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Title: Sustainability – Why is it way beyond the Triple Bottom Line?
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Abstract

Research into improving the sustainability of urban water management systems at the site level within an engineering context has revealed that this is impossible without regional level guidance on site level outcomes necessary to address specific threats and risks to the sustainability of water supply, wastewater and stormwater services within the city as a whole. Without such guidance, actions at the site level can only be directed to reducing contributions to the Tragedy of the Commons by improving hydrological efficiency and environmental performance. The sustainability of critical infrastructure systems and processes cannot be addressed through the application of generic sustainability principles and/or the consideration of Triple Bottom Line impacts at the site or project level. Extensive, coordinated, integrated, multi-disciplinary and context specific planning approaches are required at the regional level to identify threats and risks to the sustainability of critical systems and processes, and paths of action to address them. These findings support the philosophy behind current research into the long term planning for the sustainability of human cities.

Introduction

This paper presents the findings and conclusions from a research project which aimed "to further the current state of thinking and practice in New Zealand stormwater management, and to promote the application of sustainable principles in the design of urban water management systems". The research for the project was undertaken for the degree of Master of Engineering at the International Centre for Sustainability Engineering & Research (ICSER) at the University of Auckland Faculty of Engineering. The project was carried out for Harrison Grierson Consultants Ltd and funded through a Technology for Industry Fellowship (TIF) grant from Technology New Zealand.

The case study site was the Smales Farm Technology Office Park, a retangular site of approximately 10.9 hectares located adjacent to the Northern Motorway in Takapuna on Auckland's North Shore. It will be developed over the next 10 – 15 years and will eventually contain 16 buildings, extensive underground carparking, landscaped surrounds, and will have a working population of around 5,000 – 6,000 people. The proposed development is rather unique for a commercial office park in that only 49% of the land area will be used for buildings, roads and carparks, with the remaining 51% being landscaped grounds, creating a park-like atmosphere. Smales Farm is currently in the early stages of development with two buildings and temporary carparking located in the southern and eastern quadrants of the site. The remainder of the site is currently undeveloped and consists of pasture with a few small isolated trees.

Smales Farm is located in the lower part of the Wairau Valley catchment. There are no existing watercourses on the site and stormwater drainage is currently provided by a conventional reticulation system which drains to an open swale drain that runs alongside the Northern Motorway. The swale drain conveys runoff to the Wairau Creek channel and eventually discharges to the coastal environment at the Milford Marina, approximately 2km from Smales Farm. Wairau Creek has been heavily modified from its natural state and is now essentially just a concrete channel to the sea.

The current design for the site proposes that stormwater servicing will be provided by a standard reticulation system to capture runoff from the building roofs, and the internal roads and carparks (Rollo, Wilkinson, & Leahy, 2003). Stormwater treatment will be provided by two underground settlement tanks which were designed in accordance with Auckland Regional Council's Technical Publication No. 10 (ARC's TP10) to provide 75% sediment removal efficiency. Each tank will service approximately half of the site and will discharge to the open drain adjacent to the motorway. This drain will eventually become an enclosed concrete channel as part of the development of the North Shore Busway, which will run alongside of the Northern Motorway. The stormwater from the tanks will be used to supplement irrigation of the landscaped grounds. Due to the site's location in the lower part of the Wairau catchment, stormwater flows from the site will dissipate before the arrival of peak flows from further up the catchment and stormwater quantity control is therefore not required (Rollo et al., 2003). Due to the nature of the downstream channels, erosion control of stormwater flows is also not required (Rollo et al., 2003).

Original Project Approach

The project had two main objectives:

1. To develop a "more sustainable" water management system for the Smales Farm urban technology office park through the application of sustainability principles to stormwater management;

2. To document the process of development of this system in the form of a decision support framework to promote and assist the implementation of sustainable water management systems on other sites.

The focus of the project was on the stormwater management system and how it could be integrated with the water supply and wastewater services to improve the overall sustainability of the water management system on the site. For health and regulatory reasons, on-site recycling of water for potable re-use and sewerage servicing were excluded from the scope of the project.

The original project methodology was developed from a literature review of similar projects (Balkema, Preisig, Otterpohl, & Lambert, 2002; Chanan, White, Jha, & Howe, 2003; Christov A-Boal, Lechte, & Shipton, 1995; Hellström, Jeppsson, & Kärrman, 2000; Hiessl, Walz, & Toussaint, 2001; Hoffmann et al., 2000; Jeppsson & Hellström, 2002; Lundin, 1999; Lundin & Morrison, 2002; Lundin, Sverker, & Morrison, 1997; Maheepala & Zoppou, 2000; Mitchell, 2002; Mitchell et al., 2002; Ravetz, 2000; Rijsberman & van de Ven, 2000; van Moeffaert, 2003; Weigert & Steinberg, 2002). The first three steps were a review and analysis of current thinking on the concepts, definitions, principles and methods for the assessment of sustainability, the identification of objectives and constraints for Smales Farm, and the development of sustainability criteria against which various design options could be tested. The next three steps were developing a base line design for the site (basically the proposed water management system already described), developing a range of "more sustainable" options, and then undertaking preliminary designs to gather the relevant information for each option. The final two steps of the project were an assessment of the sustainability of the various options against the previously identified sustainability criteria, followed by preparation of a Decision Support Framework documenting the project methodology and results. This methodology is typical of engineering investigative procedures where a range of options are assessed against pre-defined criteria to determine the preferred option. However, the analysis of the findings from the initial literature review led to several important conclusions with significant implications regarding the validity of this approach for addressing sustainability.

