate the potential contribution of the proposed externality analysis and its data outputs.

There are seven steps in the proposed SEXTAN externality analysis methodology, as it has been applied to the assessment of regional water servicing options in this report. The simple externality analysis method is described in detail and illustrated with a basic example in Section 2.

The externality analysis methodology in this report is complemented by the ability to cross-reference to the detailed externality lists and valuations associated with the seven water supply options in the companion water externalities report (Daniels *et al.,* 2012).

The compendium in Daniels *et al.* (2012) ("Report 1") is essentially a detailing of Steps 2 and 4 of the methodology outlined in this report, that is: (1) the identification of main externalities associated with each of the seven water options considered; and (2) a compilation of existing monetary valuations of per unit externality impacts (e.g., $ per kilogram of nitrogen). This systematic collection and classification of data can provide valuable (if incomplete) inputs to the attempts at operationalising the SEXTAN externality analysis methodology described in this report. The information has been drawn from an extensive survey of existing research. The method outlined here provides a framework for the more in-depth analysis and application of the information in the companion report. The effective application of the externality analysis, valuations and overall method to specific contexts and resource issues would often require supplementary primary research.

In this report, the SEXTAN method is demonstrated using an example based upon a hypothetical planned water supply scenario. The sample scenario and empirical data use case study work associated with the project, but they are hypothetical in nature and are not intended for policy evaluation purposes.

The final section of the report discusses the potential and limitations of applying the SEXTAN externality analysis method in broader decision-making frameworks. Its role in cost-benefit analysis (and cost-effectiveness analysis) and multi-criteria analysis are emphasised to reveal its (conditional) benefits for improved decision-making.

The economic valuation estimates of the "unintended" impacts captured in externality analysis of the water options in our case study, and the broader methodology outlined in this report, are presented under the strict proviso that they are valuable inputs that form just *one* aspect of overall decision-making processes.

The SEXTAN externality analysis procedure has many direct connections to the general cost-benefit analysis (CBA) procedure – especially in Stages 2 to 4 of the framework where externalities are identified, quantified and valued. However, a major condition in the SEXTAN method is the need to retain the externality results in a disaggregated form – as individual externality effects measures.

The proposed externality analysis methodology can provide data inputs to various stages of the multi-criteria analysis (MCA) process, especially in: (1) helping the analyst to decide the relevant set of impacts (the evaluation criteria); (2) providing background information that is supplied to participants in their scoring of each predicted impact; and (3) assisting analysts in their selection of subjective weights for assessing the relative importance of each impact.

The significant problems and limitations inherent in decision-making frameworks also often constrain the overall usefulness and validity of the externality analysis method and outputs. Beyond formidable information problems that plague any systematic assessment of strategic decision outcomes, it is important to acknowledge the caveats associated with the conceptual and theoretical problems of economic valuation methodologies, and the limits of drawing valuation estimates from very different geographic, economic and political contexts.

A critical assumption underlying the externality analysis methods and valuation estimates is that the benefits of this type of approach are not solely dependent on the ability to convert all costs and benefits into dollar values. Indicative monetary values can be useful in decision-making if there is explicit treatment and awareness of the range of monetary values estimated, the reliability, completeness and accuracy of underlying data, and the need for specific contextual information.

In combination with the externality identification and valuation tables presented in the companion report (Daniels *et al.,* 2012), the SEXTAN externality analysis method outlined in this report provides a useful reference and guide for researchers, planners and decision-makers concerned with the sustainable management of water.

1. INTRODUCTION

1.1. Externality Analysis for Water Service Options

In the private sector, decisions about projects and investment have typically been dominated by direct financial criteria. This is changing with shifting community expectations about business accountability and social responsibility, and related market and regulatory demands upon the behaviour and impacts of economic actors (World Business Council for Sustainable Development, 2000). Decisions about public projects are considered to be inherently guided by society-wide impacts. Nonetheless, decision-making for major public investment and strategies in key areas such as transport, health and utilities is still often based on a limited set of decision variables such as financial cost, direct performance outcomes (e.g. quality-adjusted life years), and engineering or technical capabilities – perhaps with some recognition and assessment of major environmental, economic or social impacts. Inevitably, political and interest group influence and outcomes will also play a significant role in many decisions.

Expanding decision-making to cover effects beyond markets, to the broader welfare of the community, introduces the critical role of economic, environmental and social "spill-over" effects, or "externalities". As described in more detail in Box 1, externalities occur when one person's consumption or production behaviour affects that of another without any compensation. Compensation (paying for a good or service and receiving income for production inputs) usually occurs as a consensual agreement between buyer and seller in the marketplace. In theory, if decision options can be fully assessed in terms of both market and externality effects across society and over time, there is enhanced potential for making choices that effectively increase well-being or at least make good use of society's limited resources.

Box 1. What are Externalities?

> *Externalities refer to the effects of benefits and costs of ... resource management activities not directly reflected in the market. An externality occurs when one person's consumption or production behavior affects that of another without any compensation. The price of the ... goods need not reflect its social value in consumption and management due to presence of externalities.*
>
> Dahal (2007, p.62)

Hence, the unintended impacts of externalities often occur as a result of market failure, where costs and benefits of an action are not reflected within market transactions and the affected parties remain uncompensated (Common and Stagl, 2005, p. 327; Siebert, Young and Young, 2000, p.5). Externalities can constitute a benefit (e.g. provision of recreational habitat) or a cost (e.g. the loss of fisheries production due to water pollution). The primary concern which arises from the presence of externalities is that financial measures associated with water (e.g. prices, infrastructure and project costs) fed into decision-making about strategic options do not reflect true costs upon society and the environment (Gardner, McDonald and Chung, 2006, p.3). Thus, it can be indicative of, or lead to, inefficient water resource allocation. It is crucial that these externalities be reflected throughout decision-making and day-to-day management scenarios (Retamal *et al.*, 2009, p.8).

In reality, the "beyond-market" external effects that are juggled and bandied about in the decision-making process, are generally assessed, compared and weighed up in a very *ad hoc* manner with limited data, unfounded assumptions, value-biased assessment of their intensity and importance, media hype, and other interest group pressures and prejudice.

In this report, we summarise and exemplify a more systematic, transparent, scientific and comprehensive approach to incorporating the assessment of the full range of social costs and benefits of a project or development alternative (for example, water supply options). The methodology outlined is not presented as a complete decision-making system but a combination of scientific, engineering and economic analytical techniques to identify and measure the diversity of impacts of options on humans (directly and via environmental state changes). The method does not embrace a specific decision-making framework with a given philosophical stance about *how* to make decisions (e.g. cost-benefit analysis or multiple criteria analysis).

Rather, the externality analysis methodology outlined is intended as a guide to collecting more complete, valid and balanced data about the full range of triple bottom line (TBL) effects of options and how these might be quantified in terms, of society's resources and trade-offs, so as to design and implement options with the best outcomes from the community's point of view.

The method has emerged from research into the environmental (biophysical) and economic assessment of water supply scenarios for South East Queensland (SEQ). Although water supply conditions have now changed, SEQ experienced severe drought in the decade up to 2009 and a disturbing scenario where dam levels fell to unprecedented lows (around 17% of combined capacity in July 2007) – leaving less than a year's supply available at extant consumption levels (QWC, 2009). As the situation reached emergency levels, many new supply options were introduced or planned in an effort to meet the burgeoning demands of a rapidly growing population. These supply expansion options included desalination plants, new dams and upgrades, and a large-scale regional water pipeline grid with extensive purified water recycling capabilities. These measures were planned in addition to a range of demand management and decentralised supply options. Given rapid regional population growth, a propensity for drought, and the potential exacerbation of supply problems from future climate change, there is an increasingly urgent need for the adoption of sustainable water management practices (Sudhakar and Mamatha, 2004, p.946).

While the externality analysis proposed has been derived from work carried out for enhanced sustainable water management in SEQ, the method can be applied (with some modification) for the strategic assessment of a wide range of natural resource management and development options.

1.2. Report Aim

This report presents a relatively simple, feasible and structured method for the effective incorporation of TBL effects of project options into the community decision-making process. It focuses upon water options and uses a hypothetical example to demonstrate the method but the approach can easily be adapted to many other development option decision-making contexts.

The proposed method represents a systematic, transparent, scientific and comprehensive approach to help progress towards the more effective incorporation of the full range of social costs and benefits of a project or development alternatives into strategic policy decisions.

There are **seven steps proposed for the externality analysis** and applied to regional water servicing options in this report. They include:

1. Scenario composition based on the contribution of component water supply options (e.g., 600 ML from new dams; 400 ML from wastewater recycling per year).
2. Given the options comprising each scenario, identification of the major externalities associated with these options (e.g., for new dams: (a) loss of agricultural land; and (b) reduced downstream flood damage; for wastewater recycling: (a) increased greenhouse gas (GHG) emissions; and (b) increased phosphorus emissions).
3. For each option in the scenario, the biophysical or socioeconomic (non-monetary) quantification of each externality generated per unit output of required water quality from that option (e.g., for wastewater recycling: 1.8 t of GHG and 5.1 kg of phosphorus per ML of potable water output).
4. The economic valuation of relevant *per unit* biophysical or indicator externality impacts (typically biophysical) for *each* option (e.g., for wastewater recycling sources: $30 per tonne of CO2 and $15 per kg of phosphorus).

5. Calculation of *each* externality type's cost/benefit *per unit* water service change (e.g., for a ML of wastewater recycled water, \$54 per year (\$30 x 1.8t) for GHGs, and \$76 per year (\$15 x 5.1kg) for phosphorus).
6. Calculation of the total dollar value cost or benefit of each externality effect from the *total* planned change in water service (e.g., for the 400 ML increase in supply from wastewater recycling, the externality costs would be 400 ML x \$54 per ML, or \$21,600 per annum for GHGs and 400 ML x \$76 or \$30,400 for phosphorus).
7. Include the externality valuation results into decision-making processes; either separately for each externality impact or aggregated in various ways for the alternatives being assessed.

Steps 2 to 6 would usually require an analysis of the temporal profile of benefits and costs of externalities over the life of the projects or alternatives being considered. Depending on the various decision-making approaches deployed, discount or other adjustment of values may be applied in accordance with the temporal distribution of effects.

The contents of this report are closely associated with our first, companion water externalities report (Daniels *et al.,* 2012). Report 1 provides a detailed compendium systematically identifying relevant water-related externalities as well as an extensive survey and tabulation of existing research and estimates of the economic value of these externalities. The Report 1 compendium provides a comprehensive review of existing research into the identification and economic assessment of externalities pertinent to the adoption of seven different water supply options under consideration in the SEQ. The options included in that report are stormwater harvesting, rainwater tanks, centralised wastewater recycling, dams, desalination, groundwater and greywater reuse.

The proposed methodology is consistent and supportive of total water cycle management (TWCM) approaches adopted at regional and sub-regional scales for the *South East Queensland Water Strategy* (QWC, 2010). The systematic analysis of externalities follows the core principles of TWCM and is an appropriate response to the recognition of the need to assess the full impacts and implications of human intervention within the features and limits of natural cycles and limits, and the range of potential options and their interconnected water quantity, quality, energy and other environmental, economic and social effects.

Together, our water externalities reports are intended as a resource for widespread application in assisting researchers, planners and other key decision-makers in the successful management of water and other services. A key role of the reports is to provide indicative data and a practical method for including systematic, combined economic and environmental information into the decision-making process for effective and sustainable water and other natural resource management. Detailed information about externalities and estimated costs and benefits associated with specific water servicing options will be a growing part of the scope of water researchers, policy-makers and practitioners (Retamal, 2009, p.8). It will be necessary to meet the specific requirements and guidelines specified in the *Water Act 2000* which states that regional water supply assessments should consider environmental, social and economic factors. The SEQ Water Strategy makes similar stipulations (QWC, 2009, p.29).

1.3. Project Context

The development of this simple externality analysis and costing methodology (SEXTAN) has emerged from the research activities supported by the Urban Water Security Research Alliance (UWSRA) – the "Alliance". The Alliance has been formed to align and coordinate water research directed towards the identification and assessment of sustainable water supply strategies for SEQ. A major goal is to inform decision-making and support the efficacious implementation of the objectives, approaches and options embraced in the SEQ Water Strategy (QWC, 2009). The SEQ Water Strategy provides the primary water planning strategy in place for the maintenance of water security in SEQ and highlights the need for comprehensive assessment of alternatives in terms of full community and resource impacts and the connections between human use and the characteristics and limits of natural water cycles.

The water externalities research has been part of the *Evaluation Methods for Evidence-based Total Water Cycle Management Planning* project (the TWCMP project) and the pre-cursor to that project, the *Life Cycle Assessment – Integrated Modelling (LCA-IM)* project. The TWCMP project has incorporated researchers from the University of Queensland (UQ), Griffith University (GU), and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The project has targeted the provision of methodologies for quantifying water flows, nutrient discharges, energy use and GHG emissions of different urban water management options in an integrated life cycle perspective (within the total water cycle context). It involved the development and testing of methodologies for quantifying (including economic quantification where possible) the major service, biophysical, and socioeconomic outcomes of a range of potential alternative urban water management options for SEQ. In the first three years, the project included a specific focus upon the Logan-Albert catchment within the wider SEQ region.

The biophysical emissions and water quality consequences, linked to quantitative water supply changes from the range of potential options, has established the basis for more detailed externality analysis and economic valuation assessment of the options being considered in the study area.

The outputs from the research will have extensive application for planners and researchers investigating and assessing options for sustainable water management. Again, it is important to emphasise that the information presented in this study is intended for exploratory economic appraisal of water-related externalities associated with different strategic options, rather than a comprehensive decision-making tool in itself.

2. AN OUTLINE OF EXTERNALITY ANALYSIS METHODOLOGY

2.1 Introduction

In this section, we provide a basic explanation of the methodology proposed as a useful approach for evaluating and incorporating externality impacts concerning water and other natural resources. Sustainability principles and TBL accounting assessment are embedded in most contemporary natural resource management approaches and the proposed methodology is consistent with these perspectives.

The main steps of the method are described in this section in order to emphasise the fundamental logic of the proposed method. In Section 3, the approach is demonstrated with an example analysis of a hypothetical planned water supply scenario comprised of a new combination of existing and alternative water supply options. The example scenario and empirical data are based on case study work associated with the project, but they are hypothetical in nature and are not intended for policy evaluation purposes.

The practical and valid incorporation of externalities into resource management decision-making is an ambitious, if laudable, objective. The essence of such efforts is to identify and, where possible, quantify (and ideally monetise) the full range of social costs and benefits associated with the various options available for providing adequate and sustainable water for a region. Without a consideration of externalities, with explicit attempts at measurement and assessing trade-offs, decisions tend to made on the basis of a combination of financial analyses, and political power and lobbying that draws upon generalised, partial and typically biased assessments of option effects.

Financial analysis includes only direct market-based costs and benefits, such as the construction, operation and treatment costs of supplying water from a new dam. Externality analysis provides more systematic and comprehensive inputs to guide decision-making. It does this by identifying, quantifying, and helping to assess the relative trade-off values that might be associated with the *complete* range of long-term costs and benefits of proposed water options.

Box 2. Externality Analysis

In this report, “externality analysis” is considered to cover:

- the identification and measurement of the full financial, ecological and social impacts (and their connections) of proposed projects or policies;
- the review and analysis of indicative economic (monetary) values of these effects (where possible and with full acknowledgement of limitations); and
- the systematic preparation of externality information and valuation estimates for consideration in decision-making.

Comprehensive externality analyses are consistent with the notion of integrated resource management and total water cycle management, as the underlying objective is to trace the extensive interconnections and flow-on effects across natural and economic systems (for example, see Beven, 2007; Coombes and Kuczera, n.d.; Fletcher, 2008). Ideally, this requires consideration of supply chain and life cycle effects encompassing all significant biophysical, social and economic implications of proposed water options and technologies.

A critical assumption underlying the proposed methodology is that the benefits of externality analysis are not solely dependent on the ability to convert all costs and benefits into dollar values. The process is more open than this and many positive outcomes simply derive from the systematic identification of a proposed development or project’s full range of impacts affecting society. This comprehensive coverage is superior, for overall assessment of net community impacts, to the more limited purviews of conventional environmental and social impact assessment (and strategic environmental assessment).

The TBL accounting/externality analysis approach provides detail on the nature and relative extent of social and economic impacts of biophysical environmental, socioeconomic and policy actions (well beyond the direct private market transactions covered in financial analysis). Indicative monetary values can be very useful in decision-making provided that there is full recognition of the reliability and completeness, variability, and context-relevance of estimates. As such, monetary estimates of "unintended" impacts captured in externality analysis can offer potentially valuable inputs to, and *as one part of*, the decision-making process for water and other resource management.

This often occurs via their systematic compilation and examination within cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), risk analysis, the range of multiple criteria analysis (MCA) techniques, and other decision-making tools (see Section 4). For example, CBA attempts to identify the full range of private *and external* costs and benefits in dollar terms for each year over the life of the option. When externality analysis is extended to full CBA, the costs and benefits for each year are aggregated and converted to net present values (NPV) by applying social discount rates. "Standardised" values are summed across the project lifespan to derive possible benefit-cost ratios and other comparative measures of the community economic welfare impacts of alternative options.

However, as discussed in the closing sections of the report, the use of CBA as a standalone, primary decision-making tool has many limitations. Most of these are derived from high levels of uncertainty regarding present and future cost and benefits, the problems of needing to convert all effects to monetary values for overall aggregation, the selection and application of discount rates, accounting for the uneven spatial and socio-demographic distribution of costs and benefits, and overall resource (money, time, information) demands for its effective completion[1]. For many of these reasons, CBA is not widely used. However, the general approach is growing in both its theoretical sophistication and application and it is likely to continue to contribute and co-evolve with an array of increasingly popular decision-making frameworks such as MCA. In this report, we consider three decision-making frameworks which can use information generated from the proposed externality analysis methodology. Cost-benefit analysis, cost-effectiveness analysis and multiple criteria analysis are discussed in more detail in Section 4.

2.2 Existing Relevant Research and Project Innovations

There have been many other efforts at developing and applying TBL assessment frameworks related to water servicing management. As discussed in the previous, companion report (Daniels *et al.,* 2012), there also some existing major published and on-line databases or inventories of benefit and cost transfer valuation estimates.

The compendium and accompanying methods provided in our reports are not intended to compete with or replace these studies. Each existing approach has its own unique sphere of relevance and set of limitations. The externality list and valuation information linked to our seven specific water supply options, and the proposed SEXTAN method, are provided to complement and build on this existing work. It is important to note that the objective and focus of the research here is to facilitate the specification and policy application of a comprehensive and accessible set of externality impacts and valuations for many of the major water servicing options relevant to the Australian context.

There are many existing studies that present guidelines and analyse the externalities of specific water servicing options or water management in general, or create frameworks for the structured incorporation of externality procedures within broader decision-making processes. There is considerable variation in the purpose, coverage and approach taken.

Siebert, Young and Young (2000) and Young (2000) provide guidelines for analysing and managing water-related externalities. An overview of their proposed guidelines and framework is provided in Figure 1 below. Taylor (2005) and Taylor and Fletcher (2005) have also developed a TBL method for assessing and including the costs and benefits of urban stormwater in their CRC Catchment Hydrology

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[1] Note that most decision-making approaches suffer from great uncertainty in establishing the full community impacts of long-term changes.

report. The focus is on the development of a structured and comprehensive framework for decision-making for a single water servicing option (urban stormwater). As in many water management studies, there is an emphasis upon the multi-criteria analysis (MCA) approach. They compare their framework with the MCA-based European Sustainable water industry asset resource decisions (SWARD) program.

