THE UNCERTAIN UNCERTAINTY OF RIVER BASINS: ACCOUNTING FOR UNCERTAINTY IN INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)

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Abstract:

Integrated Water Resources Management was officially established under the 1992 Dublin Principles. A set of standard principles was thought to be the 'state-of-the-art' solution to problems of ensuring good management, governance, distribution, and usage across the world. Therefore, this 'perfect' solution has become a leading discourse in water governance and management. However, current water related problems leave the Principles unrealistic and too idealistic for real success. Without responding to the lack of transparency and accountability, IWRM will not have the capacity to manage uncertainty in the future as global environmental changes continue. Following a case study from the Mekong River Basin, this paper will discuss how IWRM does not accurately account for issues of uncertainty in the water system and provides a plausible solution to this problem.

Key Words: River basins, uncertanity, water resources management

Introduction

Water governance and management practices have been changing drastically over the past few decades to accommodate the world's growing population with a finite water supply. Partnerships, networks, frameworks, and dialogues, are implemented at each level of water governance, attempting to create optimal management strategies. The water sector is far from reaching these goals and "though the water sector has lagged behind in explicitly addressing water challenges in a governance framework, 'fixing' various water-related challenges…is now increasingly seen in terms of getting the 'right' governance system in place."[3] Implementing Integrated Water Resource Management (IWRM) principles into water governance and management strategies is seen as the 'state-of-the-art' solution to water related problems. However, this method to 'fix' water-related challenges has been met with varying criticisms.

IWRM of today is based on the Dublin Principles of 1992 and were developed at the World Summit in Rio. Throughout this paper I will attempt to address the perception that IWRM is too idealistic and does not cope nor account for uncertainty within the water system.

Developing IWRM in 1992 was an important step towards improving water governance. Environmental movements of the 1960s and 1970s opened the eyes of many within the water sector to the future of the world's vulnerable resource. Standard principles that could ensure good management, governance, distribution, and usage across the world seemed the practical solution to a complicated problem. Water is important and we are facing a management crisis and needs to be addressed sooner rather than later.

Using a case study of the Mekong River Basin (MRB) will solidify my argument that IWRM does not consider the consequences or account for issues of uncertainty. Poor implementation of the principles in regions without adequate transparency and accountability makes them almost irrelevant fixtures in policy documents and signed agreements. But, at the same time, best practices through IWRM are strived for among water experts meaning that improvement to the framework is welcome. Through implementing interactive on-line mapping systems, major sources of uncertainty can be addressed. Different levels of uncertainty exist and will be elaborated on below.

[3] Tropp, H. (2007). *Water governance: trends and needs for new capacity development*. Stockholm, Sweden: Stockholm International Water Institute.

In this paper I will first provide background information on the MRB, which I will use throughout my paper to give context to my argument. Second, I am going to provide an overview of IWRM in terms of water governance and management, the Dublin Principles of 1992, and the IWRM framework. Third, as a core section to my paper, I will examine issues of uncertainty and the consequences for IWRM of failing to recognize it. I will then conclude the paper with one practical recommendation, which has the capacity to comprehensively address the issues of uncertainty at hand by improving transparency and accountability at all levels.

Introduction to the Mekong River Basin – A Case Study

The Mekong River, located in Southeast Asia, as seen in Figure 1[4], is one of the world's largest rivers and starts at the Tibetan Plateau in China and flows through Laos, Myanmar, Thailand, Cambodia, and Vietnam before emptying into the South China Sea. The river supports over 70 million people. This heavy reliance revolves around livelihoods of: "fishing, agriculture, hydroelectric power, transportation, biodiversity, and so on".[5&6] The large populations and diverse uses of the ecosystems leave the river vulnerable to complexities from increasing numbers of development projects and other transboundary governance issues in the region, which is not in the scope of the paper. Figure 2 also highlights future uncertainty from development projects by showing the quantity of existing dams, those under construction and the plans as of 2009. Development projects are a major source of conflict and the reason why shortcuts are taken by development teams to hide the multitude of uncertainties that accompany hydropower projects.