Literature Review and Analysis – Findings, Conclusions and Implications for the Project Methodology

Because the proposed project methodology relied upon the application of sustainability principles to guide the identification of sustainability criteria and "more sustainable" options for stormwater management on Smales Farm, a key focus of the background research was on identifying commonly agreed principles for sustainable urban water management. However, it was discovered that just as there are a great many similar but different definitions of the concept of "sustainable development" (Murcott, 1997a; Royal Melbourne Institute of Technology, 2000) there are also a great many similar but different sets of sustainability principles (Murcott, 1997b). Even with regard only to the concept of sustainable urban water management the number of different sets of sustainability principles identified was extensive (Expert Group on the Urban Environment, 1996; Grotter & Otterpohl, 1996; Heaney, Pitt, & Field, 1999; Hellström et al., 2000; James, 1999; Lawrence, Ellis, Marsalek, Urbonas, & Phillips, 1999; Loucks, 2000; Lundin, 1999; Mitchell, 2002; Mitchell et al., 2002; Parliamentary Commissioner for the Environment (PCE), 2001; Weigert & Steinberg, 2002; World Meteorological Organisation, 1992).

Although there were similarities between them, every set of principles was different not just in terms of the scope of the principles, but also in terms of the strength of the language used. This presented difficulties when any attempt was made to use them as a means of identifying sustainability issues on Smales Farm. It was concluded that sustainability issues cannot be adequately identified simply by applying some generic set of principles in any or every situation. Sustainability principles can potentially guide more sustainable actions at the individual or site level in certain circumstances, but they should not be viewed as strict rules to be followed when designing a specific solution in any situation. Rather they should be viewed for what they are, which is generalised statements of essential outcomes and actions that must be achieved at regional and global levels and across the breadth of human society for the long-term sustainability of the global human community. Indeed, by their very nature most sustainability principles are simply too broad to allow the identification of specific sustainability issues or to guide actions to address them in any situation. Their application and relevance for this purpose is limited by the influences and constraints of the specific situational context, the constraints associated with scope of consideration (which is frequently too narrow to address many of the wider issues), the difficulties and uncertainties which arise due to the complexity and dynamic nature of the surrounding human and natural systems, and uncertainties over the timeframes that must be considered.

In addition, consideration of sustainability principles alone is not sufficient to justify alternative courses of action in any and every situation, especially in the face of significant societal, economic, political and institutional constraints. Simply because an alternative course of action has the potential to uphold or work toward a sustainability principle does not override the need for the real world justifications required for implementation, particularly those of economic viability, regulatory compliance, and stakeholder satisfaction. Furthermore, taking action in accordance with sustainability principles is no guarantor of sustainability, or even of viability, in the face of significant systemic and temporal uncertainties.

In light of these findings it was concluded that reliance on the application of generic principles to identify issues with respect to the sustainability of water related services on Smales Farm was a rather irrational and unstructured approach to problem framing. Engineering is a process of providing specialised solutions to problems and involves the identification of specific issues to be addressed (problem framing) and the development of a solution or solutions to address those issues (problem solving). The application of sustainability principles alone is not sufficient to ensure identification of all or even the critical sustainability issues that need to be addressed. If the resulting decision support framework from the project was to be used by engineers on future projects, the approach to identifying sustainability issues would have be more structured as part of the normal problem framing and problem solving processes that engineers use.

The original project proposal also did not take into account the need to justify why alternative stormwater management options should even be considered, or why they should be implemented. It was assumed that the application of sustainability principles and the outcomes of the sustainability assessment process (which was to incorporate economics) would be sufficient justification. However this is not the case in the real world where options have to be presented and justified to clients. Certainly, where there is no regulatory requirement or incentive to adopt more environmentally or socially conscious options over cheaper, more conventional options, there appears to be little justification to do so from the client's perspective. This issue was quite significant on Smales Farm where the environmental or social benefits of implementing any alternative options would be very minor or even indeterminate.

Because the project methodology intended to use sustainability assessment techniques to assess the existing stormwater management design and the "more sustainable" alternative options against a range of sustainability criteria, the background literature review also focussed on current thinking and approaches in these areas. Much effort is currently being expended around the world in the research, development and testing of sustainability criteria and indicators, and methods for the assessment of sustainability (Bossel, 2000; Buselich, 2002; Calderón, 2000; Cornelissen, van den Berg, Koops, Grossman, & Udo, 2001; Gibson, 2002, 2003; Guijt & Moiseev, 2001; Hardi & Zdan, 1997; Hellström et al., 2000; Hiessl et al., 2001; Hoffmann et al., 2000; International Institute for Sustainable Development, 2000;