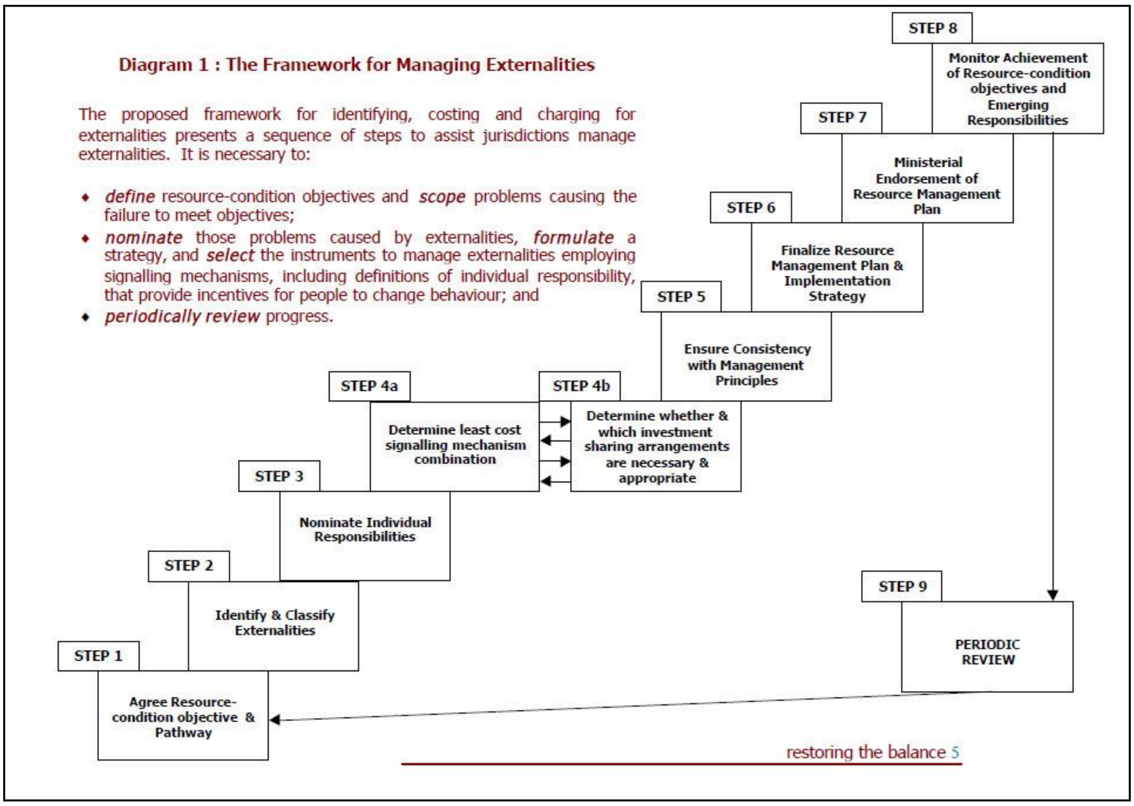

Diagram 1 : The Framework for Managing Externalities

The proposed framework for identifying, costing and charging for externalities presents a sequence of steps to assist jurisdictions manage externalities. It is necessary to:

- ***define*** resource-condition objectives and ***scope*** problems causing the failure to meet objectives;
- ***nominate*** those problems caused by externalities, ***formulate*** a strategy, and ***select*** the instruments to manage externalities employing signalling mechanisms, including definitions of individual responsibility, that provide incentives for people to change behaviour; and
- ***periodically review*** progress.

Figure 1: Siebert et al.'s (2000) framework for managing externalities.
Source: Siebert *et al.* (2000) p.5.

Sharma, Grant, Grant, Pamminger, and Opray (2008) outline a generalised environmental and economic assessment framework developed with an emphasis on externalities associated with water quality and contamination and less on social and the extensive range of other TBL impacts. They also incorporate MCA within their detailed decision-making structure.

Van Bueren and MacDonald (2004) provide a good review of the general nature and types of water externalities. They also present a process for valuing externalities (based on choice modelling valuation results).

The Institute of Sustainable Futures (ISF) also created the "Urban Water Externalities Toolbox" with many similarities to the general approach taken in our reports (Plant, Herriman, and Atherton, 2008). Their aim was to develop the methods (tools and processes) for estimating the costs of externalities related to Melbourne's urban water servicing options (that increase supply or decrease demand). The Toolbox is comprised of a series of detailed and elaborate spreadsheets providing valuation estimates for water managers. At the time of publication, the Toolbox does not appear to be available publicly online.

All of these studies are useful and many key concepts and ideas have been included in the approach taken here. However, none are well-suited to our major objective of this research – the identification, analysis and economic valuation of a comprehensive range of externalities as inputs for the comparative TBL assessment of multiple water servicing options. A key goal is to maintain practicality and simplicity and the open-ended and flexible nature of the individual externality effects and, where possible, their valuation estimates[2].

Hence, the water servicing option externalities list and valuation compendium (in Daniels *et al.,* 2012) and in the SEXTAN externality analysis method are presented as innovative and valuable contributions to better sustainable water management. The unique and innovative value of our approach includes the following contributions:

- The detailed tables of relevant potential externality effects and benefit transfer valuations have been specifically prepared for a set of seven widely-used water supply options. Hence, the targeted approach will be of **more direct and convenient use to water managers concerned with the TBL assessment of major water service planning options** than generalised lists of externalities associated with water.
- The analysis incorporates greater **detail about each externality effect** including:
    - key scientific references and sources for technical descriptions and economic valuations;
    - the type of impact – classified in a way which is generally consistent with the total economic value concept underpinning most contemporary externality valuation. This classification covers greenhouse gas emissions (GHG); energy (En); water quality (WQ); nutrients (N); production values (P); recreation values (R); amenity values (A); health values (H); ecosystem values (E); biodiversity values (B); non-use values (NU); and other values (O);
    - the positive, negative or ambivalent nature of the impact; and
    - whether impacts tend to occur predominantly downstream, upstream, or within the immediate surrounds of the supply infrastructure.
- The full analysis of externalities across life cycle stages of proposed options.
- The analysis has a distinct focus upon the specific physical and human geographic context of SEQ, and hence the externality identification process can obviously be applied more directly to water managers in that region (and, to a lesser extent, in Australia in general). However, the externality list tables (and valuations) provide a good basis for customisation and extension to any regional context.
- The relevant externalities for each supply option are tabulated in concise and convenient summary form with a direct link between the externality lists and benefit transfer values.
- The externality identification and valuation compendium is supported by the proposed method for simple externality analysis (SEXTAN) to guide the use of these data.
- The externality analysis and assessment methods are intentionally proposed as being retained in a disaggregated and open-ended way in order to retain as much specific information as possible and maximise the transparency and flexibility of its application in ongoing decision-making activities and policy prescription. Economic valuation of individual externality effects (with limitations noted) can provide very valuable supporting information to strengthen and enhance conventional environmental impact and related assessment techniques which have the ultimate goal of avoiding or mitigating the negative environmental and social (and hence economic) impacts of proposed projects. This would include information for identifying priority areas and the cost-effectiveness of responses.
- Our approach is presented as a valuable template for general externality analysis and valuation components of the TBL assessment of multiple waters servicing options – the format, structure and approach is well-suited for ready updating, extensions and modifications to support decision-making for water managers.

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[2] The elaborate and sophisticated spreadsheets and procedures in the ISF's "Urban Water Externalities Toolbox" are far more complex and structured in their intent and application than the method presented in this report.

2.3 The Major Steps in the Externality Analysis Method – A Summary

The following discussion outlines the proposed methodology for the systematic and effective collection and analysis of the information required for incorporating externality effects into relevant decision-making. The procedure has been targeted in its development for application to water-related strategic planning but it could also be adapted to cover most forms of natural resource management. This would include broader urban and regional planning scenario and option assessment that embraces principles of sustainability and TBL accounting. As noted, the goal is not to generate single indicators based on social cost-benefit analysis. Rather, the aim of the methodology outlined here is to identify the range and proximate economic magnitude of the biophysical implications of scenarios and their component option outcomes that affect people's welfare, but are not included and compensated for in informed, intentional and consensual market-based activity.

Given the background research project directives, the specific externalities focused upon here do not provide extensive coverage of inter-generational effects or more social-oriented externalities such as cultural, sociological and psychological impacts. While the procedure described could easily be adapted to include a better range and detail of social externalities, these impacts tend to be less amenable to costing techniques. The methodology has been devised as an outcome of case study work undertaken for the Logan-Albert Catchment in SEQ and the options, scenarios, externalities, and biophysical and monetary estimates tend to reflect this context, though many of the biophysical impact measures and monetary valuations are based on research from across Australia and the rest of the world.

There are seven steps proposed in the simple externality analysis (SEXTAN) methodology for regional water servicing options. In the companion report (Daniels *et al.,* 2012), detailed tables have been compiled with extensive data covering: (1) the externality effects typically associated with seven selected options; and (2) a survey of existing economic values for these external effects. However, in this report we are primarily concerned with describing the nature of the proposed procedure for externality analysis and the large tables of externality lists and valuations, for each option, are not replicated here. Hence, the reader may wish to review the companion report (Daniels *et al.,* 2012) in tandem with the following methodology description in order to access more detailed examples of indicative results for steps 2 and 4 of SEXTAN.

The seven major steps of the proposed externality analysis method are summarised in Table 1 below.

Table 1: A summary of the major steps in the proposed externality analysis methodology.

STEP 1 Define Scenarios to Assess in Terms of Water System Options

SCENARIO x OPTIONS ⇒ Planning Phase

Note : "Options" include different supply sources such as new dams or dam level changes, wastewater recycling, and demand management changes.

This involves scenario composition based on the contribution of component water supply options to be investigated for the study region (e.g. 600 ML from new dams; 400 ML from wastewater recycling per year). Scenarios may be described in terms of: (1) the volume or percentage of water to be derived from each supply or demand options; or (2) as a change in the water volumes, in ML or % of supply, that will be supplied by a particular option. This may also include some prescription of water quality objectives or water quality requirements from different sources though this more complex approach is not described here.

For example, Scenario 1 might be defined as an increase in wastewater recycling of 100 ML per year of potable water and 200 ML of water from desalination. (A different example scenario is analysed in Section 3)

STEP 2 Identify the Main Externalities associated with each strategic water option

OPTION x SIGNIFICANT EXTERNALITIES ⇒ Primary or Secondary Research/Data

The analysis of the major externalities (types and characteristics) associated with each relevant water servicing option across it life cycle stages of implementation.

For example, the characteristics of significant externalities associated with wastewater recycling

(e.g., for wastewater recycling: (a) increased greenhouse gas emissions (GHGs); and (b) increased phosphorus emissions).

STEP 3 Quantify each Externality generated per unit water service from that option (in biophysical or other non-monetary indicator terms)

OPTION x BIOPHYSICAL EXTERNALITY IMPACT MEASURES ⇒ Primary or Secondary Research/ Data

Identification of "typical" or anticipated biophysical flows and state changes associated with unit water quantity or quality change. It could refer to socioeconomic changes and indicators for social impacts.

For example, the nitrogen and greenhouse gas emissions per ML of potable drinking water obtained from wastewater recycling.

STEP 4 Value each Externality per Unit Quantity Impact

EXTERNALITY x VALUATION ESTIMATES ⇒ Primary or Secondary Research / Data

For example, economic costs of $100 per kg for nitrogen emissions from wastewater recycling assessed via an "averaging", modification or meta-analysis of costs drawn from existing secondary sources (benefit transfer) or from primary research within the study context.

STEP 5 Calculate each Externality's Cost or Benefit *per Unit Service Change* for each option

EXTERNALITY VALUES PER UNIT WATER SERVICE CHANGE ⇒ Calculation

For each option (e.g. wastewater recycling), calculate each externality type's (e.g. nitrogen) cost/benefit per unit water service change.

For example, $100/kg N * 25 kg N per ML = $2,500 as the externality cost of N emissions change per ML from wastewater recycling.

STEP 6 Calculate each Externality's Cost or Benefit *from the Total Planned Change in Water Service* for each option

EXTERNALITY VALUES FOR THE PROPOSED WATER SERVICE CHANGE ⇒ Calculation

For each option (e.g. wastewater recycling), calculate the cost/benefit value of the total planned change in water service (vs. per unit change in Step 5).

For example, $2,500 per ML (N costs) * planned 100 ML per year supply increase from wastewater recycling = $250,000/year.

STEP 7 Incorporate the Externality Values into the Decision-Making Process

Include the externality valuation results into the decision-making processes; either separately for each externality impact or aggregated across the different externality types in various ways for the scenarios being assessed. This would usually require an analysis of the time profile of benefits and costs of externalities over the life of the projects or alternatives being considered. Depending on the various decision-making approaches deployed, discounting or other adjustment of values may be applied in accordance with the temporal distribution of effects.

2.4 The Major Steps in the Externality Analysis Method – Detailed Description

This section provides a more detailed description of the individual steps in the externality analysis methodology.

STEP 1 Define Scenarios to Assess in Terms of Water System Options

In the first step of the externality analysis, one or more scenarios are identified for study. For the purposes of externality analysis, "***scenarios***" are probably best defined in terms of the contribution of the various supply and demand management ***options*** that will used to meet water servicing objectives. A simple example would be the percentage (and volume) of the total water balance or specified quality volumes from different options such as: (a) existing, new or modifications to dams; (b) wastewater recycling; (c) demand management; (d) system loss reduction; or (e) desalination production. Naturally, this step requires that analysts have adequate knowledge of the nature and range of potential options viable for the study region.

A regional study area context focus upon the Logan-Albert Catchment in SEQ has influenced the specific options adopted as examples in this report (see Section 3). However, the same logic and approach can be utilised for any relevant options under consideration. The scenario component options considered for the purposes of the background study included:

1. Stormwater harvesting
2. Desalination
3. Dams
4. Wastewater recycling
5. Groundwater
6. Greywater reuse
7. Rainwater tanks

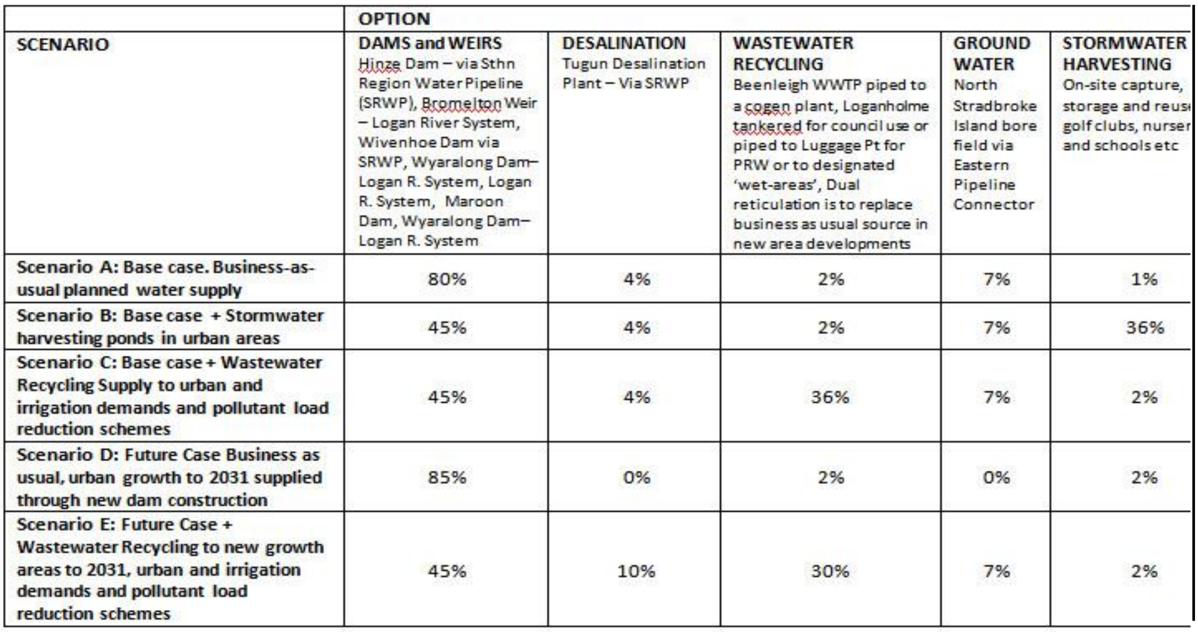
The companion report for this document (Daniels *et al.,* 2012) provides background descriptions of the typical technical nature and related externality sources relevant to these options, and should be consulted for more detailed information.

An example extract from a table showing the output from Step 1 is provided below in Table 2. For each scenario (row), a cell in the table shows the percentage or volume of water to be provided from the options being considered (columns). The table shows indicative percentages for two potential scenarios that were mooted for the Logan-Albert catchment. These could easily be converted into volume measures.

STEP 2 Identify the Main Externalities associated with each Scenario Option

In the next step, each option considered as part of the various scenarios is analysed to identify relevant externality types and characteristics. The impacts of options are assessed both in general terms and across the various stages of their life cycle. Individual options, for example stormwater harvesting, do encompass substantial variation in technologies, processes, infrastructure and specific contextual mode of implementation, and therefore generalised analyses will need to be customised for on-site applications and settings. In the compendium presented in the companion report (Daniels *et al.,* 2012), externality lists have been identified from technical descriptions and existing research focused upon the water supply options under study.

Table 2: Example - STEP 1 - Scenario descriptions for the Logan-Albert Catchment (by option component contribution).



	OPTION				
SCENARIO	**DAMS and WEIRS** Hinze Dam – via Sthn Region Water Pipeline (SRWP), Bromelton Weir – Logan River System, Wivenhoe Dam via SRWP, Wyaralong Dam– Logan R. System, Logan R. System, Maroon Dam, Wyaralong Dam– Logan R. System	**DESALINATION** Tugun Desalination Plant – Via SRWP	**WASTEWATER RECYCLING** Beenleigh WWTP piped to a cogen plant, Loganholme tankered for council use or piped to Luggage Pt for PRW or to designated 'wet-areas', Dual reticulation is to replace business as usual source in new area developments	**GROUND WATER** North Stradbroke Island bore field via Eastern Pipeline Connector	**STORMWATER HARVESTING** On-site capture, storage and reus golf clubs, nurser and schools etc
Scenario A: Base case. Business-as-usual planned water supply	80%	4%	2%	7%	1%
Scenario B: Base case + Stormwater harvesting ponds in urban areas	45%	4%	2%	7%	36%
Scenario C: Base case + Wastewater Recycling Supply to urban and irrigation demands and pollutant load reduction schemes	45%	4%	36%	7%	2%
Scenario D: Future Case Business as usual, urban growth to 2031 supplied through new dam construction	85%	0%	2%	0%	2%
Scenario E: Future Case + Wastewater Recycling to new growth areas to 2031, urban and irrigation demands and pollutant load reduction schemes	45%	10%	30%	7%	2%

Externalities can be classified in many different ways. The approach taken in this report has been significantly influenced by the research foci upon water options for the Logan-Albert test catchment in SEQ. In the background project for this research, the analysis of externalities was concentrated upon GHG emissions and related energy use, and nutrient and sediment impacts. However, other significant environmental flow and state changes can include broader water quality and ecosystem and biodiversity issues and several of these effect types have been included in this analysis.