I am using the MRB for a case study because of the river's transboundary nature and its socio-political issues: "widespread poverty, high population growth, a history of conflict and which caused by the weak governance structure".[7] It is an interesting case because despite these socio-political issues the lower four riparian states came together to become the first transboundary river to attempt reducing regional conflict through the establishment of The Mekong Committee in 1957.[8]

Integrated Water Resources Management in Depth

Water Resources Management Through Water Governance

Among development mentalities and frameworks, governance has always played a central role. Surprisingly, water governance has only recently become significant, moving from "something that was close to a political taboo…to being more widely accepted as a critical issue that needs to be addressed in order to come to grips with unsustainable development and poverty".[9] This has resulted in the recognition of water governance challenges and has allowed for a more open look at the roles of politics, corruption and power in management practices.

[4] Institute for Environmental Security. (Producer). (2009).*Dams in the mekong river basin*. [Print Map]. Retrieved from http://www.envirosecurity.org/espa/MekongRiverBasin/maps_images.php

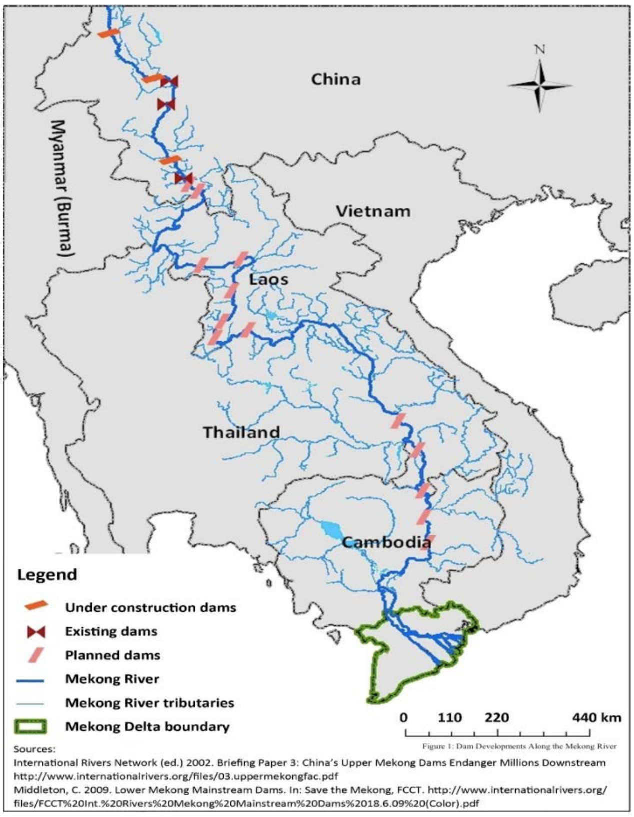
[5] Belay, A. A., Haq, S. A., Chien, V. Q., & Arafat, B. (2010). The challenges of integrated management of mekong river basin in terms of people's livelihood. *J. Water Resources and Protection*, (2), 61-68.

[6] Petropoulos, S., & Valvis, A. (2011). International relations and environmental security: Conflict or cooperation? contrasting the cases of the maritza-evros-meric and mekong transboundary rivers. In J. Ganoulis, A. Aureli & J. Fried (Eds.),*Transboundary Water Resources Management: A Multidisciplinary Approach*Germany: Wiley-VCH.

[7] Belay, et. al (2010)

[8] Varis, O., Ranhaman, M.M., & Stucki, V. (2008). Integrated Water Resources Management Plans: The Key to Sustainability? *Water & Development Publications.* Helsinki University of Technology, 173-183.