Jeppsson & Hellström, 2002; Lundin, 1999; Lundin & Morrison, 2002; Lundin et al., 1997; Maheepala & Zoppou, 2000; McDonald, Creighton, & Erlanger, 2000; Mitchell, 2002; Mitchell et al., 2002; Parris & Kates, 2003; Ravetz, 2000; UNESCO Working Group M.IV, 1999; Weigert & Steinberg, 2002). In general most approaches to sustainability assessment involve:

1. Development of some form of guiding vision and objectives for sustainability that are specific to the policy, plan, project etc under consideration, and specific to the local systemic context. The vision and objectives are commonly agreed by stakeholder consensus;

2. Determining criteria which represent achievement of the objectives. The objectives and criteria are generally specified in terms of the three spheres of sustainability (i.e. economic, social, environmental);

3. Selection of indicators as a means of measuring performance with regard to each of the criteria and objectives;

4. Collection of data and quantification of the indicators;

5. Analysis of the indicators to determine a measure of sustainability. In some cases the various indicators are aggregated to give economic, social and environmental indices of sustainability, or even a single combined "sustainability" index.

The proposed methodology for the Smales Farm project was originally modelled on this type of approach. However, there are a significant number of issues with this approach:

- There is a significant focus on only negative social, environmental and economic impacts (Gibson, 2002);

- Although most assessment techniques attempt to assess impacts in multiple spheres (e.g. environmental, economic, social, cultural), they do not integrate the assessment across these spheres (Buselich, 2002);

- Sustainability assessment practices are not integrated with project development and decision-making processes, but are rather "tacked on" as an extra activity, frequently to comply with regulations (Buselich, 2002; Gibson, 2003);

- The focus on openness and participation, and particularly the desire for stakeholder consensus when agreeing on the guiding vision and principles of sustainability, introduces significant practical difficulties (Parris & Kates, 2003) and does not really challenge existing paradigms of thinking. It is a weakness in existing assessment methods because it allows the views of powerful stakeholders with significant interests in the status quo to control the assessment process.

- There are significant problems with the use of quantitative indicators for sustainability assessment, particularly their over-simplification of the responses and interactions of highly complex human and natural systems, and their inability to handle the complexities, uncertainties and indeterminacies associated with the functioning of those systems (Bell & Morse, 2001; Kelly, 1998) (see below); the confusion that can result from the attachment of multiple different values and interpretations to the same indicator (Ravetz, 2000); the lack of relevance of chosen indicators to the needs of decision-makers (Parris & Kates, 2003); and the difficulties in measuring qualitative information such as community values and feelings (Bell & Morse, 2001; Buselich, 2002);

- Most assessment methods also lack provision for the inclusion of fundamental sustainability principles, particularly the application of the Precautionary Principle (Buselich, 2002).

There is no disputing that existing "sustainability assessments", or "sustainability-based assessments", as they are more appropriately called by Buselich (2002), are a significant advancement over previous, narrowly focussed, solely economic or solely environmental assessments (Gibson, 2002). However, the assessment of impacts, no matter how integrated across the Triple Bottom Line (i.e. across environmental, social and economic spheres), is not an assessment of sustainability. While the impacts of an activity on the surrounding human and natural systems may have a bearing on the ability of that activity to be continued into the future, they are not the only factors. Limiting the focus of the assessment only to social, environment and economic impacts is too restrictive if the real sustainability issues are to be identified.

It is also doubtful whether existing assessment techniques are even capable of measuring the full nature and extent of the impacts they purport to assess. With their focus on the assessment of impacts, the measurement of indicators and evaluation against pre-defined criteria, existing techniques of sustainability assessment are heavily grounded in the prevailing paradigm of scientific endeavour, which is based on the pursuit of rational knowledge through reductionism, repeatability and refutation (Checkland, 1976; Emblemsvåg & Bras, 2000; van Gigich, 1979). However, natural and human systems, the interactions between them, and their responses to human induced impacts are highly complex, which presents difficulties when one tries to quantify sustainability using existing assessment techniques. The issue of complexity arises because the number of component parts is large, their interactions are complex, the quantity of information required to make sense of the complex systems will be significant and the information will be, in part, subjective, and there will be uncertainties due to incomplete information (Geldof, 1997). The problem is that the rational, reductionist paradigm of scientific endeavour is inadequate for understanding the functioning, responses and interactions of highly complex human and natural systems which exhibit emergent, counter-intuitive and frequently unpredictable properties (Allen, 1988; Emblemsvåg & Bras, 2000; Goodwin, 2001; Hardi & Zdan, 1997; Kay, Regier, Boyle, & Francis, 1999; van Gigich, 1979). Many of the aforementioned difficulties and issues which have been identified in the literature on sustainability assessment stem from the fundamental inadequacies of the scientific paradigm within which current approaches to sustainability assessment are grounded.

In light of these findings, and given that a key objective of the Smales Farm research project was to address sustainability, the use of Triple Bottom Line assessment techniques was not considered appropriate. In addition, due to the nature of the development on Smales Farm and the location of the site in the lower part of the Wairau catchment, the quantifiable significance of any environmental, social and economic impacts would be very small or even indeterminate between the alternative stormwater management options without a detailed design of the options. In particular, actual environmental or hydrological impacts would be minor because of the nature of the downstream environment. Also the techniques covered in the literature review are simply too complicated, data and time intensive, and too expensive to be considered as a practical tool for engineers to use on an everyday basis, except perhaps for the assessment of large projects where the budget and personnel are available. There was thus little point in using such assessment techniques if they are unlikely to used by engineers in the future for these reasons.