While these are primarily biophysical pressure or state changes, it also critical to consider the socioeconomic effects of water servicing options. For example, GHG emissions can have a broad range of actual cost and benefits upon society, ranging from changes in direct economic output, health, and rapid changes in climatic, hydrological, and other conditions affecting habitats, biomes and related productivity for humans. Hence, a range of additional externality types – based on actual socioeconomic costs and benefits of option impacts – have been included in the externality groupings "checklist" for the options. These include costs and benefits linked to production, recreation, amenity, health, and "non-use" values (such as existence or vicarious welfare effects and options for use in the future). Many of these impacts are also inter-related. For example, health impacts will affect production and most ecological impacts are felt by humans as affecting well-being related to production and consumption (broadly defined, as they should be). These impact categories have been selected on the basis of their identified relevance and focus in existing research into water-related externalities.

The externality scheme adopted here (see Table 3 below) is identical to that used for the seven options analysed in the companion report (Daniels *et al.,* 2012). As noted, this classification scheme may need to be modified for appropriate application to and analysis of individual case studies.

In the accompanying compendium, the option-externality matching process has been presented for each option in two separate formats. Both table formats are disaggregated according to:

(1) general features of the option; and

(2) specific life cycle and operational phases of the option (typically collection; treatment; storage, use and distribution; and decommissioning).

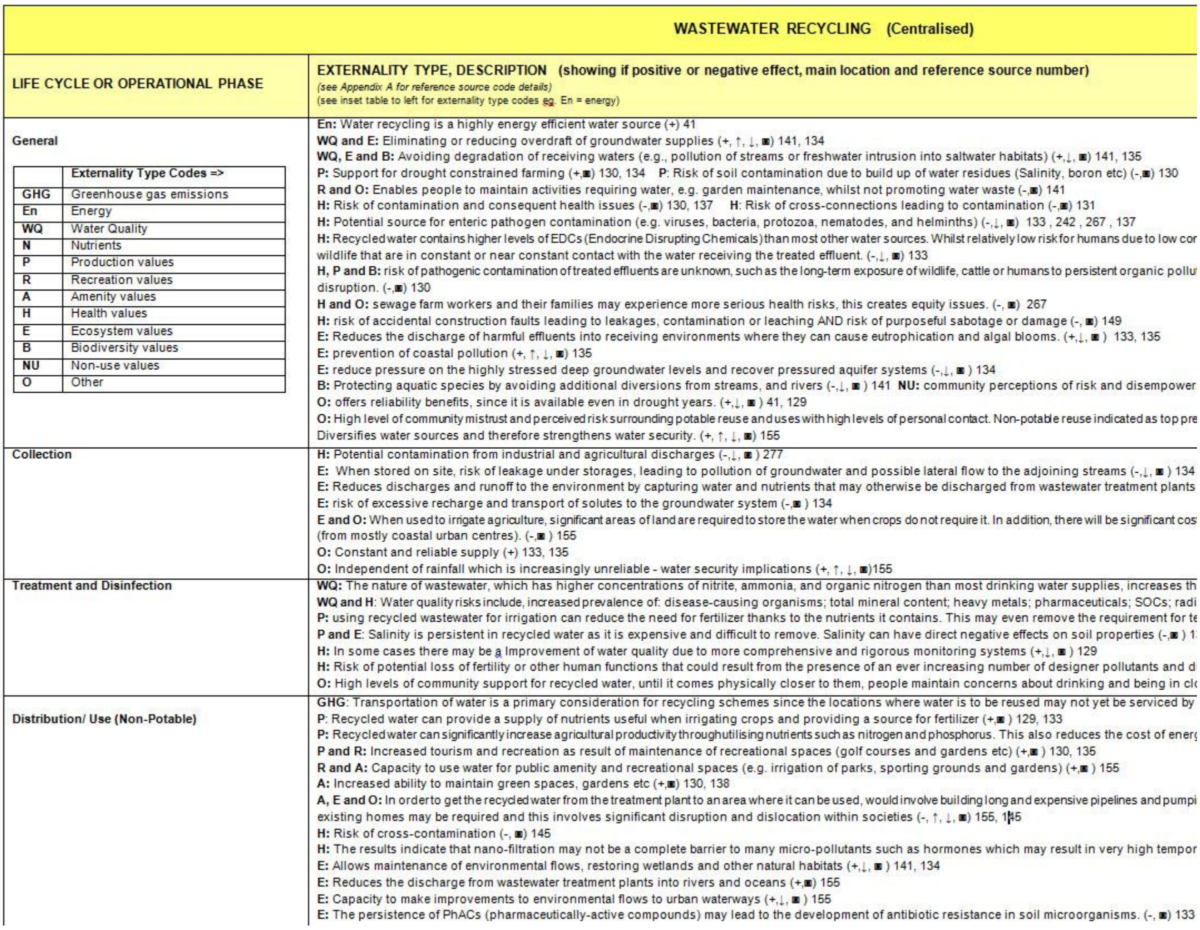
Table 3: The classification of externality types.

Externality Type	Abbreviation	Description
Environmental pressure or state change indicators		
Greenhouse Gases	GHG	The GHG emissions associated with the water option.
Energy	En	The energy consumed by the water option (ideally throughout its life cycle).
Water Quality	WQ	The impacts, positive or negative, which the option has upon water quality. This could relate either to the actual water supply or demand change from the option or its upon the water quality of surrounding waterways.
Nutrients	N	The nutrient loads and associated effects resulting from the water service option.
Ecosystem	E	Impacts which affect the ecosystem. This refers to the ecosystem as a whole, including, the interactions between various species. For example, a wetland or a waterway.
Biodiversity	B	Impacts which affect the biological populations of the area in question. These externalities refer to a specified population or community within an ecosystem. For example, waterbirds or the lungfish, or even waterside native vegetation.
Socioeconomic costs and benefits		
Production	P	The impacts that the option has upon any commercial industries, specifically in terms of indirect third party external impacts e.g. desalination effects reducing fish populations and associated catches.
Recreation	R	Impacts which affect people's recreational activities. These can be positive (e.g. provision of additional areas for swimming) or negative (e.g. decreased access to walking tracks).
Amenity	A	The impacts upon the amenity of the region, e.g. desalination plants may detract from the amenity values of the coastal ecosystems.
Health	H	Impacts which affect human health.
Non-Use	NU	Non-use values are those which make up the total economic value (TEV) of a resource. TEV consists of both use non-use value (See Figure 1 below).
Other	O	Other significant impacts which do not fit the existing categories.

In the compendium report, the first table for each option lists and briefly describes all identified externality effects for that option – for each life cycle phase and an overall, general category (e.g., see Table 4). The individual list of externalities is classified according to the externality type classification outlined earlier in this section (for example, GHG = greenhouse gas emissions; N = nutrients). The description also notes whether the externality tends to be a positive (+) or negative (-) impact and if the effect predominantly occurs upstream (↑), downstream (↓) or in the localised area (◙) of the supply infrastructure. Reference details are provided in Daniels *et al.* (2012). A second table format (not shown here) provides a more condensed version of this first table in order to facilitate ready identification of key externalities and their type of effect.

At a broader, theoretical level, the diversity of external costs to society is increasingly studied as the loss of the total economic values (TEV) of nature and its resources for humans (Landell-Mills and Porras, 2002). The total economic value of a natural resource is the positive value or benefit of a natural resource derived from the complete range of functions and services it provides to human society. The purpose of the TEV scheme is to systematically identify, compile and potentially measure all of the economic and socio-cultural benefits of natural resources (including long-termer term services, and benefits across global society). It covers the source, sink, life support and amenity values functions of nature. A more detailed description of the TEV scheme is provided in the companion report (Daniels *et al.,* 2012).

Table 4: STEP 2 - Identifying the main externalities associated with each strategic water option – Wastewater Recycling example (extract).



WASTEWATER RECYCLING (Centralised)	
LIFE CYCLE OR OPERATIONAL PHASE	EXTERNALITY TYPE, DESCRIPTION (showing if positive or negative effect, main location and reference source number) *(see Appendix A for reference source code details)* (see inset table to left for externality type codes eg. En = energy)
General	**En:** Water recycling is a highly energy efficient water source (+) 41 **WQ and E:** Eliminating or reducing overdraft of groundwater supplies (+, ↑, ↓, ■) 141, 134 **WQ, E and B:** Avoiding degradation of receiving waters (e.g., pollution of streams or freshwater intrusion into saltwater habitats) (+,↓, ■) 141, 135 **P:** Support for drought constrained farming (+,■) 130, 134 **P:** Risk of soil contamination due to build up of water residues (Salinity, boron etc) (-,■) 130 **R and O:** Enables people to maintain activities requiring water, e.g. garden maintenance, whilst not promoting water waste (-,■) 141 **H:** Risk of contamination and consequent health issues (-,■) 130, 137 **H:** Risk of cross-connections leading to contamination (-,■) 131 **H:** Potential source for enteric pathogen contamination (e.g. viruses, bacteria, protozoa, nematodes, and helminths) (-,↓, ■) 133 , 242 , 267 , 137 **H:** Recycled water contains higher levels of EDCs (Endocrine Disrupting Chemicals) than most other water sources. Whilst relatively low risk for humans due to low cor wildlife that are in constant or near constant contact with the water receiving the treated effluent. (-,↓, ■) 133 **H, P and B:** risk of pathogenic contamination of treated effluents are unknown, such as the long-term exposure of wildlife, cattle or humans to persistent organic pollu disruption. (-,■) 130 **H and O:** sewage farm workers and their families may experience more serious health risks, this creates equity issues. (-, ■) 267 **H:** risk of accidental construction faults leading to leakages, contamination or leaching AND risk of purposeful sabotage or damage (-, ■) 149 **E:** Reduces the discharge of harmful effluents into receiving environments where they can cause eutrophication and algal blooms. (+,↓, ■) 133, 135 **E:** prevention of coastal pollution (+, ↑, ↓, ■) 135 **E:** reduce pressure on the highly stressed deep groundwater levels and recover pressured aquifer systems (-,↓, ■) 134 **B:** Protecting aquatic species by avoiding additional diversions from streams, and rivers (-,↓, ■) 141 **NU:** community perceptions of risk and disempower **O:** offers reliability benefits, since it is available even in drought years. (+,↓, ■) 41, 129 **O:** High level of community mistrust and perceived risk surrounding potable reuse and uses with high levels of personal contact. Non-potable reuse indicated as top pre Diversifies water sources and therefore strengthens water security. (+, ↑, ↓, ■) 155
Collection	**H:** Potential contamination from industrial and agricultural discharges (-,↓, ■) 277 **E:** When stored on site, risk of leakage under storages, leading to pollution of groundwater and possible lateral flow to the adjoining streams (-,↓, ■) 134 **E:** Reduces discharges and runoff to the environment by capturing water and nutrients that may otherwise be discharged from wastewater treatment plants **E:** risk of excessive recharge and transport of solutes to the groundwater system (-,■) 134 **E and O:** When used to irrigate agriculture, significant areas of land are required to store the water when crops do not require it. In addition, there will be significant cos (from mostly coastal urban centres). (-,■) 155 **O:** Constant and reliable supply (+) 133, 135 **O:** Independent of rainfall which is increasingly unreliable - water security implications (+, ↑, ↓, ■)155
Treatment and Disinfection	**WQ:** The nature of wastewater, which has higher concentrations of nitrite, ammonia, and organic nitrogen than most drinking water supplies, increases th **WQ and H**: Water quality risks include, increased prevalence of: disease-causing organisms; total mineral content; heavy metals; pharmaceuticals; SOCs; radi **P:** using recycled wastewater for irrigation can reduce the need for fertilizer thanks to the nutrients it contains. This may even remove the requirement for te **P and E**: Salinity is persistent in recycled water as it is expensive and difficult to remove. Salinity can have direct negative effects on soil properties (-,■) 1 **H:** In some cases there may be a Improvement of water quality due to more comprehensive and rigorous monitoring systems (+,↓, ■) 129 **H:** Risk of potential loss of fertility or other human functions that could result from the presence of an ever increasing number of designer pollutants and d **O:** High levels of community support for recycled water, until it comes physically closer to them, people maintain concerns about drinking and being in cl
Distribution/ Use (Non-Potable)	**GHG**: Transportation of water is a primary consideration for recycling schemes since the locations where water is to be reused may not yet be serviced by **P**: Recycled water can provide a supply of nutrients useful when irrigating crops and providing a source for fertilizer (+,■) 129, 133 **P:** Recycled water can significantly increase agricultural productivity through utilising nutrients such as nitrogen and phosphorus. This also reduces the cost of ener **P and R:** Increased tourism and recreation as result of maintenance of recreational spaces (golf courses and gardens etc) (+,■) 130, 135 **R and A:** Capacity to use water for public amenity and recreational spaces (e.g. irrigation of parks, sporting grounds and gardens) (+,■) 155 **A:** Increased ability to maintain green spaces, gardens etc (+,■) 130, 138 **A, E and O:** In order to get the recycled water from the treatment plant to an area where it can be used, would involve building long and expensive pipelines and pumpi existing homes may be required and this involves significant disruption and dislocation within societies (-, ↑, ↓, ■) 155, 145 **H:** Risk of cross-contamination (-, ■) 145 **H:** The results indicate that nano-filtration may not be a complete barrier to many micro-pollutants such as hormones which may result in very high tempor **E:** Allows maintenance of environmental flows, restoring wetlands and other natural habitats (+,↓, ■) 141, 134 **E:** Reduces the discharge from wastewater treatment plants into rivers and oceans (+,■) 155 **E:** Capacity to make improvements to environmental flows to urban waterways (+,↓, ■) 155 **E:** The persistence of PhACs (pharmaceutically-active compounds) may lead to the development of antibiotic resistance in soil microorganisms. (-, ■) 133

	Externality Type Codes =>
GHG	Greenhouse gas emissions
En	Energy
WQ	Water Quality
N	Nutrients
P	Production values
R	Recreation values
A	Amenity values
H	Health values
E	Ecosystem values
B	Biodiversity values
NU	Non-use values
O	Other

The TEV scheme facilitates the systematic measurement of the value of the complete range of costs or losses of source input, waste sink, amenity and life support services of the environment, as a result of major developments or interventions. However, its benefits are not limited to narrow economic valuation functions as it also provides a very useful, systematic and comprehensive conceptual framework for impact analysis and related decision-making. A major strength lies in the ability to detect, record, classify, and systematically analyse all of the biophysical, economic and social benefits, and hence potential losses, associated with natural resources.

The externality classification based on socioeconomic costs and benefits utilised in the methodology tables (e.g. production, recreation and health effects) does not match, on a one-to-one basis, the benefit classes in the TEV scheme. The TEV categories are broad groups of value types that typically contain many specific forms of welfare from natural resources that are often better quantified on an individual basis. For example, use values in the TEV scheme will cover direct externality impacts on production, recreation and health as well as many indirect use benefits such as those provided by ecosystem services.

The production, recreation and other socio-economic externalities relate more to the specific functions affected by externalities, as shown in the bottom row of Figure 1 of Report 1 (Daniels *et al.*, 2012). However, the overall TEV scheme provides an ideal overarching perspective for systematic and comprehensive identification of externality effects associated with water servicing options. Most of the option, existence, bequest, and vicarious benefits from the TEV scheme fall under the "non-use" category of our externality classification in Table 4.

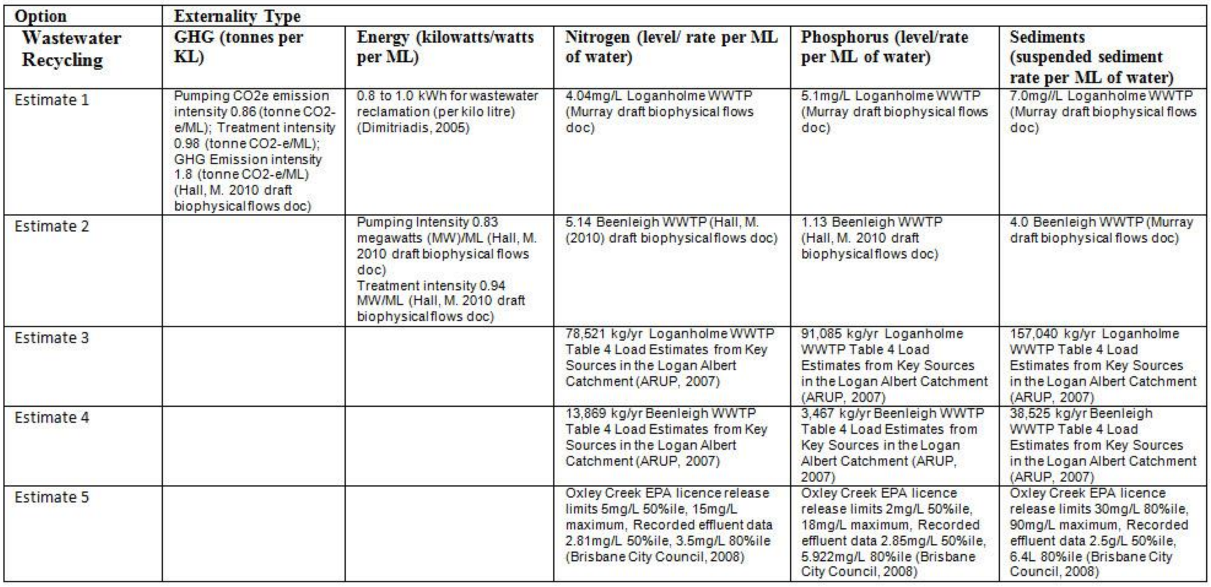
STEP 3 Measure the Magnitude of each Externality Effect generated per Unit Water Service from that Option (in biophysical or socioeconomic indicator units)

This stage of the methodology involves the compilation of estimates of the magnitude of changes in biophysical flows or (non-monetary) socioeconomic states that are the source of economic and other impacts affecting human welfare. These quantities are the basis for efforts at attributing economic values, or at least providing descriptions and indicators of the absolute and relative magnitude (or problem theme contribution) of anticipated effects. Total external cost and benefit monetary values are calculated in the same way as total sales, that is, dollar value per unit multiplied by the overall magnitude of the impact. Step 3 provides the magnitude as “physical” or socioeconomic indicator units for this calculation in Step 5[3].

The biophysical assessment of changes in water supply and quality and associated energy and material flows such as energy use, GHG emissions and nutrient and sediment loads are primarily the domain of natural scientists and engineers. Sources of data include technical analysis and modelling of the options’ infrastructure, processes and technologies, and natural water cycles and systems of human hydrological intervention, as well as existing estimates from related project studies. Dose-response models and existing empirical data play a major role in this stage of the externality analysis and valuation process (Edwards-Jones, 2000). These estimates of biophysical levels and change form the basis of the subsequent economic assessment. However, it is important to specify and understand the details of likely biophysical outcomes of component options under study.

In the Logan-Albert catchment case study undertaken as the basis for this report, the focus has been placed upon GHG emissions, energy, nitrogen, phosphorus and sediment characteristics (see Table 5). For these factors, the example review lists a diverse range of potential biophysical impact measures, typically quantified as emissions or use per unit service (water supply or demand change volume or quality change). There is considerable variation in such estimates which can be drawn from a wide range of studies, contexts and technologies and information. Data that specifically relate to the actual option that is proposed within the study setting is likely to be more accurate and useful for the externality analysis process and outcomes.

Table 5: STEP 3 - Magnitude of each Externality Effect generated per Unit Water Service – Wastewater recycling example.