[9] Tropp (2007)



Water management has traditionally focused on infrastructure development and technology investments to improve access to water. However, it is common for these not to reach their fullest potential. For this reason, governance and management must co-exist to where governance is more than just government actions. Governance needs to involve the horizontal (across different sectors and between urban to rural regions) and vertical approaches (moving between the local to international scale) with the importance of civil society and private sector.[10]

Moving to the present, water management still see the importance of developing infrastructure but now encompasses resource allocation, resource protection, and incorporating incentives for efficient water use while ensuring financial sustainability throughout.[11] As I will discuss below, water management is a complex process. Financing water management techniques needs constant monitoring and adaptability as "new information and technology gradually become available under changing and uncertain external impacts, such as climate change."[12]

Dublin Principles 1992

Prior to the 1992 Dublin Principles, water resources management was not a new concept. It dates back to the 1977 United Nations Water Conference in Mar del Plata, Argentina when dialogue and networking emerged between water policy actors.[13] Current IWRM strategies are modelled after the Dublin Principles and were developed at the World Summit in Rio de Janerio in 1992 in response to criticism of previous top-down approaches.

Principle 1, as described by the Global Water Partnership, is: "Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment".[14] This finite resource recycles itself continuously through the global water cycle. Water can be tainted by large amounts of pollution making it unusable for centuries but, as a finite resource, it cannot be created; making sustainable usage and management practices especially important. Due the interdisciplinary nature of water, the integration of management needs to account for both supply and demand of the resource. A

[10] Tropp (2007)

[11] Lenton, R., & Muller, M. (2009). *Integrated water resources management in practice: Better water management for development*. Sterling, Va, USA: Global Water Partnership, Earthscan.

[12] Van der Keur, P., Henriksen, H.J., & Refsgaard. J.C. (2008). *Identification of Major Sources of Uncertainty in Current IWRM Practice. Illustrated for the Rhine Basin.* Water Resource Manage. 1677-1708.

[13] Conca, K. (2005). Expert networks: The elusive quest for integrated water resources management. In P. Dauvergne (Ed.), *Handbook of Global Environmental Politics*Edward Elgar Pub.

[14] Global Water Partnership. (2012). *What is iwrm?* Retrieved from http://www.gwp.org/en/The-Challenge/What-is-IWRM

hydrographical management approach is used, meaning it recognizes the interconnectedness of aquatic ecosystems and environmental health. Under this approach, a river basin is the assigned unit for water management.[15]

Principle 2 is used to explain how water as a resource affects everyone: "Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels."[16] Principle 2 revolves around true participation where all actors, stakeholders and affected people are involved to reach long-term success. Participation is interpreted differently at different levels; meaning agreements are not always met, especially between governments and vulnerable groups or communities. This principle attempts a bottom-up approach to decision making – starting with consensus from those with the most at stake.[17]

Principle 3 plays off of principle 2 and centres around the importance of women: "Women play a central part in the provision, management and safeguarding of water."[18] Women play an important role in the transportation and usage of domestic and agricultural water. However, the role of women is viewed as being lesser than men during decision-making processes. Gender research shows that there are strong linkages between gender equality, improved local water management and improved water access.

Principle 4 is, to me, the most compelling of the principles: "Water is a public good and has a social and economic value in all its competing uses".[19] Water must be recognized as a human right and should be accessible at an affordable price to everyone because it is vital to support life. At the same time, there are costs associated with management, distribution, infrastructure, etc. – for this reason water is also an economic good. This recognition is important for effective distribution across different sectors and users.

IWRM Framework

The IWRM focus strives to reach equilibrium of the 'three Es'' – efficiency, equity and environment. The three Es' seek to promote and ensure sustainable development while addressing water challenges of the present and future.[20] Figure 2[21] shows the general framework for IWRM that promotes economic efficiency of management instruments, ecological stability through enabling the environment, and social equity through institutional roles. This framework was designed to avoid and mitigate for fragmentation of possible water management solutions. Through creating an enabling environment for policies, legislation and international cooperation, the institutional roles are more appropriately and equitably filled. This allows for management tools to be the most effective and produce desirable results under the Dublin Principles of 1992.[22]

[15] Wenger, R., Rogger, C., & Wymann von Dach, (2003). S. Swiss Agency for Development and Cooperation (SDC). *Integrated Water Resources Management (IWRM): A way to sustainability.* InfoResources Focus.
[16] Global Water Partnership (2012)

[17] Global Water Partnership (2012)
[18] Global Water Partnership (2012)
[19] Global Water Partnership (2012)
[20] Lenton & Muller (2009)
[21] Global Water Partnership (2012)
[22] Global Water Partnership (2012)

