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It is the paper published as:

Author: R. J. Watts and C. Allan

Title: Sustainable dam planning and operations: reflections on innovative international practices

Year: 2012

Editor: J. R. a. R. Grove, I.D

Conference Name: 6th Australian Stream Management Conference

Publisher: River Basin Management Society

Date: 6-8 February, 2012

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URLs: <http://www.asm6.org.au/assets/6ASM/Abstracts/067.pdf> http://researchoutput.csu.edu.au/R/?func=dbin-jump-full&object_id=40079&local_base=GEN01-CSU01

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Sustainable dam planning and operations: reflections on international practice to guide local adaptation

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Key Points

- Sustainable dam planning and operations is achievable. We should seek win-win outcomes with multiple benefits for society and the environment.
- The best solutions occur at the scale of systems or catchments. There are a different range of opportunities in developed and undeveloped catchments.
- Close collaboration between participating organisations and stakeholders is essential for successful outcomes. An adaptive management approach is required.
- To achieve all of the above, there is a need for i) more investment in trials to develop a better understanding of outcomes and impacts of changed practice ii) demonstration sites to illustrate new approaches and solutions, iii) mechanisms to share knowledge to encourage social acceptance and broader adoption of changed practices.

Abstract

Large dams provide important socioeconomic benefits but also have negative impacts. New approaches for dam planning and operations that optimize benefits across a range of values are required to achieve more sustainable outcomes. In 2010 the United Nations Educational, Scientific and Cultural Organization sponsored an international workshop “Challenges and Solutions for Planning and Operating Dams for Optimised Benefits”. This paper outlines lessons from innovative practices presented at that workshop, drawing on case studies where sustainable approaches have been identified or implemented. The key lessons were 1) sustainable dam planning and operations is achievable, with win-win outcomes for society and the environment, 2) the best solutions occur at the scale of systems or catchments, 3) close collaboration between participating organisations and stakeholders is essential for successful outcomes. To achieve this there is a need for more investment in trials, demonstration sites and mechanisms to share knowledge and encourage broader adoption of these practices. Dams around the world give rise to similar impacts and management issues. Sharing experiences will help us adapt to changing conditions precipitated by climate change and increasing human population. Many of the lessons from the UNESCO workshop could be implemented in Australia to achieve more sustainable dam operations.

Keywords

Dam, river regulation, hydropower, water supply, flood control, win-win, adaptive management, progressive learning

Introduction

Large dams provide critically important socioeconomic benefits, including electricity generation, flood control and water supply. Dams also have negative impacts; the World Commission on Dams Report (2000) revealed serious economic, social, and environmental impacts from dam development, and called for increased attention to sustainability principles. Current dam management practices do not adequately address the mix of competing needs such as reliability of water supply, flood risk, health, agriculture, energy generation and aquatic ecosystem health. New approaches for dam planning and operations that optimize benefits across a range of values are required to achieve more sustainable outcomes. Climate-change predictions and recent

droughts and floods have resulted in heightened awareness of issues associated with the management of dams and have increased societal understanding of the need to adapt, creating an opportunity to re-examine policies and procedures governing the management of river infrastructure.

Many of the adaptation measures adopted around the world have been structural measures, such as increasing the size of dams or transferring water between catchments (Bates *et al.*, 2008; Hirji and Davis, 2009a, 2009b). Such structural adaptation measures taken in isolation can exacerbate stresses on communities and already highly altered aquatic ecosystems downstream of dams. There is a need to consider a broader set of alternatives and actively seek options that result in benefits for both society and the environment.

UNESCO workshop

In October 2010 an International workshop “*Challenges and Solutions for Planning and Operating Dams for Optimised Benefits*” was held in Paris. Sponsored by the United Nations Educational, Scientific and Cultural Organization (UNESCO), The Nature Conservancy (USA), and Charles Sturt University (Australia), the workshop was held under the umbrella of the UNESCO International Hydrological Program that aims to improve the scientific and technological basis for the development of methods for the rational management of water resources, including the protection of the environment. The workshop brought together seventeen experts from Australia, Brazil, China, France, Nepal, South Africa, and the USA with experience in demonstrating potential for more sustainable dam planning, design, operations.