Option	**Externality Type**				
Wastewater Recycling	**GHG (tonnes per KL)**	**Energy (kilowatts/watts per ML)**	**Nitrogen (level/ rate per ML of water)**	**Phosphorus (level/rate per ML of water)**	**Sediments (suspended sediment rate per ML of water)**
Estimate 1	Pumping CO2e emission intensity 0.86 (tonne CO2-e/ML); Treatment intensity 0.98 (tonne CO2-e/ML); GHG Emission intensity 1.8 (tonne CO2-e/ML) (Hall, M. 2010 draft biophysical flows doc)	0.8 to 1.0 kWh for wastewater reclamation (per kilo litre) (Dimitriadis, 2005)	4.04mg/L Loganholme WWTP (Murray draft biophysical flows doc)	5.1mg/L Loganholme WWTP (Murray draft biophysical flows doc)	7.0mg//L Loganholme WWTP (Murray draft biophysical flows doc)
Estimate 2		Pumping Intensity 0.83 megawatts (MW)/ML (Hall, M. 2010 draft biophysical flows doc) Treatment intensity 0.94 MW/ML (Hall, M. 2010 draft biophysical flows doc)	5.14 Beenleigh WWTP (Hall, M. (2010) draft biophysical flows doc)	1.13 Beenleigh WWTP (Hall, M. 2010 draft biophysical flows doc)	4.0 Beenleigh WWTP (Murray draft biophysical flows doc)
Estimate 3			78,521 kg/yr Loganholme WWTP Table 4 Load Estimates from Key Sources in the Logan Albert Catchment (ARUP, 2007)	91,085 kg/yr Loganholme WWTP Table 4 Load Estimates from Key Sources in the Logan Albert Catchment (ARUP, 2007)	157,040 kg/yr Loganholme WWTP Table 4 Load Estimates from Key Sources in the Logan Albert Catchment (ARUP, 2007)
Estimate 4			13,869 kg/yr Beenleigh WWTP Table 4 Load Estimates from Key Sources in the Logan Albert Catchment (ARUP, 2007)	3,467 kg/yr Beenleigh WWTP Table 4 Load Estimates from Key Sources in the Logan Albert Catchment (ARUP, 2007)	38,525 kg/yr Beenleigh WWTP Table 4 Load Estimates from Key Sources in the Logan Albert Catchment (ARUP, 2007)
Estimate 5			Oxley Creek EPA licence release limits 5mg/L 50%ile, 15mg/L maximum, Recorded effluent data 2.81mg/L 50%ile, 3.5mg/L 80%ile (Brisbane City Council, 2008)	Oxley Creek EPA licence release limits 2mg/L 50%ile, 18mg/L maximum, Recorded effluent data 2.85mg/L 50%ile, 5.922mg/L 80%ile (Brisbane City Council, 2008)	Oxley Creek EPA licence release limits 30mg/L 80%ile, 90mg/L maximum, Recorded effluent data 2.5g/L 50%ile, 6.4L 80%ile (Brisbane City Council, 2008)

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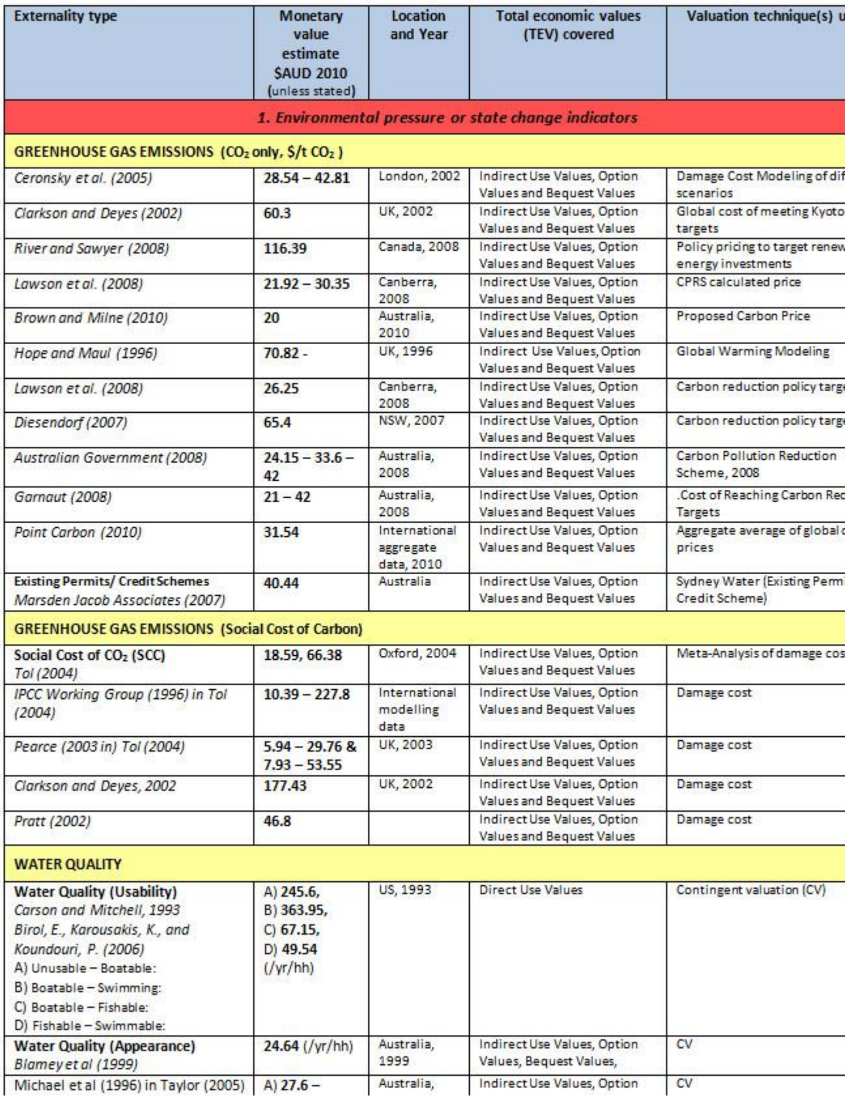
[3] Examples of socioeconomic impact magnitude indicators are unemployment levels or quality-adjusted life years (or QALYs).

Ideally, the temporal period relevant to the occurrence and magnitude of externality impacts will also need to be identified. In addition, full life cycle and supply chain externality effects can be traced throughout project time periods. Suitable techniques such as environmental input-output (EIO) analysis and process-based life cycle assessment (LCA) (and hybrid EIO and LCA approaches) are advancing rapidly and are already being applied for the more comprehensive sustainability assessment of infrastructure and a wide variety of other economic activities (e.g., see Lenzen and Dey, 2002; Minx *et al.,* 2009; Mont and Power, 2010).

STEP 4 Value each Externality per Unit Quantity Impact

As the foundation for the subsequent economic assessment, the externality values are first assessed in averaged dollar measures per biophysical or non-monetary numerical unit terms. For example, economic costs of $100 per kg for nitrogen emissions from wastewater recycling may be derived from the costs of appropriate prevention methods. The biophysical units describe the specific externality implications (e.g. GHG emissions and sediment loads) of the water supply and demand study options that form the focus of Step 3. An extract from the extensive compilation of per biophysical unit values for water-related externalities (from Daniels *et al.,* 2012) is presented in Table 6.

Table 6: Example extract - Step 4 - Economic valuation estimates for water-related externalities.



Externality type	Monetary value estimate $AUD 2010 (unless stated)	Location and Year	Total economic values (TEV) covered	Valuation technique(s) u
1. Environmental pressure or state change indicators				
GREENHOUSE GAS EMISSIONS (CO₂ only, $/t CO₂)				
Ceronsky et al. (2005)	**28.54 – 42.81**	London, 2002	Indirect Use Values, Option Values and Bequest Values	Damage Cost Modeling of dif scenarios
Clarkson and Deyes (2002)	**60.3**	UK, 2002	Indirect Use Values, Option Values and Bequest Values	Global cost of meeting Kyoto targets
River and Sawyer (2008)	**116.39**	Canada, 2008	Indirect Use Values, Option Values and Bequest Values	Policy pricing to target renew energy investments
Lawson et al. (2008)	**21.92 – 30.35**	Canberra, 2008	Indirect Use Values, Option Values and Bequest Values	CPRS calculated price
Brown and Milne (2010)	**20**	Australia, 2010	Indirect Use Values, Option Values and Bequest Values	Proposed Carbon Price
Hope and Maul (1996)	**70.82 -**	UK, 1996	Indirect Use Values, Option Values and Bequest Values	Global Warming Modeling
Lawson et al. (2008)	**26.25**	Canberra, 2008	Indirect Use Values, Option Values and Bequest Values	Carbon reduction policy targ
Diesendorf (2007)	**65.4**	NSW, 2007	Indirect Use Values, Option Values and Bequest Values	Carbon reduction policy targ
Australian Government (2008)	**24.15 – 33.6 – 42**	Australia, 2008	Indirect Use Values, Option Values and Bequest Values	Carbon Pollution Reduction Scheme, 2008
Garnaut (2008)	**21 – 42**	Australia, 2008	Indirect Use Values, Option Values and Bequest Values	.Cost of Reaching Carbon Re Targets
Point Carbon (2010)	**31.54**	International aggregate data, 2010	Indirect Use Values, Option Values and Bequest Values	Aggregate average of global prices
Existing Permits/ Credit Schemes *Marsden Jacob Associates (2007)*	**40.44**	Australia	Indirect Use Values, Option Values and Bequest Values	Sydney Water (Existing Perm Credit Scheme)
GREENHOUSE GAS EMISSIONS (Social Cost of Carbon)				
Social Cost of CO₂ (SCC) *Tol (2004)*	**18.59, 66.38**	Oxford, 2004	Indirect Use Values, Option Values and Bequest Values	Meta-Analysis of damage cos
IPCC Working Group (1996) in Tol (2004)	**10.39 – 227.8**	International modelling data	Indirect Use Values, Option Values and Bequest Values	Damage cost
Pearce (2003 in) Tol (2004)	**5.94 – 29.76 & 7.93 – 53.55**	UK, 2003	Indirect Use Values, Option Values and Bequest Values	Damage cost
Clarkson and Deyes, 2002	**177.43**	UK, 2002	Indirect Use Values, Option Values and Bequest Values	Damage cost
Pratt (2002)	**46.8**		Indirect Use Values, Option Values and Bequest Values	Damage cost
WATER QUALITY				
Water Quality (Usability) *Carson and Mitchell, 1993* *Birol, E., Karousakis, K., and Koundouri, P. (2006)* A) Unusable – Boatable: B) Boatable – Swimming: C) Boatable – Fishable: D) Fishable – Swimmable:	A) **245.6,** B) **363.95,** C) **67.15,** D) **49.54** (/yr/hh)	US, 1993	Direct Use Values	Contingent valuation (CV)
Water Quality (Appearance) *Blamey et al (1999)*	**24.64** (/yr/hh)	Australia, 1999	Indirect Use Values, Option Values, Bequest Values,	CV
Michael et al (1996) in Taylor (2005)	A) **27.6 –**	Australia,	Indirect Use Values, Option	CV

The externality compendium in the companion report (Daniels *et al.,* 2012) has been based on extensive technical and literature reviews and covers most major relevant and contemporary effects for the seven options under study. However, it has not included an exhaustive review of all relevant information in the massive EVRI and ENVALUE infobases of externality valuations for benefit transfer approaches[4]. Given the limitations of these databases, we recommend careful searches for additional information from these sources for the TBL assessment of options in water-servicing case studies.

The per unit values can be sourced on a benefit (cost) transfer basis (that is, from other relevant studies), or they can be calculated, usually with significantly more time and expense, from primary research or proxy data directly based on the study area and its context-specific characteristics. Estimates from transfer methods may also be adapted or adjusted on the basis of the unique features and conditions of the study context. Appropriate monetary value ranges, or median, modal or other typical or "average" measures are identified for unit externality impacts (e.g. per tonne of $C0_2$). In the next stage, these values are subsequently multiplied by the overall biophysical externality impact measures resulting from the water service change from the option under study.

This step must include an understanding of the nature and weaknesses of the various valuation techniques that are appropriate for generating monetary estimates of the cost and benefits associated with the "external" biophysical and non-monetary quantitative socio-economic impacts of the options analysed. Valuation techniques used tend to be related to the type of socio-economic impact, or specific natural resource benefit or use or non-use value, as depicted in the total economic value (TEV) concept critical for Step 2 (and described in more detail in Daniels *et al.,* 2012). While there are many different classifications of externality economic valuation techniques, a summary overview of the classification and types, used in this research, are provided in Box 3 below.

For detailed information on individual environmental economic valuation techniques, see the NSW Department of Environment, Climate Change and Water's ENVALUE database at http://www.environment.nsw.gov.au/envalueapp/ and the Qld Department of Environment and Resource Management's (DERM) environmental management impact assessment web pages at http://www.ehp.qld.gov.au/management/impact-assessment/environmental_economics.html/.

The basic step in monetising an environmental or social impact involves biophysical and non-monetary socioeconomic quantification and the subsequent assignment of per unit monetary values to the resulting measures (Matthews and Lave, 2000). When there are no existing markets, economists identify surrogate markets or construct hypothetical markets by asking people what they would be willing to pay (WTP) or accept to prevent or be compensated for environmental service loss. However, there are many criticisms surrounding the validity and accuracy behind the figures provided from such research (Matthews and Lave, 2000).

In general, direct and indirect *use* values from the TEV scheme are often suited for market-based valuation techniques (see Table 7). These techniques attribute monetary values to externalities by directly linking their impact to existing, similar or related markets, and changes in production or welfare attributed to the external effect can then be assessed with market price data (OECD, 2006). These techniques are called "revealed preference" approaches and draw largely upon existing and surrogate market data. Dose- (or exposure) response models and estimates are often required to establish the quantitative link between natural environment flows or state changes (e.g. some water contamination measure) that society is exposed to and actual damage or well-being impacts upon humans and their social and economic systems (e.g., illness incidence) (United Nations, 2003).

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[4] For more information on the EVRI and ENVALUE databases see https://www.evri.ca/Other/AboutEVRI.aspx and http://www.environment.nsw.gov.au/envalueapp/ respectively.

Box 3 – Relevant Economic Valuation Techniques

VALUATION TECHNIQUE	Description and Examples
EXISTING DIRECT MARKET DATA - Revealed preference - Actual and Potential	
Change in productivity and output/production function	Examine changes in the dollar value of outputs resulting from a change in the quality of an environmental good, e.g. crop output value change from water yield and reliability changes; fisheries, tourism income change from water pollution.
Loss of earnings/Human capital approach (change in labour income; foregone earnings; cost-of-illness studies)	Examines forgone earnings and cost of illness to value an environmental good, eg. the health impact of air pollution of work days lost; travel time cost of congestion.
Preventative, mitigation or defensive expenditure (actual or potential expenditure or behaviour)	Indirect, partial only - Examines expenditures made to prevent the effects of environmental quality loss, e.g. park management expenditure. Unlikely to reflect full social benefits of conserving the natural resource. Arguably, minimum estimates of TEVs at best but may be misinformed. Can be based on observed, stated or expert valuations. E.g. cost of double glazed windows to reduce traffic noise; cost of extra filtration to purify water.
Repair and damage cost (actual or potential)	Closely related to preventative expenditures. Uses estimates of the cost of repair or rehabilitation of environmental resources after environmental damage. E.g. the cost of land rehabilitation after open-cut mining; the cost of replacing soil and nutrients that would be lost through erosion (if the action was not taken).
Replacement or restoration cost (mainly potential)	Similar to repair and damage costs but tend to be potential expenditure measures. Uses estimates of the cost of replacing the services of damaged productive assets or restoring them to their original undamaged state. Difficulties in fully replacing natural resources and their services. E.g. cost of engineering works to prevent soil erosion after land clearing.
Shadow projects cost (mainly potential)	A special case of the replacement cost technique. Estimated the cost of replacing the *entire range* of environmental goods and services provided by a physical asset and threatened by a project. E.g. cost of artificial lagoon to replace all the services of an estuary lost to port development (for example, fish breeding, fish catches, bird habitat, and recreational activity).
Relocation costs **(mainly potential)**	A special case of the replacement cost technique. It considers the potential costs of relocating a physical facility as a measure of the cost of improving or restoring desired environmental services and is often used in comparison with the estimated social benefits of some action to improve, recover or maintain environmental quality. E.g. cost of moving a meat rendering plant to another site; cost of relocating a water supply intake because a noxious water polluting activity is established upstream.
Opportunity cost	Indirect, partial only – Estimates the benefits foregone from not developing natural resources/areas. Not really a TEV valuation technique. Mainly used to compare the social benefits of the conservation to the economic losses of alternative, more consumptive uses. Unlikely to reflect full social benefits of conserving the natural resource.
PROXY MARKET DATA - Revealed preference	
Hedonic price	Uses differences in prices of market goods (housing, property and land prices, wages) to value an environmental good
Wage differential	A form of hedonic pricing based on wage differentials due to environmental, safety condition differences
Travel cost method	Uses the cost of travelling to environmental assets to impute their value (usually used for national parks or other high recreational amenity sites)
Proxy good or averting behaviour	Uses value of a close market good substitute to value an environmental good. Also called 'averting behaviour', since this estimation technique infers a value for changes in spending on ways to reduce the impact of the lower environmental quality (close to mitigation, repair approaches but values taken from proxy markets). Marketed goods as environmental surrogates.
CREATED or HYPOTHETICAL MARKETS – Stated preferences. Survey, market simulation, experimental approaches	
Contingent valuation	Uses survey methods to directly elicit a people's willingness to pay or to accept compensation for different qualities of an environmental good.
Choice modelling	Choice modelling uses preferences for a set of scenarios to determine preferences and prices for attributes of the environmental good being examined.

Sources: Compiled and adapted from Edward-Jones *et al.* (2000); Qld Government Inter-Departmental Committee (IDC) on Environmental Economic Valuation, (2003).

Table 7: Externality valuation techniques appropriate for total economic value type.

	VALUATION TECHNIQUE TYPE								
TOTAL ECONOMIC VALUE (TEV) TYPE	**EXISTING DIRECT MARKETS**				**PROXY MARKETS**			**SIMULATED MARKETS**	
	Product'n change	Human capital	Preventive	Damage, repair, replacement, shadow	Hedonic (Property, wage)	Travel cost analysis	Proxy goods; averting behaviour	Contingent valuation (CV)	Choice models and experiments
USE VALUE (Personal use in near-term)									
Direct use values[1]	XX	XX	XX	XX	XX	XX	XX	X	X
Indirect use values[2]	X	X	X	XX	XX	XX	XX	X	X
USE/NON-USE VALUES (Mix)									
Option values	X	X	XX	XX				X	X
NON-USE VALUES (Non-personal use now and future)									
Bequest values								XX	XX
Vicarious values								XX	XX
Existence values								XX	XX
OTHER									
Intrinsic values									

X = appropriate XX = highly appropriate

1. Primarily direct economic inputs including non-consumptive e.g. recreation
2. Mainly current ecosystem services, including waste sink or assimilation functions

Sources: Compiled and adapted from Birol *et al.* (2006); Edward-Jones *et al.* (2000); Francis Gray Consulting Economist At Large (1996); Landell-Mills and Porras (2002, p14); Munasinghe (1993); and Spangenberg and Settele (2010).

Alternatively, non-use values (including existence, bequest, vicarious and most option values) are much more likely to be valued via stated preference or hypothetical market techniques such as contingent valuation or choice modelling.