Figure 2: General Framework for IWRM
Source: Global Water Partnership, 2012

Issues of Uncertainty

Complexity Leading to Uncertainty

Uncertainty is seen throughout every management decision; therefore, it should be an integral part of the IWRM framework. Management frameworks are generally well received as theoretically practical solutions. However, outside of the written application, complexity sets in as implementation of IWRM produces different cases of path-dependency resulting from seemingly uniform decisions made at the beginning. Nothing is linear in our current environmental system and changes "can trigger sudden and surprising changes"[23] to systems. Over the past decade it has become clearer that in order to handle uncertainty, flexible, adaptable and interdisciplinary frameworks are the best option[24]. Uncertainty sets in at the very first levels of management "because the first interventions in water resources management are driven by individual users who abstract and store water for their particular purpose. But the interconnected nature of the water cycle means that individual actions often have [unforeseen] impacts".[25]

Transboundary water systems, are complex due to high levels of uncertainty. Here, complexity is understood to be how the ecosystem adapts to changes brought on by the unpredictability of human impacts, global environmental change, and changing human values.[26]

Types of Uncertainty

Understanding the discourse of uncertainty in IWRM is useful for recognizing different types within data, models, frameworks, and in specific cases. When used successfully, it translates to better understanding of IWRM strategies and management scenarios. The first step is to identify the nature of the uncertainty – ontological or epistemic. Ontological refers to uncertainty that cannot be reduced and is "due to inherent variability in the system".[27] Epistemic uncertainty, on the other hand, can be reduced depending on the type and source and is "due to imperfect knowledge of the system".[28] However, with more information uncertainty can, at times, increase with the idea that 'the more we know, the more we do not know'.

Figure 3: Uncertainty Scale, shown below, looks at the transition of uncertainty from determinism to total ignorance. The state of determinism is when, based on the information gathered,

[23] Galaz, V. (2007). Water governance, resilience and global environmental change – a reassessment of integrated water resources management (IWRM). *Water Science & Technology*. 56, 4, 1-9.
[24] Brugnach, M., Dewulf, A., Henriksen, H. J., & Van der Keur, P. (2011). More is not always better: Coping with ambiguity in natural resources management. *Journal of Environmental Management*, (92), 78-84.

[25] Lenton & Muller (2009)
[26] Van der Keur, et. al (2008)
[27] Van der Keur, et al (2008)
[28] Van der Keur, et al (2008)

everything is known – complete certainty in a situation. This is the ideal situation but is never achieved due to complexity of the water system.[29]

Statistical uncertainty is generally referred to as potential measurement errors or any form of inaccuracy in data collection or interpretation. Moving left on the scale; *scenario* uncertainty is not based on statistics or data. This type is in the analysis of policy and is used to explain potential system changes based "as a function of known controls like changes in management, technology and price structure".[30] Scenario uncertainty is largely based on past experiences and considers potentially known outcomes when the probabilities of those outcomes are unknown. *Qualitative* uncertainty appears when statistical explanations cannot be provided and scenario outcomes are also relatively unknown. *Recognized* ignorance is true when those involved are aware that there is a lack of knowledge and information on a given topic but do not know how to move forward. In this case, predictions are often impossible regardless of continued research. This is also the point of indeterminacy. Finally, *total ignorance* is when there is a complete lack of awareness that the situation contains gaps in knowledge and information.[31]

For the sake of the recommendations section below it is necessary for me to outline uncertainty in a natural, technical and social context based in the Mekong River Basin. Technical uncertainty it is an incomplete understanding or a lack of knowledge on the technology and efficiency of an existing hydropower dam. Natural uncertainty is relatively broad where there is overall limited understanding of processes involved in collecting further data and knowledge at a project site. In this case, it can be reduced and understanding gained from surrounding ecosystems. Referring back to Figure 1: Dam Developments Along the Mekong River, the proposed dams are presented to stakeholders, and potentially affected community members, in very simplistic terms. These proposals are often misrepresenting the reality of future harms a dam could have on the local environment. Finally, social uncertainty is with regards to potentially limited knowledge of the social and economic system aspects. An example "could be uncertainty on statistical economic data from a river basin, because all existing data bases are disaggregated into administrative units and are not coinciding with river basin boundaries".[32] With proper distribution and communication of the knowledge at hand this type of uncertainty can be reduced.