A New Approach to Identifying Sustainability Issues

The overall conclusion was that sustainability could not be addressed using the original project methodology. A more rational and structured methodology for identifying sustainability issues was subsequently developed from the risk-based planning approaches of Boyle (2004) and Tonn (2004). Their work has focussed on planning for the sustainability of human cities in the very long term (e.g. 1000 years). It is concerned with identifying events and scenarios which could pose threats to the sustainability of critical systems and processes within human cities, and attempting to determine the probability that these threats will actually eventuate (Boyle, 2003, 2004; Tonn, 2004). Over such long time frames the actions of the present generation must be seen in a new light, particularly where they may threaten the very existence of humans on earth (e.g. the destruction of tropical rainforests) or where they may conflict with physical, geological or environmental limits thus threatening the provision of critical needs in the future (Boyle, 2004; Tonn, 2004). The consequences of an event or scenario that could threaten the functioning, development or even existence of a city would be so severe that it is desirable that such an event should never occur. Actions must be taken to eliminate or minimise the probability of such an occurrence. Unfortunately, for many such threats it may not be possible to reduce their probability of occurrence. Indeed recent publications have surmised that there are several such threats looming on the horizon in the very near future, including the problems of declining oil supplies within 5 – 10 years (Swinney, 2004), abrupt global climate change within 10 – 20 years (Schwartz & Randall, 2003) and global biodiversity loss within 50 years (Thomas et al., 2004; University of Leeds, 2004). In such cases actions must be focussed on dealing with and minimising the severity of the consequences of these events.

Because of the very long term focus of these planning approaches, they are concerned with threats to the sustainability of whole human cities and societies. They do not focus on sub-systems or processes within those societies or settlements because over such extremely long time frames the nature of human societies and cities, and their populations and technologies is impossible to predict. It is simply assumed that these societies will exist and that they will continue to have certain critical needs such as food, water, materials and energy. The focus of the long term planning is not to determine how these needs can be met in the future, but rather ensuring that they can be met at all.

However, many cities around the world are already facing threats to the sustainability of these critical needs, or will be facing such threats in the very near future. For example the provision of fresh water and the management of water pollution are critical issues around the world (Cosgrove & Rijsberman, 2000; Gleick, 2000; Simonovic, 2002; World Water Assessment Programme, 2003). In Auckland the provision of aggregate for construction is a becoming a major issue because most of the high quality aggregate sources in the Auckland metropolitan area have been either exhausted or eliminated through urbanisation and environmental restrictions, requiring that high quality aggregate for roading, construction and concrete be supplied from sources north of Albany and south of the Bombay Hills (Christie, Thompson, & Brathwaite, 2001; Happy, 2001; Riley, 1996).

It is therefore necessary that long term planning approaches should be complemented with similar risk-based approaches to planning in the shorter term to address the issue that significant threats to the sustainability of important systems and processes within our society will arise in the relatively near future. The sources of these threats are the inefficiencies inherent in our current technologies, production processes and infrastructure systems, and the escalating costs and logistical difficulties associated with meeting ever increasing demand with increasingly scarce resources and overstrained infrastructures. Quantitative short-term planning is therefore necessary to allow the nature of the supply / demand conflicts to be quantified, to allow costs to be assessed, to predict timelines for the occurrence of threats, critical break points and deadlines for actions, and to allow specific actions to be identified to change current ways of doing things.

From this perspective it is clearly evident that sustainability is not something that can be addressed at the level of an individual or on a single site or within a single development. The sustainability of any activity or process cannot be assured at the site level alone because the site must be considered within the wider context of a sustainable society. With regards to water management on Smales Farm the sustainability of the water supply, wastewater and stormwater services on the site is entirely dependent on the sustainability of the centralised regional water supply and wastewater reticulation networks, and the stormwater system within the Wairau catchment. If any of these systems were to cease functioning at the regional level then so too would the systems on Smales Farm. This realisation was further clarified by a qualitative assessment of threats and risks to the sustainability of water related services on Smales Farm. The structure of the assessment was derived from Boyle (2004) and Tonn (2004), as well as the work of Bossel (2000) who identified that when addressing the sustainability of any system or process it is necessary to consider two aspects:

1. The viability or performance of the specific activity, system or process under consideration; and

2. How the specific activity, system, or process affects or contributes to the viability and performance of other human and natural systems and processes.

Adapted from: (Bossel, 2000)

Consequently the assessment sought to identify:

1. Factors which threaten the viability or performance of the water management system on Smales Farm, or the sustainability of the regional water management systems; and

2. Factors stemming from the construction, operation, maintenance, upgrading or replacement of water management systems (both at the site and regional levels) which threaten the viability or performance of other human and natural systems and processes.

The assessment looked for factors originating at the site level (i.e. within Smales Farm), and factors originating external to the site. It also attempted to determine the root causes of the threats, how they threatened sustainability, and an indication of the magnitude of the associated risks.

