www.water-alternatives.org
Volume 3 | Issue 2
Tullos, D.; Brown, P.H.; Kibler, K.; Magee, D.; Tilt, B. and Wolf, A.T. 2010. Perspectives on the salience and magnitude of dam impacts for hydro development scenarios in China. Water Alternatives 3(2): 71-90

Perspectives on the Salience and Magnitude of Dam Impacts for Hydro Development Scenarios in China

Desiree Tullos
Assistant Professor, Biological and Ecological Engineering, Oregon State University, Corvallis, OR, US; tullosd@engr.orst.edu

Philip H. Brown
Associate Professor of Economics, Colby College, Waterville, ME, US; phbrown@colby.edu

Kelly Kibler
PhD student, Water Resources Engineering, Oregon State University, Corvallis, OR, US; kiblerk@engr.orst.edu

Darrin Magee
Assistant Professor, Environmental Studies, Hobart & William Smith Colleges, Geneva, NY, US; magee@hws.edu

Bryan Tilt
Assistant Professor, Department of Anthropology, Oregon State University, Corvallis, OR, US; bryan.tilt@oregonstate.edu

Aaron T. Wolf
Professor of Geography and Chair, Department of Geosciences, Oregon State University, Corvallis, OR, US; wolfa@geo.oregonstate.edu

ABSTRACT: Following the principles and priorities outlined by the World Commission on Dams, managers are increasingly considering a greater variety of impacts in their decision making regarding dams. However, many challenges remain in evaluating the biophysical, socioeconomic and geopolitical impacts of dams, including the potential diversity of stakeholder perspectives on dam impacts.

In this analysis, we surveyed representatives of non-governmental organisations, academics and hydropower and government officials in Yunnan Province, China, to better understand how stakeholder group views on the size (magnitude) and importance (salience) of dam impacts vary. We applied the technique defined by the Interdisciplinary Dam Assessment Model (IDAM) to simulate three dam development scenarios: dams in general, a single large dam and multiple small dams. We then surveyed the experts to measure their views on the magnitude and salience of 21 biophysical, geopolitical and socioeconomic impacts for the three scenarios.

Survey results indicate differences in the perceived salience and magnitude of impacts across both expert groups and dam scenarios. Furthermore, surveys indicate that stakeholder perceptions changed as the information provided regarding dam impacts became more specific, suggesting that stakeholder evaluation may be influenced by quality of information. Finally, qualitative comments from the survey reflect some of the challenges of interdisciplinary dam assessment, including cross-disciplinary cooperation, data standardisation and weighting, and the distribution and potential mitigation of impacts. Given the complexity of data and perceptions around dam impacts, decision-support tools that integrate the objective magnitude and perceived salience of impacts are required urgently.

KEYWORDS: Hydropower impacts, salience, decision making, stakeholders, World Commission on Dams, China

INTRODUCTION

Though hydropower development provides many known benefits, negative impacts are often distributed across social and environmental systems (WCD, 2000; Scudder, 2005). In addition, perceived costs and benefits are likely to vary among stakeholder groups (Ünver, 2008) linked to the river and affected by the project in an assortment of ways.

In 2000, the World Commission on Dams (WCD) reported the need for more equitable, interdisciplinary and sustainable decision making with respect to large dams, and that new models of decision making must involve key stakeholders throughout the process. Much subsequent research has also advocated for improving decision-making processes (McCully, 2001; Mokorosi and van der Zaag, 2007; Koch, 2002; Dingwerth, 2005). However, important challenges in implementation remain unresolved. Chief among these is how best to carry out equitable and sustainable decision making in situations in which information is scarce, or in which there exists strong institutional resistance to WCD recommendations such as opening assessment procedures to public scrutiny or comment (Dubash et al., 2002). A number of approaches are under development with the intent of improving governance and decision making related to water resources development (WCD, 2000; van der Zaag et al., 2009; Turner et al., 2003; Simonovic and Fahmy, 1999). The Integrative Dam Assessment Modelling (IDAM) tool (Brown et al., 2009) is one example of a new process that seeks to fulfil the WCD's recommendations. Of the seven Strategic Priorities[1] for the equitable and sustainable development of water resources promoted by the WCD, the IDAM tool contributes most directly to facilitating comprehensive options assessments that equally consider the environmental, technical, social, economic and financial components of alternative development scenarios.

Interdisciplinary Dam Assessment Model (IDAM)

The goal of the IDAM instrument is to support more informed and transparent decision-making processes around dam development. Rooted in the three pillars of sustainability (biophysics, socioeconomics and geopolitics), as proposed at the 1992 Rio Declaration on Environment and Development (UN Committee on Economic Development, 1993), IDAM was established to promote the full and equal consideration of the three pillars in dam decision making. IDAM is distinct in its ability to simultaneously consider costs and benefits across the three pillars, as opposed to the discrete analyses (e.g. in social impact assessments, environmental impact assessments, and benefit cost analyses) often used to appraise dam decisions.

Moreover, the IDAM framework provides transparency for documenting information used in evaluating dam development alternatives. In addition to enhancing the transparency of the decision-making process, documentation throughout IDAM evaluation provides testimony as to the quality of information used to reach a decision.