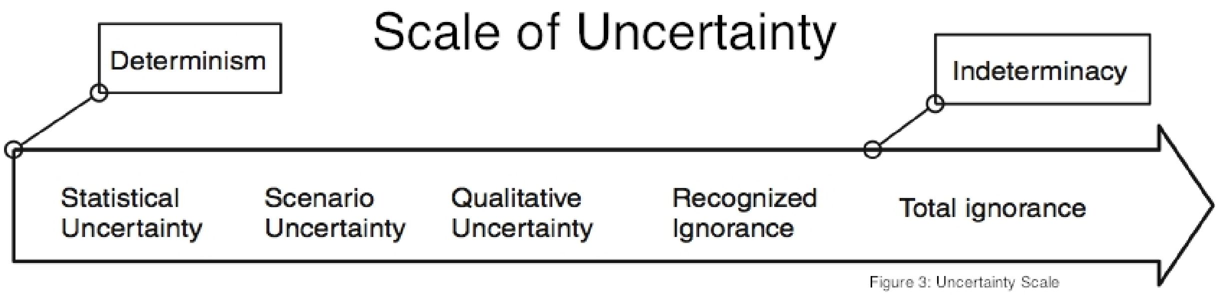


Figure 3: Uncertainty Scale

Brugnach, et al explains the importance of coping with ambiguity in a river basin ecosystem. Ambiguity is distinct from the types of uncertainty listed on the scale above and results come from the "simultaneous presence of multiple valid, and sometimes conflicting, ways of framing a problem."[33] Ambiguity shows the inconsistencies between how different actors translate and understand problems. Unfortunately, as more actors are added into a decision-making process ambiguity is sometimes unavoidable. As a result, a clear solution, distinguishing who should be involved and the next course of action is not always available. It suggests that more than one method might be available for a given system, meaning ambiguity is not a direct knowledge gap. The question is then posed for how to cope with ambiguity in a river basin ecosystem under IWRM strategies? To cope, different strategies must be recognized at all stages of management. This means full participation is key; listening to all stakeholders to decide where and what values should be incorporated during decision-making.[34]

[29] Van der Keur, et al (2008)
[30] Van der Keur, et al (2008)
[31] Van der Keur, et al (2008)
[32] Van der Keur, et al (2010)
[33] Brugnach, et al (2011)
[34] Brugnach, et al (2011)

Sources of Uncertainty

As visualized in Figure 3: Scale of Uncertainty, uncertainties vary. However, identifying the types can help identify where the sources of uncertainty are. IWRM has guidelines for determining these sources that generally focus on certain processes within the framework, which are "notably on uncertainty associated with the modelling process and monitoring data".[35] The importance of having guidelines is to localize uncertainty to ensure informed actions within the decision-making process. Many of the guidelines I found in the literature range from generic and ambiguous to very specific. These varying guidelines can be useful for context specific cases and the range of users within the management process.

The following flow chart, Figure 4: Finding Uncertainty in Decision-Making[36], is one of the guidelines I found to be very descriptive in the literature and will outline the steps that are taken in a best case scenario of the IWRM decision-making process. Each of the five steps is a representation of either a single or group of possible uncertainties. The literature by Sigel, et al describes the flaws of the guidelines: "As these steps aim to describe the entire selection process, [technically] a description of sources of uncertainty based on this structure can claim to be complete. However…a different structure may lead to other descriptions of the sources of uncertainty".[37] This represents statistical uncertainty and highlights the biased thought process that these are part of a linear system. The below guidelines disregard the IWRM's first principle of following the hydrological approach where a river ecosystem exhibits non-linear behaviour and is within a complex system.