Key Findings & Discussion

The main finding of the assessment was that specific risks to the sustainability of the water related services on Smales Farm stem from threats to the regional systems of water supply, wastewater and stormwater management, not from any particular factors on the site itself. Threats to the regional systems in Auckland include possible water restrictions as demand exceeds supply; increased costs associated with managing increasingly complex infrastructure; increased costs for the operation, maintenance, upgrading and replacement of water related infrastructure; increasing probability and consequences of system failures due to increasing complexity; the possibility of system failure due to energy restrictions as a result of the decline in oil supplies; escalating operational costs due to rising energy costs; and increasing susceptibility to droughts and extended dry periods coupled with the possibility that droughts and extended dry periods may become more common as a result of global climate change.

These are not issues that can be dealt with at the level of an individual site and must be addressed across the entire Auckland region through a structured planning process such as that already described. Only when these threats have been assessed across the whole region to determine the level of risk associated with each, can actions be taken to address them. Guidance is required from the regional level to direct actions at the site level as to the types of outcomes that are required (e.g. water use efficiency targets, the use of new or alternative technologies and the implementation of alternative water management methods).

Threats to other human or natural systems and processes originating from Smales Farm itself amount only to minor contributions to environmental impacts (e.g. quality and quantity impacts of stormwater discharges on the coastal environment at Milford), and contributions to the increased demand on the regional water supply and wastewater systems. On their own these impacts are insignificant. They are contributions to what is known as the tragedy of the commons (Hardin, 1968). It is only when all the site level contributions or impacts are summed across the whole Wairau catchment or across the whole of the Auckland Region that they become significant; e.g. the stormwater quality or quantity impacts on the coastal environment at Milford from Smales Farm alone are insignificant, whereas the combined impacts from the whole of the Wairau catchment are very significant. There has been some attempt to manage environmental (and social) impacts at the regional level, and site level actions are guided by the Auckland Regional Council's Air, Land & Water Plan, and also by the Resource Management Act. However, in the same way that Triple Bottom Line assessments do not assess sustainability, actions taken in accordance with these regulations do not address specific sustainability issues, but rather environmental and social impacts.

This distinction is significant. The sustainability of critical systems and processes such as water supplies, wastewater treatment and stormwater management (and other essentials such as transportation, energy supplies, construction, food supplies) cannot be addressed by uncoordinated incremental changes at the site level, or by focussing only on social, economic or environmental impacts alone. Extensive, coordinated, integrated and context specific planning approaches are required at the regional level to identify and address threats and risks to the sustainability of such systems and processes, and the courses of action that are required to eliminate or reduce the risks to acceptable levels. In the absence of guidance from the regional level, there is little that can be done within the scope of a single project, development or site other than to reduce contributions to the tragedy of the commons. On Smales Farm this could be done by making general improvements to hydrological efficiency and environmental performance and a range of options was therefore investigated to reduce stormwater runoff, improve stormwater treatment, and to reduce the demand for potable water by capturing and using stormwater runoff to supplement the irrigation needs on site. The results of these investigations are not reported here.

Conclusions

The main conclusions from the Smales Farm research project were:

- Sustainability issues cannot be identified through the application of generic sustainability principles in any situation. Sustainability principles are too broad and non-specific to identify issues and guide specific action at the site level;

- Taking action in accordance with sustainability principles does not guarantee sustainability;

- Taking action in accordance with sustainability principles is not sufficient reason within itself to justify alternative courses of action in the real world;

- There are significant issues and barriers to the use of sustainability assessment techniques by engineers as an effective decision-making tool on an everyday basis;

- Triple Bottom Line assessments, no matter how integrated, do not actually assess sustainability, but rather impacts. Focussing only on environmental, social and economic impacts is insufficient to address sustainability;

- It is difficult, if not impossible to meaningfully identify and address sustainability issues at the site level, because of the interdependence with external human and natural systems;

- Extensive, coordinated, integrated, multi-disciplinary and context specific planning approaches are required to identify and address critical threats and risks to the sustainability of important infrastructure systems and citywide processes over short, medium and long term futures;

- Such planning must be carried out at the highest level sufficient to encompass the whole system or process (e.g. at the regional level). It is only at this level that the cumulative effects of individually insignificant site level actions can be assessed and any associated sustainability risks identified and addressed.

Future Directions

These conclusions represent a paradigmatically different approach to sustainability than the conventional Triple Bottom Line concept, and they have important implications for those who manage citywide infrastructure systems and processes. The sustainability of such systems and processes cannot be assured through triple bottom line assessments at the site or project level, or even at the regional level. Indeed, some sources of threats and risks to sustainability may have nothing at all to do with the environmental, social and economic impacts of the systems or processes in question. This does not mean that addressing triple bottom line impacts is not important. On the contrary, these impacts must continue to be addressed even more vigorously than they are now.