Direct uses from the TEV scheme are commonly measured by specific techniques such as market analysis, change in production, hedonic pricing, travel cost analysis (TCA), replacement and restoration costs, and less frequently, contingent valuation (CV) (Turner *et al.*, 2000). Indirect uses can be analysed by approaches based on damage costs, production functions, hedonic pricing, defensive expenditure, relocation, replacement and restoration costs and contingent valuation.

Hence, in the externality types covered in this report, production impacts would tend to be assessed mainly with existing market techniques such as change in production, and replacement and repair costs; recreation impacts with TCA and some existing markets approaches; amenity effects with hedonic pricing, CV and TCA; and health impacts with human capital (cost-of-illness) and surrogate market techniques. Ecosystem and biodiversity loss would also be suitable to some production change and replacement cost approaches, but also exhibit non-use values that would require stated preference approaches such as CV and choice modelling (see Box 3). Non-use values are clearly limited primarily to the stated preference valuation techniques.

STEP 5 Calculate each Externality's Cost or Benefit *per Unit Service Change* for each option over the project life

In this step, the selected externality value estimate(s) *per unit biophysical output* from Step 4 are multiplied by the per unit water service biophysical change information identified in Step 3. For each option (e.g., wastewater recycling), we calculate each externality type's (e.g., nitrogen) cost or benefit per unit water service change. Ideally, these values would be based on primary data from the study context or would at least include appropriate modification of benefit transfer valuations in view of local data.

For example, the externality cost of nitrogen releases per ML from wastewater recycling would be $100/kg of nitrogen (N) * 25 kg N per ML = $2,500 per ML of water from this option.

Given the temporal distribution of externality effects, discounting aims to adjust all the costs and benefits associated with an action (in this case the adoption of a particular water supply option) to current dollar values (thus it converts all costs and benefits regardless of when in time they occur). This is intended to enable comparison of costs and benefits over extended periods of time. As a result, it converts costs and benefits into present value (PV) using a process which is the obverse of 'compounding' as commonly applied to interest rates. Accordingly, the social and private discount rates applied will determine the extent to which costs and benefits **now** are greater than those occurring in the **future.** It thus impacts upon intergenerational equity. Discounting is an element of valuation subject to serious contention – especially given its crucial impact on the overall 'sustainability of water management decisions' (Birol *et al.*, 2010, p.839). This issue is discussed in some more detail in Section 4.

STEP 6 Calculate each Externality's Cost or Benefit *from the Total Planned Change in Water Service* for each option

In this step, the cost or benefit value of each externality type is calculated in light of the total planned change in water service for each option (e.g., wastewater recycling). This is simply derived by multiplying the per unit change externality value in Step 5 by the total service change.

For example, $2,500 per ML (N costs) * 100 ML per year (supply increase from wastewater recycling) = $250,000/year.

STEP 7 Incorporate the Externality Values into the Decision-Making Process

Once the individual estimates of externality impacts for the planned water supply change from each option have been determined, results can be included into the strategic decision-making process. They can be considered separately for each externality impact or aggregated across the different externality types in various ways for the scenarios being assessed.

Based on the water service change planned for each scenario (incorporated in Step 6), the values for each externality type (e.g. all N) can be summed across the relevant options, or all externality values can be summed within each option to give an overall option externality (e.g., nitrogen and GHG) economic impact. For example, $250k for N plus, say, $720k for GHGs = $950k as the total annual cost estimated for the planned 100 ML/year increase in supply from wastewater recycling if N and GHGs are the primary external effects of this option.

These various aggregates can also be summed to produce total scenario externality values. For example, if the externality values from the Scenario 1 200 ML supply increase from desalination were $1.2m per year in total, then the total for the scenario based on desalination and wastewater recycling would be $1.2m + $950k (for 100 ML wastewater recycling increase) = $2.15m per year.

Utilising externality valuation information in decision-making would usually require an analysis of the time profile of benefits and costs of externalities over the life of the projects or alternatives being considered. Depending on the various decision-making approaches deployed, social discounting or other adjustment of values may be applied in accordance with the temporal distribution of effects.

It is beyond the purview of this report to provide a detailed exposition of the potential for including the economic analysis of externalities into broader natural resource management decision-making. However, in Section 4, we provide some more discussion of the potential for application of the outputs of the proposed methodology (generated by Step 6 of the procedure) in the assessment of strategic options using common frameworks such as cost-benefit analysis and multi-criteria analysis.

3. AN EXAMPLE APPLICATION OF THE METHODOLOGY – A Water Supply Option Case Study

The reticulated water supply area of the Logan-Albert catchment is used to demonstration the externalities assessment methodology described in Section 2 of this report. Land uses in the catchment include grazing, intensive agriculture (such as dairy and poultry production), lifestyle blocks, urban development and industry (SEQ Catchments, 2010). There are a number of national parks at the top of the catchment and several conservation zones scattered throughout the catchment. The region's water supply is comprised of a several supplies including dams, desalination and groundwater bore fields as well as decentralised supplies such as rainwater tanks, greywater and stormwater storage ponds.

The water supplies located within the Logan-Albert catchment include the Maroon Dam, the new Wyaralong Dam and a number of smaller weirs and off-stream storages. The region is also connected to the SEQ Water Grid and may import or export water depending on storage levels in the region. Water supply sources external to the catchment include the Tugun desalination plant, the Brisbane River system, Hinze Dam and the North Stradbroke bore field. Wastewater is treated at a number of centralised wastewater treatment plants and a small percentage of the 'Class C' recycled water produced has been reused for irrigation of agriculture and residential gardens. The majority of the treated wastewater is discharged into the Logan and Albert Rivers.

In this section, we demonstrate the proposed externality analysis methodology by applying the procedure to a simple scenario that has been mooted for the Logan-Albert region. The water service scenario used for this example application is drawn from a set of test case scenarios investigated for possible application of the integrated regional urban water modelling tool, "Hydroplanner", to the Logan-Albert catchment (Ashbolt *et al.*, 2010). The Hydroplanner tool was developed within the Life Cycle Assessment-Integrated Modelling (LCA-IM) project of the Urban Water Security Research Alliance that has also supported the research focused upon relevant water supply externalities (as covered in this report and Daniels *et al.*, 2012).

The scenarios examined in the test implementation of Hydroplanner included:

1. **Base Case:** Present day conditions with business-as-usual urban water management.
2. **Base Case + Stormwater Harvesting:** Present day conditions with two stormwater harvesting ponds in urban areas.
3. **Base Case + Wastewater Recycling:** Present day conditions with wastewater recycling to urban and irrigation demands.
4. **Future Case Business-As-Usual:** Future (+20 years), including urban growth (changes to demand and land use) and construction of a new dam, with business-as usual urban water management.
5. **Future Case + Wastewater Recycling:** Future conditions with wastewater recycling to urban and irrigation demands and pollutant load reduction schemes. Load reduction includes changes to constituent generation from land use based on anticipated water sensitive urban design and reductions in discharge from point sources.

Source: Ashbolt *et al.* (2010).

In this example application of the methodology, we analyse the impacts of the increase in recycled water that is associated with the fifth scenario "future case + wastewater recycling". For the sake of simplicity, we do not consider the distribution of external impacts that would be relevant for longer-term timeframes.

The overall method is akin to a CBA without the externality valuation aggregation phases (Steps 4-6). Individual externality data series are retained for more broad-based data feeds into a range of decision-making processes that weigh up social costs and benefits.

STEP 1 Scenario Description (Scenario 5)

Based on the fifth scenario for the project case study, the hypothetical scenario selected for the example application is a 10 ML per annum increase in wastewater recycling for the Logan-Albert region.

The key externalities associated with the use of an additional 10 ML of recycled water from a centralised wastewater treatment plant have been identified. The centralised plant chosen is similar to those located in the Logan-Albert Catchment such as the Loganholme and Beenleigh Wastewater Treatment Plants (WWTPs). The water is assumed to be utilised through a combination of dual reticulation garden watering, industrial use and agricultural irrigation.

In practice, strategic water planning scenarios would tend to be comprised of a set of options. Here, we consider the simple case of a scenario based water service from just one option – wastewater recycling.

STEP 2 Identify the Main Externalities Associated with Wastewater Recycling

Step 2 of the methodology involves the identification of the major externalities associated with wastewater recycling. In practice, this process should carefully consider site-specific detail and assess relevant local and more general effects.

Based on the information provided for wastewater recycling in Section 3 of the companion report (Report 1) (Daniels *et al.*, 2012), Table 8 lists some of the primary externalities associated with this option. As discussed, the companion report provides detailed data on externality effects and indicative values for six major water servicing options. The format and symbols used in Table 8 are described in Section 2 of this report and Section 3 of Report 1.

Table 8: Major externalities associated with the recycled wastewater increase scenario.

KEY EXTERNALITIES - *WASTEWATER RECYCLING*
Greenhouse Gas Emissions (GHGs)
Diffuse emissions, energy consumption of treatment and distribution, transport of waste products (Collection, Treatment and Use Stages (-,↓, ◙))
Nutrients
Reduced nitrogen and phosphorus discharge to receiving waters (Collection and Treatment Stages (+,↓, ◙))
Ecosystem
Reduced degradation of receiving waters improving aquatic ecosystem health (Collection and Treatment Stages (+,↓, ◙))
Social
Contamination risks and associated health impact (Treatment and Use Stages (-,◙))
Low levels of community acceptance for 'high-contact' uses (Use Stages (-,◙))
Productivity
Additional water resource available to drought constrained farmers and other industries (Collection and Use Stages (+,◙))
Increased capacity for maintenance of 'green spaces' throughout droughts – amenity and recreational benefits (Use Stages (+,◙))
Risk of soil contamination. (Use Stages (-,↓, ◙))
Additional nutrients found within recycled water may serve as potential sources of fertiliser for agricultural uses. (Use Stages (+,◙))
Reduced degradation of receiving waters improving fisheries and tourism (Collection and Treatment Stages (+,↓, ◙))

The example application of the externality analysis described in this report is summarised in the information presented in Table 9. References for the data used can be found in the tables of Section 3 of Daniels *et al.* (2012).

Step 1 is shown as the simple scenario with one option comprised of a 10ML/yr increase in decentralised wastewater recycling supply in the Logan-Albert region (top row). Step 2 involves the identification of major externalities associated with each option (in this case, just wastewater recycling). This is represented by the externalities listed in column 1 of Table 9.

STEP 3 Quantify (usually in biophysical or at least non-monetary numerical terms) each Externality Generated per Unit Water Service from Wastewater Recycling and their Distribution Over Time

Some indicative values quantifying the externality impact of a ML of recycled wastewater are shown in column 3 of Table 9. The majority of the biophysical data has been identified in the literature survey. However, several health and social impacts lack data and hence approximations, assumptions and hypothetical values have been used to help demonstrate the general approach.

STEP 4 Estimate the Cost or Benefit Value of each Externality Unit

These externality unit cost (or benefit) value estimates have been drawn from the detailed listings in Section 4 of Daniels *et al,* (2012). These values are transferred from existing studies and, as required in such benefit or cost transfer approaches, further research would be necessary to assess their relevance and adjustment for the case study context. The costs utilised in this example often consist of a combination of market values, contingent valuations, opportunity and damage costs that have been identified in the survey of economic valuations of relevant externalities. The minimum, median and maximum values from the benefit or cost transfer process have been considered in the example application.

STEPS 5 and 6 Calculate each Externality's Cost or Benefit Value *per Unit Water Change* (Step 5) and the *Total Change in Service* (10 ML) (Step 6) for Wastewater Recycling

Steps 5 and 6 have been combined in the final columns. Externality costs per unit water supply change (ML) have been multiplied by the value of the externality impact per ML, and the overall result multiplied by 10 (for 10 ML total change). The minimum, mean and maximum values are provided in the final three columns and can be summed across the externalities. The example indicates a net positive impact from using recycled water if the mean or maximum externality values are used. However, there is a large variation in values for each externality from the literature and, when the minimum values are used, the result is negative. Another limitation is that whilst an externality may be identified as negative or positive, the exact impact response is unknown, for example the degree of the impact of the discharge of nitrogen into the river on the fish stock in the river. Using dose-response models and Bayesian network modelling approaches may help to demonstrate the relationship between externalities and the costs and benefits that may be attributed to each externality (Bromley *et al.*, 2005; Castelletti and Soncin-Sessa, 2006; Hamilton *et al.,* 2007).

This example is also limited by lack of data for a number of externalities. The absence of existing valuation research was particularly apparent for the health risks and community acceptance of recycled water and the impact of an increase in water availability. The limitations of the general cost benefit analysis methodological approach are described further in Section 4 of this report. Of course, even if these values were sufficiently valid for consideration in the strategic decision-making process (in Step 7), they would have to be considered over the scenario lifetime (with appropriate adjustments) and be recognised for their underlying conceptual weaknesses.

Table 9: **Application of the externality analysis method to a simple, hypothetical wastewater recycling scenario.**

STEP 1 **– *Scenario* = 10ML/yr increase in decentralised wastewater recycling supply in the Logan-Albert region**						
STEP 2* - *Externalities Identified for Wastewater Recycling	**Impact (+/-)**	***STEP 3* - *Externality Impact per Unit Water*** (Biophysical per unit water)	***STEP 4* - *Cost per Externality Unit ($s)*** (min, median, max) hh = household	***STEPS 5 & 6* - *Total Valuation of Externalities***		
				Min	**Median**	**Max**
GHGs						
energy, diffuse emissions, transport	-	1.8 tonne CO_2/ML	$ 5.95, $30.35, $277.80 /tonne CO_2	-$107	-$1650	-$3194
NUTRIENTS						
nitrogen	+	4 kg N/ML	$ 861, $29250, $234000 /tonne N	$359	$1040180	$2040000
phosphorus	+	5.1 kg P/ML	$1073, $21397, $41722 /tonne P	$55	$4641027	$9282000
ECOSYSTEM						
benefit to eco-system services	+	10 ha wetland[1]	$24056, $37149 /ha wetland/yr	$240560	$65465	$371490
BIODIVERSITY						
native fish preservation	+		$2.56, $7.13, $30.17 /yr/hh (WTP)[2]	$25600	$71300	$301700
HEALTH						
health risk of use	-	1/yr/10,000 people[3]	$488.52 /hospital visit	-$489	-$489	-$489
community acceptance	-		$70 /hh (WTP)[2]	-$700000	-$700000	-$700000
PRODUCTIVITY						
water availability during restrictions	+	no data available for $ loss of productivity during drought for agriculture and 'green spaces'				
risk of soil contamination	-	no data available for $ loss in profit due to soil contamination from wastewater reuse				
fertiliser benefits	+	4kg N/ML	$0.97/kg N	$39	$39	$39
reduced impact on fisheries	+	1 % loss in revenue[5]	$4.68 million/yr	$46800	$46800	$46800
reduced impact on tourism	+	1% loss in tourism[5]	$3.7 million/yr	$37000	$37000	$37000
			Total	**-$393,637**	**$5.16mill**	**$11.34mill**

[1] 10 ha is the hypothetical amount used for this example

[2] 1 case per year is the hypothetical amount used for this example

[3] Willingness to pay (WTP) based on 10,000 households

[4] WTP based on 100 anglers

[5] 1% impact on total annual profit from fisheries and tourism is a hypothetical scenario for this example.

4. USING EXTERNALITY ASSESSMENT IN DECISION-MAKING

4.1 A Brief Overview

There are seven steps in the proposed SEXTAN externality analysis methodology, as it has been applied for the assessment of regional water servicing options in this report. The simple externality analysis method has been described in detail in Section 2 and demonstrated using an example based upon a hypothetical planned water supply scenario in Section 3.

The externality analysis methodology in this report is complemented by the ability to cross-reference to the detailed externality lists and valuations associated with the seven water supply options in the companion water externalities report (Daniels *et al.,* 2012).

In this section of the report, we discuss the potential, and limits of applying the SEXTAN externality analysis method in broader decision-making frameworks. Its role in cost-benefit analysis (and cost-effectiveness analysis) and multi-criteria analysis are emphasised to reveal its (conditional) benefits for decision-making. The economic valuation estimates of the "unintended" impacts captured in externality analysis (of water options in our case study), and the broader methodology outlined in this report, are presented under the strict proviso that they are valuable inputs that form just *one* aspect of overall decision-making processes.

The aim of our two reports – the externality impact and valuation compendium in Daniels *et al.* (2012) and the proposed simple economic externality analysis (SEXTAN) methodology outlined in this report – is to provide a systematic and practical means of feeding information about the full range of costs and benefits into decision-making approaches available for effective natural resource management. In this section, we demonstrate this potential by considering how the data and methods provided can link to at least three decision-making systems – cost-benefit analysis (CBA), cost-effectiveness analysis (CEA) and multi-criteria analysis (MCA). In recent years, risk analysis is intrinsic to most project evaluation techniques.

While not considered in detail here, economic valuations of externalities can play a similar role in investigating risk valuations, as they do in CBA. This is in the provision of important data feeds for estimating probability-cost levels and for informing community risk preferences. If private costs and benefits from the financial analysis of proposed project options are combined with the outputs from the first six steps of our externality analysis method, we have the primary informational basis for economic-based techniques such as CBA and CEA.

As discussed, the SEXTAN externality analysis methodology presented is not just part of a broader recommendation for decision-making based solely on economic criteria and frameworks. Rather, it is intended as a mechanism to generate useful data series reflecting the magnitude and trade-off values of economic, environmental and social externality effects for application in whatever strategic assessment approaches are deployed.

In this section, we provide a brief overview of some of the major decision-making techniques popular in contemporary natural resource management and explore how the externality analysis method and outputs described in this report may be utilised for planning that integrates TBL principles. This is completed to exemplify the potential role and application of the method in the general policy assessment process. It is not meant to be restricted to the frameworks discussed. The key features and structure of the frameworks are outlined to identify the potential role and contribution of the externality analysis method. As the use of the method within each framework will be circumscribed by their assumptions and limits, their strengths and weaknesses are also noted.

At this point it is important to highlight that the SEXTAN method presented in this report is not intended as a full cost-benefit analysis (CBA) approach. Rather, it is focused upon the systematic appraisal and incorporation of indicative externality values for the anticipated biophysical outcomes per unit time (typically a year) for proposed scenarios. A more complete CBA method would need to include financial costs and benefits, and the temporal allocation of all costs and benefits across the project/scenario component life cycle. It would also require the application of appropriate discount rates to ascertain net present values.

The more partial approach taken here circumvents many of the associated problems of CBA and is meant as a general input for a broader range of decision-making methodologies (including multiple criteria assessment). It is anticipated that the method outlined here will be applicable to cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), risk analysis and, to a lesser extent, multi-criteria analysis (MCA). It is acknowledged that each framework has its own strengths and weaknesses, and that, at this point in time, none are considered to stand out as preferred approaches for sustainable water management.

Economic valuations of externalities can be applied in many ways, and to varying degrees, in strategic water research, management and planning. It is quite rare to see the full-scaled adoption of decision-making frameworks (such as CBA and CEA) that measure and make recommendations based on the comprehensive assessment of full social (that is, private and external) costs and benefits. While there is an impeccable logic in the idea of selecting options that truly maximise net well-being outcomes to society (with all main effects covered), exclusive reliance on social CBA approaches would represent strong faith in the reliability and inclusiveness of market measures and monetisation. There are some serious conceptual issues limiting the efficacy of aggregating monetary values intended to represent the diverse range of tangible and intangible effects of potential strategic choices. Furthermore, there are also the extensive time, material, energy and financial resources required for primary research to accurately establish context-specific monetary values.