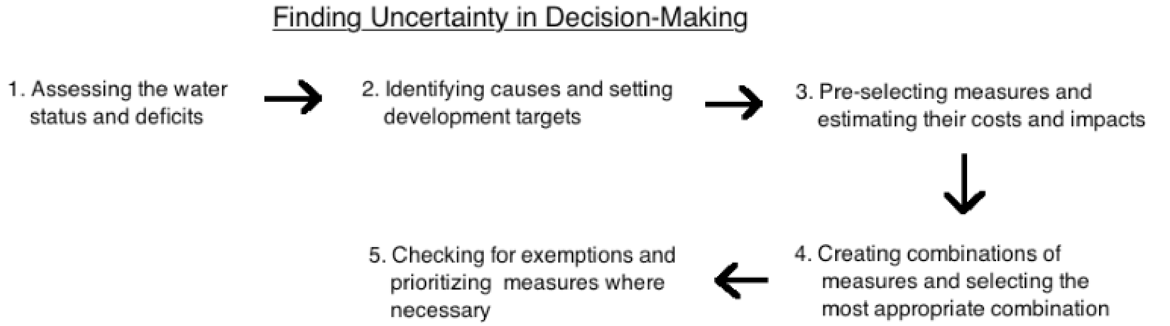


Figure 4: Finding Uncertainty in Decision-Making

One of the biggest problems contributing to IWRM's inability to address uncertainty in the MRB is due to a lack of political commitment or an uneven level of commitment between states sharing the same basin. This idea will be addressed below when looking at China's relationship with the lower riparian states. Without political commitment there is minimal state representation, power and influence and none of the necessary components for effective action plans. In order for IWRM to be effective, state commitment needs to be backed "by a solid and accurate understanding of the dimensions of the problem"[38]. Being informed to the point of statistical uncertainty will ensure for the best possible management outcomes.

The competitive nature of states and the desire for state sovereignty can lead to even lower levels of cooperation or an inability to see the potential of cooperation in the future. Disengagement of information sharing and technology transfers between riparian states can also be from a lack of mutual trust – especially when involved in competition for shared resources and have similar interests.[39]

Analysing Uncertainty in the Mekong River Basin

Another somewhat simpler form of guidelines under the IWRM framework are a set of three questions posed in preparation of a failure due to uncertainty in the system. I found this set of guidelines useful because it incorporates types of uncertainty into the equation and thus, attempts to cover a broader scope with fewer steps. These questions are posed sequentially:

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[35] Van der Keur, et al (2010)
[36] Sigel, et al (2010)
[37] Sigel, et al (2010)
[38] Ganoulis, J. & Salame, L. (2011). *A Risk-Based Integrated Framework for Conflict Resolution in Transboundary Water Resources Management.* In J. Ganoulis, A. Aureli & J. Fried (Eds.), Transboundary Water Resources Management: A Multidisciplinary Approach. Germany: Wiley-VCH

[39] Ganoulis & Salame (2011)

"1) When could the system fail?
2) How often is failure expected?
3) What are the likely consequences?"[40]

Steps one and two are addressed to determine the uncertainty of the system. Question one is found by putting together a critical scenario – scenario uncertainty – and determining the potential outcomes based on past experiences. Question two examines the potential frequency of failure through probability calculations and statistical analysis – statistical uncertainty. Finally, question three puts the results of the above questions together to determine any potential losses or gains – qualitative uncertainty.[41]

Using the Mekong case study I will use these guidelines to address the uncertainties of China's absence in signing regional agreements with the other riparian Mekong states in the context of building dams for energy production. By looking at the process of answering the questions it will become clear that based on the IWRM's current structure and idealistic values, it does not accurately account for uncertainty in the system.

As China's population grows, so do domestic energy demands, thus increasing the amount of dam proposals along the upper Mekong River – refer back to Figure 1: Dam Developments Along the Mekong. This figure shows that, in China alone, there are three existing dams, three under construction, and plans to construct two more as of 2009.

1) When could the system fail?