Rather the conclusions drawn from this research project serve to highlight the misnomer that triple bottom line assessments are synonymous with achieving sustainable development. Triple bottom line concerns are essential but are not the limit to what has to be done to tackle sustainability. Even in New Zealand, the threats and risks to the sustainability of critical infrastructure systems and the processes they support, and subsequently to the sustainability of our cities and our societies are significant. These are not long term risks that may or may not be encountered by future generations, they are risks that are faced by the present generation, and they will have enormous consequences for the way we live our lives. The kind of planning approaches presented in this paper are an essential way forward for identifying and tackling these risks, and they must be started now. The International Centre for Sustainability Engineering & Research is currently in the process of initiating several such planning projects with both government and non-governmental organisations in Auckland.

Implications for Engineers

Engineers have been told that they have a "tremendous responsibility in the implementation of sustainable development" (WFEO, 1997) because of their "unique capacity to address the priorities" (FIDIC, 2002). But engineers cannot tackle sustainability alone. It is well established in the literature on sustainable development that technological advances alone are insufficient to ensure sustainable development and that far reaching social, cultural, economic, political, legislative, regulatory and institutional changes are also required, collectively known as the eco-restructuring of society (Weaver, Jansen, van Grootveld, van Spiegel, & Vergragt, 2000). Until such eco-restructuring catches on, engineers are caught in a difficult Catch-22 situation where they are frequently blamed for society's problems and shouldered with the responsibility of fixing them, while at the same time society constrains their ability to do so. Beyond tackling triple bottom line impacts within the scope of a single project or development, there is little that engineers can do on an everyday basis to address specific risks to the sustainability of larger systems and processes. This requires planning for sustainability using the kind of approaches discussed in this paper. Because of their expertise, knowledge and roles in society, engineers must necessarily be part of (or even lead) such planning, but the issues which must be addressed extend far beyond the expertise of engineers alone, and thus require truly integrated and multi-disciplinary approaches:

> Because sustainability is a function of various economic, environmental, ecological, social, and physical goals and objectives, [sustainable development] must inevitably involve multi-objective tradeoffs in a multi-disciplinary and multi-participatory decision-making process…. no single discipline, and certainly no single profession or interest group, has the wisdom to make these tradeoffs themselves. They can only be determined through a political process involving all interested and impacted stakeholders.

From: (Loucks, 2000, p3)

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References

Allen, P. M. (1988). Dynamic Models of Evolving Systems. *System Dynamics Review, 4*(1-2), 109-130.

Balkema, A. J., Preisig, H. A., Otterpohl, R., & Lambert, F. J. D. (2002). Indicators for the sustainability assessment of wastewater treatment systems. *Urban Water, 4*(2002), 153-161.

Bell, S., & Morse, S. (2001). Breaking through the Glass Ceiling: who really cares about sustainability indicators? *Local Environment, 6*(3), 291-309.

Bossel, H. (2000). *Assessing viability and sustainability: a systems-based approach for delivering comprehensive indicator sets.* Paper presented at the Workshop on Integrated Natural Resource Management in the CGIAR, 21-25 August 2000, Penang, Malaysia.

Boyle, C. (2003). Sustainability Assessment: Assessing the Sustainability of Business Activities, *Unpublished article*. Auckland: International Centre for Sustainability Engineering & Research, University of Auckland.

Boyle, C. (2004). Sustainability for Engineers, *Unpublished article prepared for the IPENZ 2003 Presidential Task Force on Sustainability.* Auckland: International Centre for Sustainability Engineering & Research, University of Auckland.

Buselich, K. (2002). An outline of current thinking on sustainability assessment, *A background paper prepared for the Western Australia State Sustainability Strategy*. Western Australia: Murdoch University.

Calderón, E. J. (2000). An applied method for the assessment of sustainability of urban pilot projects. *Environmental Impact Assessment Review, 20*(2000), 289-298.

Chanan, V., White, S., Jha, M., & Howe, C. (2003). *Sustainable Water Management in Commercial Office Buildings.* Paper presented at the Innovations in Water: Ozwater Convention & Exhibition, Perth, 6-10 April 2003.

Checkland, P. B. (1976). Science and the systems paradigm. *International Journal of General Systems, 3*(1976), 127-134.

Christie, T., Thompson, B., & Brathwaite, B. (2001). Mineral Commidity Report 22 - Aggregate. *NZ Mining, 30*(December 2001), 6-26.

Christov A-Boal, D., Lechte, P., & Shipton, R. (1995). *Installation and Evaluation of Domestic Greywater Reuse Systems*. Melbourne: Victoria University of Technology.

Cornelissen, A. M. G., van den Berg, J., Koops, W. J., Grossman, M., & Udo, H. M. J. (2001). Assessment of the contribution of sustainability indicators to sustainable development: a novel approach using fuzzy set theory. *Agriculture, Ecosystems and Environment, 86*(2001), 173-185.

Cosgrove, W. J., & Rijsberman, F. R. (2000). *World Water Vision Report: Making Water Everybody's Business*. London: Earthscan Publications Ltd for the World Water Council.