Despite such difficulties and limited use in the past, the push for wider application of general externality identification and valuation techniques for environmental management is gaining support. For example, it has been suggested that:

> *"... externalisation of costs* [and hence neglect in decision-making] *is a major factor leading to the loss of natural ecosystems.... Policy-makers need to identify the value of this loss of welfare and implement financial and institutional mechanisms to assimilate these costs into the accounting structure"* (Bergkamp *et al.*, 2000, p.v).

Alain Lambert, Senior Advisor to the RAMSAR Convention expresses further support for the general approach:

> *"Translating these many values into economic terms is of primary importance if we are to convince of the importance of these ecosystems as life-supporting systems. This is a relatively new science but promising progress is being made." (Lambert, 2003, p.4).*

Indeed, there is a recurrent theme, in relevant environmental analysis literature, of the need for methodologies and information for the identification and best-possible valuation of externalities for water and other major natural resources to proffer useful inputs for decision-making and policy formation processes. To the authors' knowledge, this report is unique in providing a systematic guide to externality analysis and its incorporation in strategic decision-making for natural resources – especially in terms of its focus upon water and the Australian context. However, it must be acknowledged that empirical data and research in the area are limited and direct application to the SEQ context is constrained by a dearth of local studies.

4.2 Economic Decision-Making Frameworks

The externality analysis methodology outlined in this report can be utilized directly as a substantive input to two of the most common decision-making frameworks within the perspective of environmental economics. These frameworks are cost-benefit analysis (CBA), and its counterpart, cost-effectiveness analysis (CEA)[5].

Cost-benefit analysis (CBA) is a widely-known decision-making framework adopted to assess major projects, policies or programs with significant natural resource or social and environmental impacts. It is a common counterpart of environmental impact assessment (EIA) (Alam, Rolfe and Donaghy, 2008; Munda, 1996). The basic premise of CBA is that the costs and benefits of proposals can be usefully represented, and compared, in monetary terms. Under a rigid CBA approach, the proposal or option with the highest overall net benefit present value is considered as most favourable. The CBA process consists of identifying, valuing, discounting, and summing the social (private and externality) costs and benefits for each water management option (over its lifetime), with an aim of enabling effective comparison between various options under review (Alam, Rolfe and Donaghy, 2008). However, the extent to which externality valuations are aggregated and used to provide singular decision support indices depends upon the way the results are integrated into decision-making.

CEA involves accounting for the impacts of the options in question in a systematic manner with the primary aim of identifying the most "efficient" option where efficiency is defined in terms of achieving a given objective at the lowest cost (Levin, 1995)[6]. Hence, CEA also requires evaluation and comparison in monetary terms and its focus upon costs is favoured when benefits are very difficult to monetise (e.g., health projects and policy). Hence, for water management, an essential stipulation is that CEA can only be used where there are pre-determined goals or objectives (Alam, Rolfe and Donaghy, 2008). CEA allows comparison of cost against a common project target denominator. The underlying assumption is that, by selecting the option with the lowest cost, society is able to allocate its resources most efficiently (Alam, Rolfe and Donaghy, 2008).

CEA and CBA are very similar in many ways. They both seek to compare costs and benefits in monetary units, and utilise similar methodologies that potentially identify the suite of relevant costs and benefits (though, in CEA, benefits are of less interest, tending to be assumed in the selection of the given objective), valuation, and discounting (Gafni, 2006). The key point of difference between the two is CEA's fixed focus upon a specified management objective, eg, a 45% reduction in nutrient loads. Thus, CEA tends to highlight the option which achieves the reduction target for the lowest monetary cost.

CEA shares many of methodological features, and hence difficulties, of CBA. Elimination of some key problems is typically achieved by simplification and omission of the steps where the problems occur (for example, removing the need to measure social benefits beyond simple presumed targets, and the less extensive coverage of externalities). It is important to bear these weaknesses in mind when applying the externality analysis method from the stance of CBA or CEA.

Given similarities in underlying data needs, a more detailed overview of CBA and CEA and the major limitations are reviewed in the following sections.

4.2.1 Cost-Benefit Analysis

It is useful to identify the typical key stages or procedural steps in CBA in order to clarify the potential role (and limits) of the proposed externality analysis method.

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[5] The application of CEA, in particular, is varied in the extent to which externalities are monetised and incorporated. CEAs with covering social costs and benefits tend to be called "extended CEA".

[6] As noted, the definition and coverage of external versus financial "costs" varies considerably in CEA.

Typical Stages of Cost-Benefit Analysis

STAGE 1: identify the problem (the gap between existing conditions and required outcomes) and define the alternatives to resolve it.

STAGE 2: identify and measure, in biophysical terms (or other non-monetary numerical indicators), the magnitude of social costs and benefits of each alternative.

- Social costs and benefits effects include both private and externality effects. The former are obtained from financial analysis and the latter from externality analysis. It is essential to procure accurate biophysical and socioeconomic "quantity" measures of potential impacts as the basis for subsequent economic valuation (in Stage 3).

STAGE 3: where possible, estimate monetary values for the social costs and benefits of each alternative.

- A range of economic valuation techniques exist for assessing externality values. A key aspect of this step often involves risk analysis to assess the probability distribution and expected value of impacts occurring so that economic values can be adjusted in terms of their likelihood.

STAGE 4: tabulate the social costs and benefits and costs for each year over the lifetime of the proposed option (into a row of the cost-benefit table).

- The net benefit can be calculated by simply summing total cost and subtracting them from total benefits.

STAGE 5: calculate the present value of the net social benefits (NSB) of each alternative.

- Net benefits vary according to when they occur in the lifetime of the project. A comparable benchmark value or "net present value" (NPV) is required. This is achieved by the application of a social discount rate which reflects the rate at which a society would be willing to trade present for future benefits or costs (or consumption). Higher discount rates imply a preference for projects that return net benefits close to the present. The discount rate tends to vary between 2 and 10% for environmentally significant projects though arguments have been presented that suggest significant long-term environmental resource impacts (especially for non-renewables and irreversible effects, and certainly life support systems) should have very low, zero or even negative social discount rates (Weitzmann, 2009).
- NPVs for each year are calculated using the selected discount rate where the calculated annual values are multiplied by 1/(1+r)t where r is the discount rate (e.g. 5% would be 0.05) and t is the number of years into the future (e.g., t = 3 yielding a discount weighting factor of 1/(1+r)3 = 0.864 or 86.6% for 2014, if the project commences in 2011).

STAGE 6: calculate and compare the net social benefit of each alternative.

- The annual NPVs can be summed to produce overall project net social benefit values.
- Alternative options can be ranked or selected on many criteria including absolute values of net social benefits or ratios or rates of return based on initial levels of resource use.

STAGE 7: sensitivity analysis to test for the effects of changes in assumptions and data on option preferences.

- For example, the effect of different discount rates, risk probabilities and valuation methods and assumptions.

STAGE 8: make final recommendations (typically as just one input to the decision-making process).

The externality analysis methodology outlined in this report is linked to, and can contribute to, several of the above stages of the CBA procedure. This is evident in the following observations:

- the problem identification stage (Stage 1) of CBA is closely matched to the scenario composition phase of the externality analysis method.
- CBA's Stage 2 identification and measurement of social costs and benefits (based on biophysical and socioeconomic indicators, not economic valuation) covers the externality identification and (physical) quantification in Steps 2 and 3 of the externality analysis technique.
- the economic valuation Steps (4 to 6) of the externality analysis build up from identifying $ *per unit* externality biophysical or indicator impacts, to the total $ value of each externality associated with the project's overall effect. This process is closely linked to CBA's valuation procedure in Stage 3.
- CBA sums the cost and benefits across different externality types in Stage 4. However, this is not an intrinsic part of the externality analysis method and the application of the externality valuation results is recommended as being left more open for use in wide variety of decision-making roles and contexts.

Hence, the externality analysis procedure has many direct connections to the general CBA procedure – especially in terms of Stages 2 to 4 where externalities are identified, quantified and valued. However, a key divergence in this report is the proposition that the generalised externality analysis valuation results obtained from these stages are retained as discrete *individual* externality type effects.

It is appropriate to consider the relative strengths, and conceptual and practical limitations of the various decision-making frameworks when considering the use and viability of the potential application of the externality analysis method. Cost-benefit analysis has many strengths, most related to its logical, rational and systematic nature. In addition, its focus on economic efficiency is often appealing to decision-makers. It also constitutes a relatively transparent process with a supporting legislative basis. At an overall procedural level, the approach is quite simple and systematic and can be traced out to ensure a reasonable level of understanding by the project stakeholders and affected community.

However, the CBA framework also has many caveats which limit its effectiveness as a sustainable water management tool (Hanley, 2001). Many of these problems are associated with its reliance on monetary valuation and discounting. CBA's specific methodological weaknesses tend to stem from numerous issues with monetary valuation, bias, conceptual and technical problems, and the choice and justification of discount rates. Its reductionist and economistic nature, and restricted capability in adequately dealing with uncertainty and complexity, are also major areas of criticism[7].

4.2.2 Cost-Effectiveness Analysis

Like many other decision-making tools, cost-effectiveness analysis (CEA) was developed in 1950s, by the US Department of Defence, as a means of comparing weapons and military strategies. The technique grew in popularity throughout the 1960s (Levin, 1995). Some 80% of all CEAs are currently performed in the health care field (Alam, Rolfe and Donaghy, 2008, p.31). However, CEA is gaining increasing acceptance in water management (Alam, Rolfe and Donaghy, 2008). In a complementary study also undertaken in the Alliance's Total Water Cycle Management Planning project, Hall (2012) has applied extended cost-effectiveness analysis to examine water supply options in a case study of the TWCM plan for the Moreton Bay Regional Council in SEQ.

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[7] This is not a problem area unique to CBA. All techniques that attempt to quantify TBL impacts will be dogged by very significant uncertainty and other data issues.

The CEA framework involves accounting for the impacts of *given* options or other measurable outcomes in a systematic manner with the aim of identifying the most efficient alternative means of achieving the service target. From the CEA perspective, the most efficient option is that which achieves the given objective at the lowest cost (hence CEA requires valuation and comparison in monetary terms). One essential stipulation is that CEA is best suited when there is a pre-determined water management goal. Hence, CEA would be largely limited to the cost side of the cost-benefit analysis approach.

The externality analysis method would be applied to CEA in much the same way as with CBA, but with greater emphasis on the latter's cost valuation focus. For example, if fresh water consumption is to be reduced by 10% by 2014, there would be a series of supply options from which to realise this reduction. Each of the supply options has externalities. In "extended" CEA, externality data generated would be monetised, along with primary cost estimates, to complete a CEA of all reduction target options. Hall (2012) provides a detailed analysis of the application of this methodology in examining water supply options.

Positive aspects of CEA include its ability to deal with uncertainty, retain focus, differentiate between options, and highlight efficient allocation. CEA's advantages derive largely from its more delimited scope and a defined focus upon a given objective followed by the identification of options that provide the most technically efficient resource allocation to achieve this predefined goal (Alam, Rolfe and Donaghy, 2008). Like CBA, CEA is also a transparent method; its process is simple and easily traced. In general, this makes CEA easily understood by the affected community and easily implemented by practitioners. In theory, CEA requires the assessment of all potential alternatives for achieving a given end. The SEXTAN externality analysis method would strengthen the systematic and comprehensive assessment of external effects of these alternative options.

Cost-effectiveness analysis can also be seen as being incompatible with many aspects of sustainable water management. Beyond its narrow-sighted presumption that an arbitrary given end is optimal from society's point of view, CEA is also reliant on problematic valuation and discounting techniques. In addition, CEA rarely incorporates public participation or different knowledge systems. Being primarily an economic tool, it can also fail to adequately address and integrate social and environmental impacts within its predisposition towards direct financial costs. All of these weaknesses should be considered when applying the SEXTAN methodology to the CEA decision-making framework.

4.3 Limitations of Valuation Methods – A Comparison of Simple Externality Analysis and Full CBA

One important conclusion to be drawn from this overview is that externality analyses which retain and highlight the full information about individual externality effects have several advantages over frameworks bound to the full CBA process and its decision criteria. While many information and valuation problems remain, the simple externality analysis method retaining individual impact information allows for:

a. the assessment and clear indication of error sources, weaknesses, variability, and veracity of valuation estimates for each effect;

b. clear acknowledgement of the partial nature of economic valuation inputs and appropriate application in ongoing decision-making;

c. ready incorporation of valuations within MCA, risk analysis and other relevant decision-making approaches; and

d. the potential for reliable estimates of even an incomplete range of TEVs affected by proposed projects to provide a sufficient basis to make decisions – notably when their estimated values exceed proposed development's net direct financial benefits, for example, food, fuelwood, tourism or recreational values from a forest exceed logging net revenues.

However, the veracity of the externality analysis method within a full CBA-related framework will be heavily influenced by the stronger assumptions of the CBA approach and its overall indicators. Many of the shared limitations of simple externality analysis and full CBA are a result of the fact the externality analysis methods are essentially a subset of Stages 2 to 4 in CBA. In addition to information and valuation challenges shared up to the Stage 3 of CBA, full CBA has a suite of other problems associated with greater aggregation, the use of social discount rates, and the single decision-making indices and criteria that ensue in its later stages.

The major limitations of predominantly economic decision-making frameworks based upon valuation techniques and aggregated indices, such as CBA and CEA, are outlined in detail in the Appendix and summarised in this Section. Many of these issues are overlapping in nature. To highlight the relative capabilities of the simple externality analysis approach and full CBA, we divide the limitations into:

(1) those that apply to the valuation of individual effects; and

(2) those that are more pronounced in the more rigid application of individual effect valuations within CBAs.

4.3.1 Weaknesses of Externality Analysis (that Relate to the Valuation of Individual Effects)

The valuation of individual externality effects is a part of the overall CBA process. Hence, any problems linked to its assumptions and methods are embodied in the full CBA approach. Most of main limitations of the effective valuation of externalities can be linked to a few major problem sources.

a. Incomplete information/uncertainty about the full range of biophysical consequences of proposed interventions and their exposure and impacts on the economy and broader society;

b. Many sources of potential error in assessing individual's preferences and valuation based on what they would trade-off for less or more external costs and benefits of some intervention;

c. Difficulties in summing trade-off values (the aggregation problem) and related issue of taking into account and managing distributional and equity impacts;

d. Trade-off choices identified for individuals or society, in valuation processes, may not be socially or culturally acceptable;

e. Money values are a poor measure of welfare or well-being change; and

f. The significant financial and time resource costs of effectively completing economic valuations of externalities.

The Appendix provides a detailed discussion of these limitations.

4.3.2 Additional Weaknesses with Extending Externality Analysis to a Full CBA Approach

As externality analysis is an essential component of CBA, the full CBA approach will be subject to all of the limits of externality analysis summarised in the Section above. On the other hand, CBA does have immediate advantages including: the more extensive aggregation of monetary values into a single measure of providing single indices intended to represent the total net present benefits of the intervention under study; and the ongoing related use of overall net present values (benefits minus costs), benefit-cost ratios, rates of return on investment and related indicators. This has the appeal of being able to compare overall, summary performance measures of the project alternatives and appears to transcend the potentially fragmented nature of externality valuation analyses that do not proceed beyond measures for individual effects.

However, there are some limitations including:

a. **Aggregating the data** - The aggregation step can exacerbate all of the informational, uncertainty and valuation problems in externality analysis and can lose sight of the very substantial variability in the accuracy and reliability of individual effect estimates. Aggregation across all externalities also masks the inevitable omission of estimates for many of the total economic values likely to be impacted by interventions. CBA presented as a concise solution set gives the illusion that all effects have been effectively and accurately covered. Increased aggregation in CBA further obscures equity implications of interventions and restricts the detail available in undertaking subsequent sensitivity analysis. These factors all promote the rather blind application of aggregate CBA for project selection criterion.

b. **Discount rate** - Discounting is an element of valuation which has been heavily criticised. The discounting rate will have crucial impacts on the overall 'sustainability of water management decisions' (Birol et al., 2010, p.839). Adopting 'best-practice' rates is often a controversial move as most often higher positive discount rates which favour decisions with high short-term benefits are chosen (Hanley, 2001, p.110), undermining key sustainability principles of long-term planning and intergenerational equity (Birol et al., 2010) by making the net short-term benefits of a certain action relatively greater (Spash, 1994). The problems of the selection and use of (often a single) discount rate across all natural resource impacts are deepened by lack of information about the preferences, willingness to pay and trade-off valuations of future generations (Spangenberg and Settele, 2011).

Most of these difficulties also apply to the simple externality valuation restricted to individual effects when, as is common, impacts are distributed across significant time spans. However, externality analysis has greater transparency and facilitates analysis based on the substantial variation that will be likely in social preference "discount" rates for different natural resources.

4.4 Multi-Criteria Analysis (MCA)

The multi-criteria analysis (MCA) decision-making framework holds substantial promise for sustainable water management. MCA aims to assess and compare proposed interventions by reference to an explicit set of objectives or criteria that are usually identified by a relevant group of technical or scientific experts. For each intervention considered, a selected "representative" group of people then score or rank each alternative in terms of each objective. These predicted impact scores are weighted or ranked according to the perceived importance of each objective and the results are often aggregated to indicate the overall performance of options.

MCA is able to incorporate multiple social, economic and ecological criteria and attributes into its process and measures option features and impacts under general notions of "value" and priority – thus avoiding monetary valuation as a primary decision-making basis. MCA is also commonly favoured for its perceived 'open' and participatory nature which is flexible and yet founded in 'logical and robust decision-making theory' (Munda *et al.,* 1994; Stirling, 2006).

It was developed and implemented throughout the 1960s and 1970s, partly as a result of military research on operations logistics, in World War II. Though MCA is rarely required by legislation in Australia, it has been steadily increasing in popularity within the field of water management (specifically in policy evaluation and strategic water supply and infrastructure planning) (Hajkowicz and Collins, 2006). For water management, MCA tends to be used for project or scenario assessment involving multiple stakeholders and complex issues generating critical impacts with long-term implications (Hajkowicz and Collins, 2006). It has been endorsed as the basis for background research and papers underpinning the *South East Queensland Water Strategy* (QWC, 2010). MCA has been considered as an appropriate method to meet the requirements of the National Water Initiative, given its ability to assess water options across social, environmental, economic and intergenerational criteria (Carden, 2006). Other examples of MCA's growing role in natural resource decision-making include its application to revegetation planning in NSW (Lesslie and Cresswell, 2008) and in "The CCA

Integrated Decision Framework: A guide for sustainable land use planning" published by the NSW Government, Department of Planning (2006).

4.4.1 Typical Stages of Multi-Criteria Analysis

Although there are many forms of MCA, typical steps in its research and decision-making process include:

STAGE 1 - Choose decision options (project or policy proposals).

STAGE 2 - Choose evaluation criteria – to assess the performance of each option.
- based on some objectives; analyst selects a set of 'impacts'.

STAGE 3 - Assign a score to each predicted impact.
- based on the effect and measured in a range of different and typically incompatible units.

STAGE 4 - The scores are adjusted by multiplying them by subjective weights that are chosen to represent the analyst's assessment of the relative importance of each impact.

STAGE 5 - The scores are then "standardised" mathematically, and summed arithmetically to provide an indication of net benefit (to make them commensurate).
- much of the variation in individual MCA approaches is based on differences in methods deployed in stages 4 and 5.

STAGE 6 - Perform sensitivity analysis – especially regarding weights; performance measures (scores); and ranking algorithms.