As this question examines scenario uncertainty, the first step would be to examine the results of past dams built in China. Consider the expected timelines of the current infrastructure and when those are expected to fail or need repairs. China abstained from signing the 1997 Convention on the Law of Non-navigational Uses of International Watercourses or onto the Mekong River Commission. Nor will they sign, knowing that it is the only treaty governing the use of shared freshwater and, that without 35 ratifications, it will not become international law. In 1996, Manwan dam was constructed in Yunnan Province, China and sits as a founder for the planned construction of eight more in the province. The Manwan dam will be used below to provide more context for questions two and three.

2) How often is failure expected?

For the purposes of this paper I will not be doing my own calculations for probability, I will instead outline a formula to develop an assessment of the risk of failure. The formula is laid out as follows to reach a level of statistical uncertainty:

(L) = Behaviour based on external stresses on the system

(r) = Resistance of the system

* These terms occur at random under probability assumptions*

Based on when L exceeds its limit, either a *failure* or an *incident* will present itself.

"FAILURE or INCIDENT: $L \geq r$, where SAFETY or RELIABILITY: $L < r$"[42]

Therefore, assuming randomness under probability, the probability of failure is a risk.

"RISK = probability of failure = $P (L \geq r)$

In this instance RISK is defined as: "the possibility of losses"

Used in an equation:

RISK = (Hazard) x (Vulnerability), or RISK = (Probability) x (Consequences) = (Expected Consequences)[43]

In order to reach statistical uncertainty under these guidelines, regulations for an acceptable data analysis are at minimum 20 years. The data series used for the Manwan Dam falls short with only 12 years – 1992-2003. Also, to make matters worse, literature shows that there are major sources of recognized uncertainty in the rating curve, which is the relationship between stage and water discharge. It was established in 1975 and was used without updates for close to 20 years until 1994.[44]

3) What are the likely consequences?

Based on results from the above questions, as well as from findings in *Probe International* and the *World Wildlife Fund Global*, I am distinguishing three consequences as the most severe for

[40] Ganoulis & Salame (2011)
[41] Ganoulis & Salame (2011)
[42] Ganoulis & Salame (2011)
[43] Ganoulis & Salame (2011)
[44] Xi Xi, et al (2008)

downstream ecosystems. The first is a loss of river sediment, or delta instability. Sediment becomes caught in the dams and as more are constructed along the river, the amount reaching the Lower Mekong Basin is significantly reduced. Reduced sediment flow leaves the basin "vulnerable to sea level rise and saline intrusion brought on by climate change."[45] The second is a decline in fish species diversity. Inefficient and lack of accountability during construction will potentially hinder fish migration necessary for fish productivity by 60%. Populations inhabiting the river basin are more than 75% dependent on the river livelihood stability. Any combination of the above consequences can result in damaged livelihoods as well as general ecosystem health. [46,47]

Overall, great uncertainty resides with China because it holds the power within the MRB. Geographically and politically it has the advantage for future negotiations on river management. Uncertainty increases as China's energy needs grow and will likely affect flow levels for the Lower River Basin.[48] Based on the results of question 2, it is clear that without proper management and transparency of appropriate information, IWRM is not going to improve and will not be able to account for uncertainty in the system.

Recommendation

Reading the literature of uncertainty within IWRM, I became aware that only a small portion of the literature dealt with the notion that uncertainty can largely be improved by implementing new forms of regulation and ensuring transparency and accountability. Man-made problems are everywhere in the water sector and produce many unknowns. However, a majority of these uncertainties can be reduced to scenario or statistical uncertainty by the simple act of collecting more information and improving how this information is presented.[49] Galaz's article describing water governance and resilience lays out the need for improved information collection very clearly: "The increased potential for regime shifts, surprises and conflict…from uncertain hydrological changes, and the desires of competing water users…calls for a much closer examination of the ways in which economic tools…can be used to facilitate or hinder adjustment to the effects of global environmental change."[50]

Uncertainty needs to be harnessed. Dynamics of the river basin ecosystem need to be under as much control as statistical uncertainty can allow. Water quality is generally more complicated and difficult to monitor and regulate than water quantity because technical knowledge is needed for both monitoring and enforcement.[51] To harness the uncertainty and lessen the complexity of monitoring and enforcement a new method and strategy is necessary. I will be giving a close look to using mapping technologies as a management tool to increase transparency and accountability to account for issues of uncertainty in IWRM. This is based on the assumptions that large amounts of information and knowledge are necessary for solving environmental problems and that access to all available knowledge is the foundation of good decision-making.[52] Caution and sensitivity is necessary in many parts of the world, especially for environmental issues in the MRB. This mapping technology has the potential to reduce knowledge gaps resulting from sensitivity as well as political and power dynamics in the Basin.