The workshop provided the opportunity to share examples of innovations that demonstrate that more sustainable approaches for dam planning and operations are possible. There were also several sessions for discussions and focussed workshops, to draw out common themes among case studies and synthesise ideas. The scope of the workshop included:

- The re-operation of old dams as well as siting, design and operation of new dams
- Single purpose (e.g. flood control, water supply, hydropower) and multipurpose water storages
- Individual dams, as well as dams in systems, e.g. cascades of dams, floodplains
- Intra -jurisdictional and inter-jurisdictional policies and operations
- Operational changes both within current operating rules, and changes to rules and guidelines

Examples of innovative approaches for dam planning and optimizing dam operations that were presented at the workshop include: altering established dam operation practices, in some case studies having demonstration sites to encourage learning and wider adoption of these practices; dam planning processes that propose to move flood-risk management out of hydropower reservoirs and to invest a portion of the consequent increased revenue from generating hydropower from the additional stored water into flood-risk management on the floodplain and ecosystem restoration and conservation; and designing new dams according to international best practice standards so that they can release both low and high flows that will coincide as closely as possible with natural inflows and natural flood events.

The workshop participants identified different types of drivers of change, including biophysical factors, such as climate change and its associated floods and droughts. Global economics was also seen as a major mechanism for driving change as the world population increases; resulting in both increased dependence and increased competition for the water stored in dams. Institutional factors were also considered to be driving change; within different jurisdictions legislation is being reviewed to respond to social and biophysical factors, and/or for structural readjustment. Participants stressed that some of the changes are prompted by changing social needs and values, such as societal demand for clean energy. Changing social values is one of the main factors shifting dam management towards more sustainable practices. This manifests as a need to ‘optimise’ outcomes across a number of agreed objectives. To meet the challenges of more precise and more complex goals requires catchment management plans, and holistic, flexible thinking.

Key lessons

The discussions and facilitated workshops highlighted a number of common themes and key lessons from the case studies.

1. Sustainable dam planning and operations is achievable, with win-win outcomes

The workshop unequivocally demonstrated that sustainable dam planning and operations is achievable. There are new approaches for dam planning and operations that optimize benefits across a range of values resulting in win-win outcomes with multiple benefits for society and the environment. A win-win situation is when there is a favourable outcome for all of the parties involved, rather than there being winners and losers.

Case studies presented at the workshop showed that through the application of innovative approaches in dam planning and operations, it is possible to increase the benefits from dams (e.g. water delivery, flood mitigation, power production) while simultaneously reducing the detrimental social, economic and environmental impacts of established dams. For example, in south-eastern Australia a series of variable flow trials from Dartmouth Dam showed that it is possible to reduce the negative impacts of transferring consumptive water between reservoirs by altering established dam operation practices. There were improvements in the biodiversity of the in-stream ecosystem as well as benefits for irrigators and recreational users through a reduction in the biomass of nuisance algae growing on cobble surfaces (Allan *et al.*, 2009; Watts *et al.*, 2010). Some of the case studies presented at the workshop described the establishment of demonstration sites to encourage sharing of knowledge. For example, the Sustainable Rivers Project, a collaboration between the US Army Corps of Engineers and The Nature Conservancy, has supported comprehensive reviews of existing dam operations in eight US river basins, facilitated scientific and stakeholder input into objective setting, and begun implementing strategically targeted dam releases to improve downstream environmental health while maintaining or enhancing project benefits such as flood protection, water supply provision, hydropower generation, and recreation. Demonstration sites have been established in some locations (TNC, 2011).

2. Best solutions occur at scale of catchments, with different opportunities in developed and undeveloped catchments

A recurring theme throughout the workshop was the need to look for solutions beyond a single dam or jurisdiction. The best solutions tend to occur at the scale of catchments or systems, because dams are only one element of water management systems within a catchment. Solutions that look beyond an individual dam and are set within a catchment context, such as integrating the energy grid within a region or incorporating floodplain management plans with dam operations, were discussed.

The workshop highlighted that the opportunities for moving toward sustainable dam planning and operations differ in developed and undeveloped catchments. There is a range of solutions and opportunities for the re-operation of existing dams in developed river systems compared to developing systems where there are different opportunities when new dams are being planned.