STAGE 7 - Make a decision.
- MCA informs, it is also not intended to present final decisions.
- expert judgement is acknowledged for issues that cannot be modelled.

The proposed externality analysis methodology can provide data inputs to various stages of the MCA process. Arguably, the externality analysis is useful in terms of identifying direct and indirect impacts to be considered throughout the MCA process and providing quantitative and economic valuation information to feed the MCA process in:

STAGE 2 – evaluation criteria – helping the analyst to decide the relevant set of impacts;

STAGE 3 – providing background information supplied to participants in their scoring of each predicted impact; and

STAGE 4 – the analysts' selection of subjective weights for assessment of the relative importance of each impact.

4.4.2 Strengths and Limitations of Multi-Criteria Analysis

In general, externality costing data are useful inputs into any economic considerations in the MCA procedure. As for the economic decision-making frameworks, any application of the externality analysis method and data outputs to MCA must be conditioned by the strengths and limitations of the approach.

MCA has several advantages over CBA and CEA in terms of sustainable water management. Firstly, its method is well-placed to incorporate the multiple, often competing, criteria that must be considered in the management of water and other natural resources. Secondly, MCA can examine trade-offs in a way that does not require monetary evaluation. Thirdly, it can integrate considerations of fairness and equity into judgements and evaluative procedures. Finally, unlike CBA and CEA, MCA can involve high levels of community participation – a feature that may enhance the chances of finding acceptable and sustainable solutions to water management problems (Prato and Herath, 2007).

The benefits associated with the use of MCA for effective sustainable water management mostly revolve around its ability to deal specifically with issues which are highly complex and involve numerous stakeholders and objectives. The 1992 Rio Earth Summit identified the need to simultaneously address multiple objectives for natural resource use as a key element of sustainability (Hajkowicz and Collins, 2006, p.1560). MCA can cater to specific characteristics that are complex, subjective, and involve numerous stakeholders; hence making it well-suited to controversial decision-making process in water management (Hajkowicz and Collins, 2006; Stirling, 2006). MCA is a valuable aid in conflict resolution as it is capable of giving 'fair' and 'balanced' analysis (Munda *et al.,* 1994; Prato and Herath, 2007). MCA processes are specifically designed to enable the integration and inclusion of social values and perspectives (Stirling, 2006). Thus, MCA, through its inclusive and participatory nature, can be useful in the identification of "shared solution space".

In addition to being participatory, MCA is transparent in that it provides an accountable decision procedure which explicitly addresses common issues, rationale, and unclear motives achieved via the definition and weighting of the decision criteria (Hajkowicz and Collins, 2006).

Another benefit of MCA over CBA and CEA is that it avoids issues of commensurability (the idea that all alternatives can be assessed against a uniform scale) and the issues of compensability (the idea that impacts upon people can be compensated with money or at least tradeoffs) (Carden, 2006). This, along with other its benefits, makes MCA particularly good at dealing with 'Wicked Problems' (e.g., water management issues such as in the Murray Darling Basin), which are complex, or involve conflicting values, or offer no obvious solution, or are poorly defined, unique, or involve serious consequences (Carden, 2006). The MCA process can also explicitly deal with equity implications. This can help in the achievement of societal goals such as poverty eradication and equitable or acceptable impact re-distribution.

Each of these identified strengths is likely to be enhanced when used in combination with the proposed externality analysis methodology, as it can provide a broad range of measures that identity and quantify direct and indirect social, economic and ecological impacts in biophysical and non-monetary and monetary numerical terms with a stress upon the trade-offs involved. This information about monetised costs and benefits and trade-offs can help provide the background data for more accurately completing Stages 2, 3, and 4 of the MCA procedure – assisting participants to make more informed judgements about the accurate and complete nature of water servicing option impacts.

However, it is necessary to also note several significant limitations of the MCA approach. These include:

- The process of weighting and criteria selection may be prone to bias (though use the proposed externality analysis methodology may help reduce this latent bias) (Munda *et al.,* 1994);
- The criteria for identifying the main impacts can be seen as rather subjective and unsystematic (with an arbitrary dimensional basis);
- The representativeness and adequacy of the sample of people used to assess and score impacts is often questionable;
- The basis of the objective or impact criteria weighting process is contentious and unreliable;
- In theory, accurate choices and scoring and weighting of impacts require comprehensive estimates of future costs and benefits (that is, most of the data and process of CBA);
- It is criticised as being both overly and inadequately transparent (Gamper and Turcanu, 2007);
- It is difficult to refrain from being either overly-reductionist and simplistic or overly-technical when communicating to multiple stakeholders (Gamper and Turcanu, 2007);
- People find it difficult to compare, rank and evaluate consistently (Carden, 2006);
- It is unable to compare options which are unrelated (Dobes and Bennett, 2009); and
- The pronounced lack of local MCA case studies and related expertise, experience and data.

The application of high quality and comprehensive externality analysis, as outlined in this report, is likely to help address some of the weaknesses of MCA. The proposed methodology can assist in the selection of more comprehensive selection criteria and weighting. It can also help identify a wide range of indirect social and environmental impacts which may otherwise be overlooked. Through the provision of cost estimates, it is also able to assist in providing an indication of the magnitude, severity and extent of the associated externality benefits and costs. This may significantly reduce weighting and selection bias in MCAs and improve the basis of participants' scoring. The methodology may also be useful in ensuring that the problems associated with consistent evaluation and ranking are minimised.

4.5 A Practical and Effective Role for Externality Valuation Analysis

This part of the report (Section 4) has highlighted the many sources of error and uncertainty in the economic valuation of externalities associated with water servicing other major proposed interventions with significant natural resource (and ongoing social and economic) impacts. Given the marked variation and highly unreliable valuations observed in many studies, it would be dangerous to apply the approach to critical ecosystem services and sources of natural capital, and then use the results as a primary basis for decision-making.

As Papandrea (2009, p.206) concludes, CBA should be recognised for what it is: "an analytical tool to assist the evaluation of proposals by policy makers, and not a mechanistic decision-making instrument". Hence, it provides a decision *support* tool and not confident decision rules. For this support function, we argue that indicative overall costs and benefits, and especially results that retain full information about the trade-offs involved for *individual* externality effects, will comprise valuable inputs. For example, whilst the total economic values bandied about in Stern's highly influential report (Stern, 2006) are subject to much criticism (for example, Byatt *et al.*, 2006), the clear identification of the order of magnitude of the extensive and probable external costs of climate change has raised awareness of the significance and dimensions of this anthropogenic disruption. Simple externality valuation analysis is a preliminary information source and catalyst for motivating further research and the development and implementation of rational and cost-effective responses.

The externality analysis approach outlined has a systematic method which is transparent and accountable. Within the overall scope of its broader CBA framework heritage, a distinct strength lies in the requirement for the (best possible) comprehensive identification of related externalities and their subsequent biophysical quantification and monetisation; and also in highlighting the allocation of costs and benefits across affected socio-demographic groups within society. The problems in fully establishing the extent and magnitude of externalities plague all impact assessment techniques. Externality valuation analysis can actually provide an advantage here as, unlike many approaches, it has a solid and comprehensive scheme to support this process (with its TEV and trade-off and preference conceptual underpinnings).

Furthermore, the challenges faced with valuation do not render the effort as futile, as many measures have robust underlying data and methods. A better approach is to present valuations with good descriptions of caveats and supporting science and other evidence (or noted evidence gaps) to justify and condition valuations, and their order of magnitude and potential variability.

Access to this systematic information enhances the ability to make informed decisions that represent the collective will or preferences of society and it helps make explicit related value judgements. Valuation techniques still comprise one of the best ways of knowing and comparing what is likely to be lost from different choices. Incomplete information is a pervasive issue, but the trade-off approach to approximating welfare change is one valid and relatively robust way of assessing people's choice priorities and true values for specified TBL costs and benefit changes in the face of scarcity. Given the limits discussed here (including the tenuous link between actual compensation or loss and changes in well-being), MCA may provide a superior tool for dealing with collective values that stump valuation approaches. However, the existing techniques in MCA do not seem to have a more defensible basis for assessing real change in well-being.

A major test of the appropriate use of externality valuation analysis (and CBA) would be "does the application of the technique result in cost-effective improvements in the quality of decision-making?" (Papandrea, 2009). We propose that the answer to this question is a definite "yes" – especially as supporting data and methods continue to rapidly improve.

When externality valuation and more complete CBA results are considered in the assessment of potential major interventions, there will be substantial variation in the availability, usefulness and accuracy of data according to the types of impacts analysed and specific study setting. Hence, the more conventional economic value and trade-off approaches are likely to provide only a partial depiction of the information required to make decisions that are really in the public interest from a long-term, sustainability or TBL perspective. The previous discussion has noted how there are a number of alternative decision-making frameworks and criteria than can be presented as more effective and appropriate than the economic approaches – particularly in the light of serious informational deficiencies regarding the actual range and magnitude of biophysical and socioeconomic effects and their accurate measurement as trade-offs choices that reflect true welfare changes.

The relationship between economic valuation, or CBA, and MCA has been discussed as an alternative broad decision-making framework. Another general option promoted in response to the perceived impossibility of objectively calculating values for integrated ecosystem and critical natural capital services is to use a "horizontal MCA" or political process that incorporates the diversity of stakeholder value systems to reach agreement about priorities, and hence derive project or policy and program evaluation criteria as "politically defined targets" (Spangenberg and Settele, 2010).

The apparent flexibility, openness and "humanised" nature of MCA provides potential advantages over the more formal economism of CBA. However, the technique is certainly nor without it faults, and we have noted problems such as: (1) the questionable representativeness of the people in the study samples; (2) all of the same information problems as CBA in terms of identifying and quantifying the full range of external impacts and in eliciting trade-off choices or rankings; (3) incommensurability; and (4) the rather arbitrary nature of weightings and evaluation criteria or dimensions. These issues will also apply to Spangenberg and Settle's (2010) political process "horizontal MCA". Together with the rather abstruse nature of the proposed alternative political method, there would seem to be a danger that it would degenerate into the common political outcome where decisions are made that favour the value systems and ethics (and often economic interests) of those with the most power, especially when information is limited. "Priority agreements" and "politically defined objectives" would suffer the same potential bias and the historical record of gaining consensus and agreement across the disparate value systems of society is not affirming.

There are also many other "technical" criteria that can be used to supersede or veto individual externality valuations, and full CBA inputs and guidelines, for making decisions regarding proposed interventions for water servicing and other goals. They all relate to projects with significant natural resource impacts and there is quite a lot of overlap between them. For example, sustainable yield levels can be identified for individual species. This must take into account ecosystem interdependencies and the natural extension of this principle leads to the range of criteria which stress the requirement that interventions do not threaten the integrity, resilience and maintenance of ecosystem functions, and related biodiversity adequate for "survival and development" (Spangenberg and Settele, 2012, p.329). Key guidelines are the assurance of safe minimum standards and other restrictions for natural resource depletion and waste emissions so as to avoid potentially severe threshold effects. This is similar to the "precautionary principle", where the existence of a risk of serious "harm", even if scientifically uncertain, requires those taking the action to prove that that it will not be harmful. A related general criterion is the maintenance of constant levels of natural assets or "capital" (O'Connor, 2000), one of the essential definitions of sustainable development. The concept has formidable information requirements in general application as its effective measurement needs to identify supply and demand, and technological and substitution conditions indefinitely into the future. It has better potential for selected environmental resources known to have limited substitution capability and in situations where projects will have irreversible damaging effects.

Another criterion that might be used in project assessment is the existing and projected level of contribution to the natural cycle or key biophysical processes that are perturbed or disrupted by human intervention. For example, the potential costs of GHG emissions are related to the fact that anthropogenic sources amount to around 7% of overall biotic carbon cycle mass flows (Schlesinger, 2003). One natural extension of this approach is to assess projects in terms of providing maximum benefit with minimum intervention or disturbance of the natural environment. Ideally, "benefits" would reflect true well-being gains and not simply those derived from the transformation or consumption (as in loss) of natural resources. This is a complex area with the need for much more development. However, there is little doubt that a major aspect of successful future economic activity will be to assess the ultimate driving forces of interventions and their real linkages to well-being outcomes.

Arguably, these alternative criteria may provide better measures for assessing the extent of impacts of projects when there is a risk of very high external costs, but it is simply not possible to confidently predict and value the nature of these impacts with available knowledge and existing valuation methodologies. Life support environmental functions and critical natural capital would be central in these situations.

Many of these criteria may well be better considered under the inclusive and open-ended approach of MCA. However, it is important to recognise that every alternative approach is subject to incomplete information problems and potential extreme variation in forecasts given profound and highly complex ecological interactivity, synergies, and feedback loops and other dynamic forces and processes. Furthermore, the underlying logic of most of these criteria means that they are not amenable to trade-off assessment. There is little to be gained by dismissing an evaluation of the full potential costs and benefits simply on the basis of some possibility of serious harm. Some scientific consensus about potential severe or catastrophic impacts is a vital factor to consider, but unwarranted caution that prohibits possible development many also have enormous trade-off costs (for example, and for nutrition and other economic security and health outcomes). Most proposals for intervention are not binary in nature but involve a balance or selection along some continuum of possible resource use. Having detailed, best possible "trade-off" (that is, economic) information in terms of the magnitude of specific externality effects, types of natural capital and total economic values will play a vital role in assisting MCA, politically defined targets, or whatever decision-making frameworks are applied for sustainable water management.

5. CONCLUSIONS

This report comprises the second of a two-part series aimed at facilitating the practical and methodical integration of externalities into sustainable water management policy. The approach is extensible to strategic natural resource policy assessment in general. Externalities are effects on people's welfare that are not taken into account directly in market-place transactions. They typically cover cost and benefits on those not involved in (or "external" to) the market activity that is the source of the effect, and cover effects that are not intended or considered in the exchange price. Examples include the potential climate change effects of desalination or water quality implications of wastewater recycling. They can be costs or benefits, and often take the form of long-term or unknown outcomes upon community well-being and are part of complex cause-effect chains.

The focus has been upon externalities associated with water within the SEQ region, and the analysis of the full social costs and benefits affecting sustainability and optimal outcomes from a long-term, community point of view. However, the underlying approach could readily be applied to other contexts, resources and management strategies.

This report presents a relatively simple and practical structured methodology for the effective incorporation of TBL effects of water resource management options into the community decision-making process. In view of the background research for the report, we examine externalities linked to water supply scenarios based on seven options mooted for sustainable water services in the SEQ region. In Section 2, we have outlined the proposed externality methodology in some detail. It is composed of six steps beginning with the scenario and option descriptions, through the identification, quantification and valuation of externality impacts, leading to a seventh and final stage where the information from the implementation of the methodology can be utilised in relevant decision-making. Section 3 gives a hypothetical example to demonstrate the use of the proposed methodology. In Section 4, we discuss the potential and limitations of utilising the methodology within the decision-making frameworks of cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), multi-criteria analysis (MCA) techniques, and other decision-making tools.

The methodology description here is complemented by the companion water externalities report (Report 1) (Daniels *et al.*, 2012), which summarises and compiles the results of an extensive investigation and survey of seven water supply options. The compendium in Daniels *et al.* (2012) represents a generalised, preliminary implementation of Steps 2 and 4 of the methodology outlined in this report. It has been built from a comprehensive review of existing research into the identification and economic assessment of externalities pertinent to the adoption of a selection of major water supply options under consideration in sustainable water management in SEQ (notably in the *SEQ Water Strategy* (QWC, 2009)). The options reviewed are stormwater harvesting, rainwater tanks, centralised wastewater recycling, dams, desalination, groundwater and greywater reuse. The Report 1 compendium aims to provide water managers, scientists, and practitioners with a detailed reference to help incorporate the full range of costs and benefits into their option and scenario assessment and decision-making.

Together, the two reports build on existing work and data to provide a systematic data source and guide for externality analysis and its incorporation in strategic decision-making for natural resources – especially in terms of its focus upon water and the Australian context. While the proposed methodology and existing externality valuation data are considered to constitute a strong foundation for more effective TBL and sustainability assessment of water and other natural resources, empirical data and research in the area are limited to date. Widespread application to the SEQ context (and beyond) would need to be supplemented by additional local context research.

Improved identification and information about the likely external effects of alternative water options, and the magnitude of their TBL impacts (in biophysical and non-monetary numerical terms, and monetary values where possible) can assist in the design and selection of strategic management options that efficiently allocate society's scarce resources and avoid unexpected costs to society later in the project life cycle (Siebert, Young and Young, 2000).

Without a consideration of externalities, decisions tend to made on the basis of a combination of financial analyses, and media suasion and interest group and political lobbying that typically draw upon impartial and biased assessments. Financial analysis includes only direct market-based costs and benefits known to the parties involved in the primary transaction or economic activity (such as the construction, operation and treatment costs of supplying water from a new dam). Externality analysis provides a more systematic and comprehensive inputs to guide decision-making by identifying, quantifying and assessing the relative trade-off values that might be associated with the full range of long-term costs and benefits of proposed water options.

One important conclusion to be drawn from this overview is that externality analyses which retain and highlight the full information about individual externality effects have several advantages over frameworks bound to the full CBA process and its decision criteria. While many information and valuation problems remain, the simple externality analysis method retaining individual impact information allows for:

a. the assessment and clear indication of error sources, weaknesses, variability, and veracity of valuation estimates for each effect;

b. clear acknowledgement of the partial nature of economic valuation inputs and appropriate application in ongoing decision-making;

c. ready incorporation of valuations within MCA, risk analysis and other relevant decision-making approaches; and

d. the potential for reliable estimates of, even an incomplete range of, TEVs affected by proposed projects to provide a sufficient basis to make decisions – notably when their estimated values exceed proposed development's net direct financial benefits, e.g., food, fuelwood, tourism or recreational values from a forest exceed logging net revenues.

The proposed methodology is also consistent and supportive of total water cycle management (TWCM) approaches adopted at regional and sub-regional scales for the SEQ Water Strategy. The systematic analysis of externalities follows the core principles of TWCM by recognising and forming an appropriate response to the need to cover the entire suite of impacts and implications of human intervention within the characteristics and parameters of critical natural cycles. It is capable of dealing with the full range of potential options and their interconnected water quantity, quality, energy, GHG, nutrient, and other environmental, economic and social impacts (QWC, 2010).

APPENDIX: Limitations of Valuation Methods – A Comparison of Simple Externality Analysis and Full CBA

The major limitations of predominantly economic decision-making frameworks based upon valuation techniques and aggregated indices, such as CBA and CEA, are outlined in this Appendix. Many of these issues are overlapping in nature. To highlight the relative capabilities of the simple externality analysis approach and full CBA, we divide the limitations into:

(1) those that apply to the valuation of individual effects; and

(2) those that are more pronounced in the more rigid application of individual effect valuations within CBAs.

The veracity of the externality analysis method within a full CBA-related framework will be heavily influenced by the stronger assumptions of the CBA approach and its overall indicators. Many of the shared limitations of simple externality analysis and full CBA are a result of the fact the externality analysis methods are essentially a subset of Stages 2 to 4 in CBA. However, in addition to information and valuation challenges shared up to the Stage 3 of CBA, full CBA has a suite of other problems associated with greater aggregation, the use of social discount rates, and the single decision-making indices and criteria that ensue in its later stages. If discounting is used to adjust values across the option lifespan, then discount rate issues will also apply to externality analysis (though preservation of individual effects can allow for the more detailed specification and defensible application of discount rates).