Emblemsvåg, J., & Bras, B. (2000). Process thinking - a new paradigm for science and engineering. *Futures, 32*(2000), 635-654.
Expert Group on the Urban Environment. (1996). *European Sustainable Cities*. Brussels: European Commission.
Geldof, G., D. (1997). Coping with uncertainties in integrated urban water management. *Water Science & Technology, 36*(8-9), 265-269.
Gibson, R. B. (2002). Specification of sustainability-based assessment decision critieria and implications for determining "significance" in environmental assessment. Canada: Canadian Environmental Assessment Agency.
Gibson, R. B. (2003). *Assessment as if sustainability mattered.* Paper presented at the joint forum of the Ontario Association for Impact Assessment and the Ontario Society for Environmental Management, Environmental Assessment - Back to the Future, 15 May 2003, Innis College, University of Toronto.
Gleick, P. H. (2000). The Changing Water Paradigm: A Look at Twenty-first Century Water Resources Development. *Water International, 25*(1), 127-138.
Goodwin, B. (2001). Evolution: Self-organization Theory. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences*. Oxford: Elsevier Science, 2001.
Grotter, M., & Otterpohl, R. (1996). *Integrated Urban Water Concept.* Paper presented at the 7th International Conference on Urban Storm Drainage, Hannover, Germany.
Guijt, I., & Moiseev, A. (2001). *Resource Kit for Sustainability Assessment*. Gland, Switzerland and Cambridge, UK: IUCN.
Happy, A. (2001). Winstone Aggregates Ltd. *NZ Mining, 30*(December 2001), 27-30.
Hardi, P., & Zdan, T. (Eds.). (1997). *Assessing Sustainable Development: Principles in Practice*. Winnipeg: International Institute for Sustainable Development.
Hardin, G. (1968). The Tragedy of the Commons. *Science, 162*(3859), 1243-1248.
Heaney, J. P., Pitt, R., & Field, R. (1999). *Innovative Urban Wet-Weather Flow Management Systems* (No. EPA/600/R-99/029). Cincinatti: US Environmental Protection Agency.
Hellström, D., Jeppsson, U., & Kärrman, E. (2000). A framework for systems analysis of sustainable urban water management. *Environmental Impact Assessment Review, 20(2000)*, 311-321.
Hiessl, H., Walz, R., & Toussaint, D. (2001). *Design and Sustainability Assessment of Scenarios of Urban Water Infrastructure Systems.* Paper presented at the "Critical Infrastructures", 5th International Conference of Technology Policy and Innovation, Karlsruhe.
Hoffmann, B., Nielson, S. B., Elle, M., Gabriel, S., Eilersen, A. M., Henze, M., et al. (2000). Assessing the sustainability of small wastewater systems: A context-oriented planning approach. *Environmental Impact Assessment Review, 20*(2000), 347-357.
International Federation of Consulting Engineers (FIDIC). (2002). Sustainable Development in the Consulting Engineering Industry: A Unique Capacity to Address the Priorities, *The Consulting Engineering Industry's Agenda 21*. Lausanne, Switzerland: International Federation of Consulting Engineers (FIDIC).
International Institute for Sustainable Development. (2000). *Compendium of Sustainable Development Indicator Initiatives*, from http://www.iisd.org/measure/compendium/
James, W. (1999). *On smart, benign drinking water, wastewater, and storm water infrastructure for a less unsustainable future - a personal vision.* Paper presented at the Great Cities/Illinois-Indiana Sea Grant Urban Water Resources Conference, Sept 16-17, Chicago.
Jeppsson, U., & Hellström, D. (2002). Systems analysis for environmental assessment of urban water and wastewater systems. *Water Science & Technology, 46*(6-7), 121-129.