In developed catchments opportunities exist for improving existing dam operations (otherwise known as dam re-operation), improving and upgrading infrastructure, and integrating dam operations with downstream floodplain management. The process of dam re-operation facilitates the recovery of some environmental and social benefits of rivers that have been lost through current dam operations without significantly compromising other benefits of dams (e.g. water delivery, flood mitigation, power production) (Richter and Thomas, 2007). A conceptual framework for dam re-operation proposed by Richter and Thomas (2007) outlines a process for assessing the needs, opportunities, benefits and constraints of re-operating a dam and provides an opportunity to identify options that provide multiple benefits for both the environment and communities. Dam re-operation is complex because it can have an impact on water users, power production, flood mitigation and communities, but beneficiaries can provide strong support for change.

There are different strategies employed for the re-operation of flood control dams, hydropower dams and water supply dams. With flood control dams, dam re-operation can reduce flood risk and improve environmental outcomes, often negating the need to enlarge dam storage capacity. One of the strategies proposed to achieve this is to reincorporate floodplains as part of flood management system and alter the dam operations accordingly. During a large flood, water released from a dam is diverted on to the floodplain to avoid flooding important infrastructure. This approach has been implemented at Sacramento, California, significantly reducing the flood risk for this city (Oppermann *et al.*, 2009). The re-operation of hydropower dams can involve the incorporation of re-regulation reservoirs downstream of hydroelectric dams, or integrating the operation of cascades of dams to limit impacts of hydro peaking or reduce the length of river impacted by hydro peaking. With water supply dams, there is a wide range of options to minimise water losses and at the same time deliver a more natural pattern of flows to improve environmental outcomes. This can be done through integration of groundwater and surface storage, linking operations of cascades of dams, changing delivery arrangements for landholders with riparian rights, or piggy-backing the delivery of environmental water with consumptive water or tributary inflows (Watts *et al.*, 2011).

There are different opportunities for ensuring sustainable dam operations in undeveloped catchments. The focus of current activities tends to be on incorporating new ideas and innovations into planning for new dams while aiming for win-win outcomes. An example is a proposal for integrated flood risk management and ecologically sustainable hydropower in the Yangtze River Basin, China (Harrison, 2010). The proposal is to link the planning of several new dams to maximize the hydropower outputs, but at the same time enhancing floodplain conservation flood risk management by transferring flood storage operations out of those dams to selected high conservation floodplain areas. The proposal includes plans for establishment of a hydropower sustainability fund that will gain revenue from generating power from additional stored water. The fund will pay for enhanced flood risk management in the floodplain and basin-wide ecosystem conservation. Another example is the Berg River Dam, South Africa, which is the first large in-stream dam in South Africa designed according to international best practice standards. This dam has the capability to deliver both low and high environmental flow releases. The flood emergency preparedness plan comes into effect during large environmental-flow releases, thus improving the management of future disasters (Van Zyl, 2010). A test environmental flow release of 200m³/s was made on 12 June 2008. Disaster Management officials were fully involved in this test, providing an opportunity to monitor systems for downstream notification and warnings.

3. Close collaboration between participating organisations and stakeholders is essential for successful outcomes.

All participants in the workshop emphasized the importance of collaboration among all stakeholders involved in, and impacted by, the management of dams. Inclusion of all stakeholders in the planning process ensures that a wide range of ideas and knowledge is incorporated into planning and that outcome is socially acceptable and is more likely to be supported and implemented. Negotiation and compromise may be needed. In some cases the negotiations may be very complex, such as the need to develop agreements for water sharing across borders, both within and among countries. There may be conflict between downstream and upstream users over issues such as water sharing and water quality, emphasising the importance of having institutional goodwill when planning for sustainable dam operations.

Many of the case studies presented at the workshop described examples of close communication between water managers, researchers, government agencies, non-government organizations, landholders and the broader community. For example, in the Dartmouth Dam case study from south-eastern Australia, stakeholders involved in the variable flow trials included the Murray-Darling Basin Authority (MDBA), Goulburn-Murray Water (GMW), university researchers, some Mitta Mitta Valley landholders, and to a lesser extent the State Water Corporation, the North- East Catchment Management Authority and AGL Hydro (Watts *et al.*, 2010). The flow trials were facilitated by the cooperative approach taken by stakeholders. For example, flow plans were developed by MDBA taking into account operational and other advice from GMW and AGL Hydro. When developing the flow plans the MDBA consulted with the contracted researchers so that

relevant lessons from previous trials could be incorporated in subsequent trials. During the implementation of the trials, there was regular communication between the researchers, MDBA and dam operators that ensured the researchers were informed of any changes to the proposed discharge patterns. Following each trial, the researchers presented the results at workshops with MDBA staff, and meetings were held to discuss the findings and future directions. The Mitta Mitta Valley community was notified of the variable flow plans in real time via a faxed or emailed Stream Flow Advice, and was periodically updated on broader objectives and results of trials through articles jointly written by MDBA and the scientists published in a local newsletter.