States and territorial boundaries are a result of the globe's modern system of political organization. These boundaries are the outcome of a major and complex European transformation. Modern cartography was a large factor to this transformation: "new mapmaking technologies changed how actors thought about political space, political organization, and political authority."[53] I think there

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[45] WWF Global (panda.org). (2012). *Mekong River Basin: Damming the Mekong.* Some Rights Reserved. http://wwf.panda.org/what_we_do/footprint/water/dams_initiative/examples/mekong/

[46] WWF Global (panda.org) (2012)

[47] Probe International (2008). *Neighbours 'face harm from Chinese dam project'.* Energy Probe Research Foundation. Probe International. http://eprf.probeinternational.org/node/5593

[48] Petropoulos & Valvis (2011)

[49] Ganoulis & Salame (2011)

[50] Galaz (2007)

[51] Lenton & Muller (2009)

[52] Sigel, et al (2010)

[53] Branch, J. (2011). *Mapping the Sovereign State: Technology, Authority, and Systemic Change.* International Organization Foundation. 1-36.

is potential for current and future digital cartographic technologies to make drastic changes again, especially for global environmental governance and IWRM.

Reliable information and up to date information is essential to every aspect of IWRM and the same is true for any form of governance. Necessary and essential information includes, at the working level, daily data levels of river basins – flows, discharge, and quality. Also, at a more complex level there is a need for "engineering structures, ecological needs of flow, quality at ecologically significant parts of the area, and calendars of local cultural events which all support the management needs at this level…patterns of demand, economic development indicators…"[54] and the list goes on. Attempting to incorporate all types of information into one database that is accessible to all relevant stakeholders is a complicated process. Therefore, of course there are limits to this form of mapping technology but it is outside the scope of this paper.

Knowledge is still limited on how mapping technologies would realistically function as a form of increasing transparency and accountability within IWRM to account for uncertainty. However, there are cases of major success in the forestry sector of global environmental governance. I believe that using results and starting points of the forestry sector there is great potential for successful implementation in the water governance sector as well.

Forestry presents many major environmental concerns that are different than those of the water sector. However, both have the same end goals that revolve around improving transparency and accountability – why should the means to those ends be different? Ecosystem mapping uses interactive maps of Geographic Information Systems (GIS) mapping techniques and satellite imagery to monitor physical forest areas. It shows and explains where, when, and how deforestation is occurring in Central West Africa. One project funded by the World Resources Institute (WRI) is the *Moabi* system used in the Democratic Republic of Congo (DRC). They take a bottom-up approach by going to the public and requesting the submittion of information in an offline setting that is transferred online every 16 days. *Moabi* then approached the public and private sector to lobby for provided information. Results were very surprising as information poured into the *Moabi* database. The website and database worked as both advocacy and an information sharing space, as well as a means for private sector actors to get name recognition and build a reputation.[55]

Conclusion

I briefly conclude this paper on accounting for uncertainty within IWRM frameworks by outlining the importance of improved transparency and accountability. The answers to IWRM problems and criticisms will not be found in past experiences. A restructuring of IWRM to include new approaches into the framework is necessary using present day technology. Satellite imagery and GIS mapping systems are, what I think to be, the way forward. They have potential to account for transparency and ensure accountability at all levels of the IWRM process, which, as described above, is extremely complex and full of varying uncertainties at every level and at the end of each decision.

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Branch, J. (2011). *Mapping the Sovereign State: Technology, Authority, and Systemic Change.* International Organization Foundation. 1-36.

Brugnach, M., Dewulf, A., Henriksen, H. J., & Van der Keur, P. (2011). More is not always better: Coping with ambiguity in natural resources management. *Journal of Environmental Management*, (92), 78-84.

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