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c. ready incorporation of valuations within MCA, risk analysis and other relevant decision-making approaches; and
d. the potential for reliable estimates of even an incomplete range of TEVs affected by proposed projects to provide a sufficient basis to make decisions – notably when their estimated values exceed proposed development's net direct financial benefits, for example, food, fuelwood, tourism or recreational values from a forest exceed logging net revenues.

1. Weaknesses of Externality Analysis (that Relate to the Valuation of Individual Effects)

As noted, the valuation of individual externality effects is a part of the overall CBA process. Hence, any problems linked to its assumptions and methods are embodied in the full CBA approach. Although the problems associated with discounting, in order to obtain net present values, are only discussed in the following section on the full CBA limits, this adjustment can also be applied to the simple externality analysis (SEXTAN) methods. If so, these caveats will also need to be recognised.

Most of main limitations of the effective valuation of externalities can be linked to a few major problem sources. Indeed, most can be attributed to the rather intractable general problem of incomplete information.

A. Incomplete information/uncertainty about the full range of biophysical consequences of proposed interventions and their exposure and impacts on the economy and broader society

These difficulties become more acute for longer-term effects. CBA is often accused of being reductionist, partial and highly simplified in terms of identifying the full social, economic and environmental impacts of projects (Stirling, 2006, p 99). The complexity with which it grapples is largely a result of the profound and intricate web of biophysical and ecological interconnections and interdependencies across the human realm and the rest of nature. As an important foundation of valuation methods, neoclassical economics typically assumes the divisibility of services – including those provided by nature (for example, ecosystem services) (Spangenberg and Settele, 2010). However, ecological reality dictates that it is very difficult to extricate or sum individual life support services such as, for a forest, water filtration, food and fuel supply, climate stability, and spiritual or amenity benefits. Isolating an individual service from its systemic context is highly problematic. The inability to correctly account for critical forms of natural capital with limited substitutability and essential roles in maintaining ecosystem integrity and resilience can lead to major errors in measuring the scope and extent of externalities.

This uncertainty means that, even prior to any form of valuation, the full costs and benefits of interventions are difficult to ascertain in terms of their existence, let alone their exact magnitude. Similarly, the full value of good and services in private markets, as captured by prices, seldom capture all of the costs of production and consumption as people do not know, consider, or predict correctly the full consequences of their choices (and the resulting welfare impacts on themselves and others).

Hence, there are many sources of errors regarding: (a) the identification and biophysical quantification of all non-market externalities; (b) existing market prices in general (due to imperfect information about actual costs and benefits); and (c) market prices in proxy markets (for the same reason as in (b)).

Unfortunately, these are all essential bases of subsequent economic valuation. Hence, externality analysis is bound to simplify the very complex ecological economic interdependencies associated with water management decisions (Stirling, 2006). Similarly, there are problems in accounting for cumulative and indirect impacts, as CBA is mainly concerned with marginal changes with a limited approach to considerations of time and space (Hanley, 2001). Valuation and the general CBA logic presume the ability to overcome the substantial levels of uncertainty and complexity associated with water management decisions – for example, assessing the intricate interactions within aquatic ecosystems when assessing desalination impacts (Hanley, 2001; Hanley and Spash, 1993).

CBA approaches can give a false sense of certitude about option outcomes and may in fact be misleading given incomplete knowledge about the extent, significance and probability of impacts – information which is an essential pre-requisite for robust valuation estimates (Alam, Rolfe and Donaghy, 2008). This danger is intensified when ongoing valuations are presented as a comprehensive and accurate representation of all costs and benefits in full-blown CBA. However, problems in predicting the full extent of impacts plague all sustainability analysis for informed decision-making.

The challenges faced from complex interdependence, and attendant prediction and measurement, are not just restricted to the ecological realm that surrounds the "anthroposphere". Although there are many input-output, computable general equilibrium and other models and accounting systems describing economic (and social) interdependencies, human systems are incredibly complex. It is very difficult to predict actual output-welfare changes from projects. Just some of the contingencies include dynamic and varied input-output relations, dynamic returns to scale, very substantial technological spill-over effects, general equilibrium effects, and unknown future technological innovations. This uncertainty is increased when complex ecological impacts and feedback loops are also reiteratively connected to the economy[8].

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[8] The theoretical and methodological development required to understand and assess economy-ecology-social links is proceeding rapidly with contemporary research into multi-regional input output analysis with environmental extensions (Wiedman *et al.*, 2011).

B. Many sources of potential error in assessing individual's preferences and valuation based on what they would trade-off for less or more external costs and benefits of some intervention

This general source of inaccuracy in moving from the initial identification and quantification of externality effects to their monetary measurement is closely related to the pervasive problem of incomplete information in A (above).

It is important to emphasise that all dollar values intended to represent the magnitude of externality effects are based on measures of trade-off choices by the individuals affected. They are often measured as "willingness to pay" (WTP) or "willingness to accept" (WTA) compensation approaches that are intended to capture how much people trade-off, or state that they would trade-off, for changes in cost and benefit patterns – thus producing a measure of relative worth or value. However, there are many difficulties in assessing an individual's true "trade-off" value in stated preference and market or revealed preference methods.

Accurate measurement of the monetary values intended to represent how people value and would trade-off various goods and services (given their costs and benefits) is jeopardised by several problems including: (1) lack of information about, and misspecification of, the "good and service bundles" being assessed or traded-off; (2) distortions in the market prices used in assessing trade-off values; and (3) sources of bias in selecting trade-off values (especially if the trade-off is hypothetical or has not yet occurred). These problems also tend to be related, and together they form many of the major limitations of specific economic techniques for valuing externalities. For example, there are problems with eliciting accurate representations of what people would actually trade-off from a hypothetical stated value that does not have to occur – especially when they know that the value they state may influence outcomes in their favour (strategic bias). There has been a great deal written on the specific caveats of individual economic valuation techniques and the reader is referred to Eshet *et al.* (2006), Goodstein (2005) and Tietenberg (2006) for examples of comprehensive overviews.

Clearly, a central problem in trying assess and measure the relative value of alternatives, as dollar values equating to trade-off situations of "indifference", is uncertainty and ignorance from incomplete information. People do not know the full biophysical, economic and social consequences of their choices. This includes the direct effects of choices upon themselves, and also the indirect flow-on effects they will feel back from the changes their actions have upon society and the rest of nature. Note that, with this limitation, we are restricting the focus to the link between choices based on anticipated trade-offs, and what outcomes actually occur – not how these outcomes actually affect people's psychic and subjective state of well-being ("happiness"). This later relationship is discussed in limitation E.

Some forms of market failure that may distort optimal trade-off choices are an uncertain mix of incomplete information about outcomes, benefits and costs and their associated risks, and simply a clash between seemingly irrational individual choices and societal preferences ("people don't know what is best for them" e.g. tobacco smoking, alcohol (over-consumption), car seat belts).

Another source of error in identifying the full set of values based on anticipated or actual trade-offs is that a substantial portion of the people we want to include in the goal of maximum community welfare – namely, future generations – do not exist, We have no way of knowing their preferences and future supply and demand, and the natural and social environmental conditions appropriate to them. Current market prices or trade-off values tend to only reflect existing knowledge, preferences and near-term supply and use structure and patterns. Few studies are also capable of identifying the full of scope of intra-generational values in terms of the preferences, willingness to pay and trade-off valuations of the world community (affected by interventions) outside their immediate study confines.

These valuation inaccuracies are further compounded by the existing price distortions from market failures in addition to incomplete or asymmetric information about the full costs and benefits of economic transactions and environmental externalities. Other market failures include imperfect competition, public goods and property rights issues (which are related to external cost and benefits), and many other externalities (notably technological spill-overs, and dynamic economies of scale and scope).

Identifying good trade-off measures (and hence value) is also closely linked to the complications associated with addressing the equity implications of external impacts, and in attempting to aggregate estimates of individual's valuations (as revealed in market prices and WTP and WTA analyses). There are ways of attempting to adjust for differences in the pattern of costs and benefits, and "ability to pay", often by weighting changes in proportion to income or wealth levels (Brent, 2009). However, a less obvious but very challenging problem is that ability to pay, and the past distribution of income, has had very substantial effects in setting (and arguably "distorting") the market prices used as the basis of production, proxy market and other revealed preference approaches.

Finally, there is also the general limitation that benefit transfer values expressing trade-off values are context-specific (in both a socioeconomic and geographical sense) and vary widely in magnitude (Brent, 2009). Hence, they are often inappropriate or potentially misleading in application to different project setting.

C. Difficulties in summing trade-off values (the aggregation problem) and related issue of taking into account and managing distributional and equity impacts

Even if we assume that there is comprehensive information available about the trade-off values preferred for existing and future individuals for whom we are trying to maximise welfare, formidable problems remain in summing these trade-offs to arrive at overall levels of "value" to society. This is a weakness for individual external effects, but is intensified amidst the increased levels of aggregation pursued in full CBA in its quest for overall project evaluation indicators such as "net social benefit" or benefit-cost ratios.

Integral to CBA is the utilitarian concept of Pareto improvement. The Paretian improvement logic suggests that: (1) for every decision, there will be winners and losers; and (2) if the winners gain more than the losers lose, then the project leads to overall societal benefits. Hence, a project that leads to a Paretian improvement indicated by CBA would represent a 'good' decision from society's point of view and would simply require some acceptable redistribution of net benefits. This logic is subject to much contention surrounding the assumption that the benefit or loss of one person can be added to the benefits and costs of another – a common criticism being that the monetary values for individuals (intended to represent utility and hence welfare) are incommensurate and not have transfer and aggregation equivalence. This is the longstanding problem of aggregation in the utilitarianism basis of neo-classical economics. It depicts the public interest and general welfare as simply an aggregate of individual utility from goods and services. Again, there is an overlap with the other limits here as trade-off values, based on existing prices as measures of relative scarcity, may be significantly distorted by the existing distribution of income and neglect of relevant externalities. There are also many ethical concerns with the aggregation process in terms of its consequences for distributive justice, individual liberty, and democratic institutions (Frankel Paul *et al.*, 2010).

With the goal of aggregation, there are the difficulties in incorporating distribution and equity outcomes of projects studied. There is a strong argument that a wealthy person will receive less utility from an additional dollar expenditure than for a poor person (Dobes and Bennett, 2009). This phenomenon of diminishing marginal utility is widely embraced in mainstream economics and presents many challenges in assessing aggregate welfare change. CBA, CEA and other approaches can use equity weightings that vary according to the income, wealth or other target criteria for affected socioeconomic groups.

D. Trade-off choices identified for individuals or society, in valuation processes, may not be socially or culturally acceptable

This is a strong point of criticism against ascribing monetary values to externalities and is often the catchcry for antagonists that rest their case upon an almost intuitive sense that some things in life are simply not "up for sale" and any effort to attribute value will be sorely misguided. In reality, such a condition would be, at least partly, the result of the problems associated with information, trade-off value assessment, aggregation, and inaccurate market price equivalents noted in the previous points.

Some of the popular sources of social benefits and costs that are often considered off-limits to valuation include ethical issues, aesthetic issues, the arts, historical and cultural resources, other irreplaceable and unique resources and assets, actions guarded by profound spiritual beliefs; quality of life, life itself, health, safety, law and order, employment, education, posterity, national pride, life-support functions of nature, highly interdependent and critical ecosystem services, community, and a sense of belonging. If trade-off and monetary values are derived for individuals (using economic valuation techniques) then there is a perceived dissonance between individual and collective preferences[9].

Examples where cultural beliefs and ethics might be at odds with calculated individual, and hence summed, trade-off values would include: (a) features of immense spiritual significance to minor groups within society; (b) cultural or religious settings where individual preferences are not considered basis for overall societal choices; (c) the value of life; and (d) the existence of major biodiversity areas or climate change impacts that are known to be of immense value by experts but not recognised or are fraught with public good or global tragedy of the commons issues so as to distort individual choices. These are all difficult situations that do not sit well with the valuation approach and its grounding in the ethical and democratic predispositions of Western socio-cultural systems.

Pareto improvements may be seen as unjust or simply wrong in view of underlying ethical principles. For example, killing or letting those die with a serious contagious disease many reduce overall life and health losses, but many would see this action as unacceptable on ethical grounds. Hence, whilst CBA may be able to mathematically identify options which generate maximum net benefit, it cannot fully account for socio-cultural acceptability and other ethical issues.

Other sources of convergence between summed individual preferences and collective views and sanctions might include the existence of complex interdependence and holism in the systems affected. Again, major contributors would include a lack of information and awareness so that individuals are misinformed, and the fact that future generations are simply not represented in the valuation process. Other problems stem from inappropriate selection and application of market price data to represent the value and impact of an action – for example, the value of medicine or dollars earned as proxies for quality adjusted life years (QALYs) or value of life.

While it is true that some aspects of socio-cultural life will be very difficult to value, wherever there is scarcity there are only two possible general options – reduce the perceived need for the welfare gain driving development, or consider and make optimal decisions regarding the trade-offs involved[10]. Societal trade-offs on many of the "scared" issues, such as health and the value of human life, are actually made every day in most societies – for example with public and private health expenditures and allocation. For example, preferences for pet health expenditure over tax increases to fund human health care. Arguably, the trade-off and valuation approach is often considered as objectionable because it is making some of these choices explicit where denial and implicitness is more reassuring.

E. Money values are a poor measure of welfare or well-being change

The ability of derived monetary values to represent accurate changes in well-being stem from the limitations encountered throughout the entire methodological chain, beginning with identifying the full extent of external impacts, to estimation of trade-off and market price values, to imputing these measures as true indicators of actual changes in welfare or well-being.

The problems are closely related to many of previous issues such as the fact that the values of existing market goods and services and externalities are distorted by ability to pay and create problems in

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[9] This view might be depicted as the obverse of methodological individualism.
[10] A focus upon technological innovation for eco-efficiency gains and impact reduction would also be a laudable response.

effective utility aggregation. However, a major difficulty arises from a variant of the condition of incomplete information – arguably, people often have a "false theory of happiness" or well-being. This relates to the situation where their choices are based on erroneous cost and benefit structures or they do not accurately predict what the cost and benefits of their choices will be either because they don't know full consequences of their actions or they just predict the welfare impact incorrectly even if they do know the consequences (for example, when additional money provided as compensation to replace lost environmental amenity services does not provide the expected increase in well-being to offset the environment loss).

In consumer society, there appear to be limited recognition that individual, personal "utility functions" are strongly affected by the well-being of others. Lack of knowledge and uncertainty regarding complex and holistic outcomes would encourage the restriction of decision criteria to myopic, selfish and short-term thinking in predicting welfare gains. The interdependent nature of links between consumption and well-being is reflected in phenomena such as positional or "status" goods (which lead to limited well-being gains despite increased resource use) and the diseconomies of wealth (for example, the impact of inequality and crime on personal freedom and wellbeing). Furthermore, the capacity for "consumers" to learn and improve their ability to link consumption and lifestyle choices to actual well-being often seems limited, and is undoubtedly influenced by debt, the "treadmill" of production and consumption, and addictive behaviours in the face of the perception of limited alternatives to achieve well-being improvements. Manipulative consumer and advertising media, vested economic interests, and inflexible economic and social structures and built environments would also tend to perpetuate the spurious assumed nexus between income, expenditure and trade-off based value information in general, and well-being. These issues are related to the limitations in B above.

In addition to problems in linking trade-off choices to true well-being change, there are also many critical areas of people's subjective well-being that are not effectively measured with existing valuation methodologies. Examples include pain, suffering, comfort, social belonging or dislocation, anomie (lack of meaning) and ennui (tedium, boredom, lack of stimulation).

When people are unsure of the well-being or "happiness" to be derived from known trade-offs (gains and losses), their preferences can be seen as unreliable or unstable. This is a serious violation of the assumptions of neo-classical microeconomic price theory which links price to utility (and well-being) and the best allocation of resources in society's interest. However, it is plausible to believe that understanding of the choice ⇔ well-being relation will change (hopefully improve) over time with learning and experience by individuals and society.

F. The significant financial and time resource costs of effectively completing economic valuations of externalities

Benefit transfer techniques, with informed adjustments, can certainly help provide substantial resource savings in the estimation of economic values for project externalities. This is enhanced with:

- the ready availability and accumulation of data in relevant valuation infobases such as EVRI and ENVALUE (as discussed in the companion report (Daniels *et al.,* 2012)); and
- the growing sophistication, accessibility and power of TBL data linked to economic activities at regional (sub-national) scales in environmental input-output and input-output analysis and life cycle assessment databases.

Of course, accurate primary data tied to local study contexts is still ideal.

2. Additional Weaknesses with Extending Externality Analysis to a Full CBA Approach

As externality analysis is an essential component of CBA, the full CBA approach will be subject to all of the limits of externality analysis reviewed in the previous discussion. On the other hand, CBA does have the immediate advantage of providing single indices intended to represent the total net present benefits of the intervention under study. This has the appeal of being able to compare overall, summary performance measures of the project alternatives and appears to transcend the potentially fragmented nature of externality valuation analyses that do not proceed beyond measures for individual effects.

Many of the additional limitations of full CBA are derived primarily from the process that generates its apparent advantages – the more extensive aggregation of monetary values into a single measure and the ongoing related use of overall net present values (benefits minus costs), benefit-cost ratios, rates of return on investment and related indicators. These measures are often presented, at least implicitly, as recommendations for decision-makers. This extra aggregation step can exacerbate all of the informational, uncertainty and valuation problems in externality analysis and introduces a number of extra caveats. For example, combining fairly robust market data on likely production output change with more contentious values of long-term option values reflects how this process can lose sight of the very substantial variability in the accuracy and reliability of individual effect estimates.

Aggregation across all externalities also masks the inevitable omission of estimates for many of the total economic values likely to be impacted by interventions. CBA presented as a concise solution set gives the illusion that all effects have been effectively and accurately covered. Increased aggregation in CBA further obscures equity implications of interventions and restricts the detail available in undertaking subsequent sensitivity analysis. These factors all promote the rather blind application of aggregate CBA for project selection criterion.

Discounting is an element of valuation which has been heavily criticised. The discounting rate will have crucial impacts on the overall 'sustainability of water management decisions' (Birol *et al.*, 2010, p.839). Adopting 'best-practice' rates is often a controversial move as most often discount rates (that is, higher positive discount rates) which favour decisions with high *short-term* benefits are chosen (Hanley, 2001, p.110). As a consequence, inappropriate discounting rates can undermine key sustainability principles of long-term planning and intergenerational equity (Birol *et al.*, 2010). They do this by making the net short-term benefits of a certain action relatively greater (Spash, 1994).

The problems of the selection and use of (often a single) discount rate across all natural resource impacts are deepened by lack of information about the preferences, willingness to pay and trade-off valuations of future generations (Spangenberg and Settele, 2011). Most of these difficulties also apply to the simple externality valuation restricted to individual effects when, as is common, impacts are distributed across significant time spans. However, full CBA is more likely to apply a single discount rate across all different types of externality effects and natural capital without regard for how critical they are. Simple externality analysis has greater transparency and facilitates analysis based on the substantial variation that will be likely in social preference "discount" rates for different natural resources.

Within the field of ecological economics, there are increasing calls for discounting methods which seek to incorporate inter-generational equity (with low rates so as to favour longer-term benefits). Some economists promote the adoption of a zero or negative rates or the use of inter-generational transfer or social time preference amounts (based on the current generations WTP for future generations to benefit from a natural resource), or the critical time rate (which measures implicit profits generated from the environment and incorporates this into the rate used (Birol *et al.,* 2010; Sáez and Requena, 2007; Weitzmann, 2009)).

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