Way forward

The workshop participants generated a number of recommendations for accelerating progress toward sustainable dam planning and operations. These are briefly outlined in a statement from the UNESCO expert group produced at the conclusion of the workshop (UNESCO expert group on sustainable dam planning and operations, 2010). This statement states the following:

“Lending institutions, national governments, and other agencies must embrace leadership roles to facilitate broader application of sustainability principles in dam planning and operations. Such leadership must include the provision of exponentially greater levels of funding to enable both existing and new dam projects to implement sustainability practices in their planning, design, and operations. Identifying, refining and implementing these practices may entail greater uncertainty initially than individual agencies or countries are willing to bear. Until the practices are more widely demonstrated and accepted as common practice, there is an urgent need for “venture capital” from international agencies and lending institutions that can support the visionary, entrepreneurial, and potentially risky investments to design and test innovative approaches. Such upfront investment will be necessary to demonstrate the efficacy and benefits of sustainable approaches so that dam interests will embrace and more regularly apply these approaches.

Specifically, much greater investment and capacity building is needed in the following key areas:

- *Demonstrating dam planning over broad geographies (i.e., river basin, national, regional scales) which identifies optimal locations for siting of new dams, as well as removal or rehabilitation of existing dams, for maximum benefits.*
- *Exploring innovative alternatives for re-designing entire irrigation, power generation, and flood risk management systems to produce broader social and environmental benefits or reduce impacts.*
- *Underwriting risk to facilitate more sustainable modes of integrated dam and floodplain management.*
- *Evaluating alternative structural designs and operational plans for dams that can produce optimal performance across economic, social, and environmental values.*
- *Evaluating ecological responses to hydrologic and physical changes caused by dams and the restoration of benefits attainable through re-operation of existing dams.*
- *Analysing economic trade-offs between traditional benefits (water supply, electricity, flood control) and non-traditional benefits (i.e., ecosystem services, riverine food production, etc).*
- *Facilitating on-going global dialogues to ensure that lessons learned and breakthrough ideas are shared.*
- *Building capacity for sustainable dam development through both formal and informal curricula.”*

Conclusion

Sustainable dam planning and operations is achievable and the best solutions occur at the scale of systems or catchments. Implementing change will generally not be straightforward. However, despite the challenges, a rich body of experience has emerged from around the world demonstrating the potential for more sustainable decisions on dam siting, design and operations. This experience shows that serious social and environmental impacts caused by dam development are neither necessary nor justifiable, and that it is feasible to achieve win-win outcomes (UNESCO expert group on sustainable dam planning and operations, 2010).

There is an urgent need to consider and implement alternatives that provide multiple benefits for society and the environment. Because dams around the world give rise to similar impacts and management issues, there are considerable opportunities for sharing knowledge and experiences to help us adapt to changing conditions precipitated by climate change and increasing human population. Many of the lessons from the UNESCO workshop could be implemented in Australia to achieve more sustainable dam operations.

Acknowledgments

The UNESCO workshop “Challenges and Solutions for Planning and Operating Dams for Optimised Benefits” referred to in this paper was sponsored by UNESCO International Hydrological Program, The Nature Conservancy, and Charles Sturt University Institute for Land, Water and Society. Thanks to all workshop participants for their inspiring presentations and discussions that contributed to this paper. Workshop participants were C Allan, M Bailey, C Brown, J K Bhusal, C J Bley, J Guo, D Harrison, J Hickey, S Khan, C Konrad, J Opperman, B Richter, A Tejada-Guibert, G Thomas, A Warner, R Watts, and B van Zyl. This paper was written with support from a Charles Sturt University Research Fellowship awarded to R Watts.

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