Kay, J. J., Regier, H. A., Boyle, M., & Francis, G. (1999). An ecosystem approach for sustainability: addressing the challenge of complexity. *Futures, 31*(1999), 721-742.
Kelly, K. L. (1998). A systems approach to identifying decisive information for sustainable development. *European Journal of Operational Research, 109*(1998), 452-464.
Lawrence, A. I., Ellis, J. B., Marsalek, J., Urbonas, B., & Phillips, B. C. (1999). *Total Urban Water Cycle Based Management.* Paper presented at the 8th International Conference on Urban Storm Drainage, 30 August - 3 September, Sydney, Australia.
Loucks, D. P. (2000). Sustainable Water Resources Management. *Water International, 25*(1), 3-10.
Lundin, M. A. (1999). Assessment of the Environmental Sustainability of Urban Water Systems, *TEP Report 1999:7*. Göteborg, Sweden: Department of Technical Environmental Planning, Chalmers University of Technology.
Lundin, M. A., & Morrison, G., M. (2002). A life cycle assessment based procedure for development of environmental sustainability indicators for urban water systems. *Urban Water, 4*(2002), 145-152.
Lundin, M. A., Sverker, M., & Morrison, G., M. (1997). *Indicators for the Development of Sustainable Water and Wastewater Systems.* Paper presented at the Sustainable Development Research Conference, Manchester, UK, April 1997.
Maheepala, S., & Zoppou, C. (2000). *Decision Support System for Assessing Integrated Urban Water Systems.* Paper presented at the IWRA Xth World Water Congress, 12-16 March, Melbourne, Australia.
McDonald, W. S., Creighton, C. L., & Erlanger, P. D. (2000). *Integrated Water Resource Assessment - Providing Information to Enhance Decision Making.* Paper presented at the IWRA Xth World Water Congress, 12-16 March, Melbourne, Australia.
Mitchell, G. (2002). *Informing the Decision Process to Improve the Sustainability of an Urban Greenfield Development Water System.* Paper presented at the International Environmental Modelling and Software Society 2002 Conference, Lugano, Switzerland, 24-27 June 2002.
Mitchell, G., Gray, S., Shipton, B., Woolley, R., Erbacher, J., Egerton, G., et al. (2002). *Evaluating Integrated Urban Water System Alternatives for Brisbane.* Paper presented at the Enviro 2002 Convention & Exhibition and IWA 3rd World Water Congress, 7-12 April, Melbourne, Australia.
Murcott, S. (1997a). *Appendix A: Definitions of Sustainable Development, from a paper presented at the 1997 American Association for the Advancement of Science (AAAS) Annual Meeting and Science Innovation Exhibition (AMSIE'97), 13-18 February, Seattle, Washington*. Retrieved 10 July 2003, from http://www.sustainableliving.org/appen-a.htm
Murcott, S. (1997b). *Appendix B: Sustainability Principles, Ecosystem Principles, from a paper presented at the 1997 American Association for the Advancement of Science (AAAS) Annual Meeting and Science Innovation Exhibition (AMSIE'97), 13-18 February, Seattle, Washington*. Retrieved 10 July 2003, from http://www.sustainableliving.org/appen-b.htm
Parliamentary Commissioner for the Environment (PCE). (2001). *Beyond Ageing Pipes: Urban Water Systems for the 21st Century*. Wellington: Office of the Parliamentary Commissioner for the Environment.
Parris, T. M., & Kates, R. W. (2003). Characterizing and Measuring Sustainable Development. *Annual Review of Environment and Resources, 28*(2003), 559-586.
Ravetz, J. (2000). Integrated assessment for sustainability appraisal in cities and regions. *Environmental Impact Assessment Review, 20*(2000), 31-64.

Rijsberman, M. A., & van de Ven, F. H. M. (2000). Different approaches to assessment of design and management of sustainable urban water systems. *Environmental Impact Assessment Review, 20(2000)*, 333-345.

Riley, G. (1996). Quarrying: An Industry Under Siege. *Contractor, August 1996,* 24-29.

Rollo, D., Wilkinson, K., & Leahy, A. (2003). *Smales Farm Development Infrastructure Report*. Auckland: Harrison Grierson Consultants Ltd (Ref: 09.13267.1).

Royal Melbourne Institute of Technology. (2000). *Descriptions of Sustainability*. Retrieved July 2003, from the Global Sustainability website of RMIT University, http://www.global.rmit.edu.au/tbl/2.1_descriptions.pdf

Schwartz, P., & Randall, D. (2003). *An Abrupt Climate Change Scenario and its Implications for United States National Security*. Washington D.C.: Global Business Network.

Simonovic, S. P. (2002). Global water dynamics: isses for the 21st century. *Water Science & Technology, 45*(8), 53-64.

Swinney, C. (2004). Putting out the fire with gasoline. *Investigate, 4*(39), 36-43.

Thomas, C. D., Cameron, A., Green, R. E., Bakkemes, M., Beaumont, L. J., Collingham, Y. C., et al. (2004). Extinction risk from climate change. *Nature, 427*(8 January 2004), 145-148.

Tonn, B. E. (2004). Integrated 1000-year planning. *Futures, 36*(2004), 91-108.

UNESCO Working Group M.IV. (1999). *Sustainability Criteria for Water Resource Systems*. Cambridge, UK: Cambridge University Press.

University of Leeds. (2004). *Press Releases 7 January 2004: Climate change threatens a million species with extinction*. Retrieved 20 January 2004, from the University of Leeds website, http://www.leeds.ac.uk/media/current/extinction.htm

van Gigich, J. P. (1979). A Methodological Comparison of the Science, Systems and Metasystem Paradigms. *International Journal of Man-Machine Studies, 11*(1979), 651-663.

van Moeffaert, D. (2003). *Multi Criteria Decision Aid in Sustainable Urban Water Management.* Unpublished MSc Thesis, Royal Institute of Technology, Stockholm.

Weaver, P., Jansen, L., van Grootveld, G., van Spiegel, E., & Vergragt, P. (2000). *Sustainable Technology Development*. Sheffield, UK: Greenleaf Publishing Limited.

Weigert, F. B., & Steinberg, C. E. W. (2002). Sustainable development - assessment of water resource management measures. *Water Science & Technology, 46*(6-7), 55-62.

World Federation of Engineering Organisations (WFEO). (1997). *The Engineer's Response to Sustainable Development*. Retrieved September 2003, from the Earth Council website, http://www.ecouncil.ac.cr/rio/focus/report/english/wfeo.htm

World Meteorological Organisation. (1992). *The Dublin Statement on Water and Sustainable Development [online]*. Retrieved 10 July 2003, from http://www.wmo.ch/web/homs/documents/english/icwedece.html

World Water Assessment Programme. (2003). *Water for People, Water for Life - UN World Water Development Report (WWDR)*. Paris: UNESCO Publishing & Berghahn Books.