The IDAM tool is structured as a set of 21 biophysical, socioeconomic and geopolitical impacts of dam construction (table 1), each of which is measured by independent analysts using an indicator that reflects the objective magnitude of the impact, which is then classified into one of five bins indicating the scale of impact. Indicators are intended to be neutral in tone and application; however, it is foreseeable that in one geographic setting, some indicators may only connote a negative impact, yet in another setting could also encompass a positive impact.

Next, a diverse group of stakeholders are asked to evaluate the importance of each impact in the context of its magnitude and geography. Where possible, measures of data quality and variability are provided so that the participants/stakeholders can weigh salience based on data/information certainty. In this way, the IDAM tool integrates information forecasting of the extent or severity of dam-related

[1] Seven Strategic Priorities (WCD, 2000): Gaining Public Acceptance; Comprehensive Options Assessment; Addressing Existing Dams; Sustaining Rivers and Livelihoods; Recognizing Entitlements and Sharing Benefits; Ensuring Compliance; and Sharing Rivers for Peace, Development and Security.

impacts (both positive and negative), henceforth referred to as the *magnitude* of impact, with information about the significance that stakeholders assign to an impact of a given magnitude, which we refer to as the *salience* of the impact.

Assessing stakeholder perspectives

Assessments of salience are likely to vary across different stakeholder groups in ways that reflect how dams relate to various groups' objectives and/or constituencies. As such, salience data may be used to demonstrate how different groups of stakeholders perceive the consequences of development alternatives, providing a loose narrative that describes how diverse groups are affected, whether positively or negatively. As salience is evaluated during the assessment of options, stakeholders are fundamentally part of the decision-making process, a key strategy identified by the WCD for gaining public acceptance of a project. Furthermore, through alternatives assessment, the IDAM helps to articulate where the costs and benefits of a project are believed to accrue. This information feeds naturally into the WCD-recommended processes of recognising the entitlements of various stakeholder groups and determining how to best share the benefits of selected projects.

The objective of the analysis presented in this paper is to evaluate how views vary across stakeholder groups and across dam development scenarios. Specifically, we ask: How do different stakeholder groups perceive the salience and magnitude of dam projects? How do those views change across three hypothetical but policy-relevant dam scenarios? Based on the experience of big dam construction in the US, we anticipate that academics and NGOs will be critical of dam construction or more cognisant of the multifaceted costs of dam construction. Further, we anticipate a great diversity of views on the cumulative impacts of small dams due to the limited public awareness of the number and characteristics of the projects.

VARIABILITY IN STAKEHOLDER PERSPECTIVES: CASE STUDY IN YUNNAN PROVINCE, CHINA

To evaluate the diversity in perspectives around dam impacts, we applied the IDAM framework to hypothetical dam development scenarios and surveyed dam experts in Yunnan Province, China, as a case study, evaluating the applicability and utility of assessing stakeholder salience within the IDAM.

Attendees of the International Conference on the Impacts of Dams, held in the Yunnan provincial capital, Kunming, in July 2009, participated in surveys pertaining to the magnitude and salience of three potential dam development scenarios. To allow for the most open discussion, fifteen water and hydro development experts were divided into three private workshop discussions as follows: professionals representing engineers, public officials and the hydroelectricity industry; representatives of environmental and civil society non-governmental organisations (NGOs); and members of the academic community. Classifications were based on the individual attendee's *danwei*, or official work unit.

Each workshop included 1) a general introduction to the project; 2) some open discussion about the impacts of dams and how to gauge them; 3) surveys on the views of dam impacts generally; 4) a presentation of simulated impacts for two hypothetical dam development scenarios (described below); and 5) a second survey regarding dam impacts for the presented scenarios. In the surveys, individuals in each expert group were asked to indicate, on a 5-point scale, their perceived salience of each of the 21 indicators for each of the dam development scenarios. Impacts perceived as being negative were evaluated on a scale of 0 (no importance) to -4 (maximal importance), while impacts perceived as being positive were evaluated on a scale of 0 (no importance) to +4 (maximal importance).

Table 1. IDAM impacts and indicators.

Biophysical			
Impact name	Positive scope of impact	Negative scope of impact	Indicator
BP1: Water quality	Reservoir may store heavy metals, pesticides and PCBs, preventing downstream contamination.	Reservoir may change the cycling of nutrients and carbon, decrease dissolved oxygen and total suspended solids, alter diel and seasonal temperature patterns and affect the growth of periphyton, which will impact fisheries and water supplies.	Change in residence time through reservoir reach.
BP2: Biodiversity	Reservoir may create potential habitat or reduce competition or predation for rare/endemic species.	Lotic and terrestrial habitats of rare or endemic species may be destroyed; migration routes may be interrupted.	Index of habitat quality- habitat classification of affected areas, species occurrence, changes to hydraulic habitat.
BP3: Impact area	Reservoir may create potential habitat or reduce competition or predation for rare/endemic species.	Aquatic, riparian and terrestrial habitats for endemic or rare species may be disturbed or destroyed.	Index of habitat quantity- surface area of the reservoir, length of river impounded
BP4: Sediment	Reservoir may store anthropogenic sources of sediment and decrease turbidity and sediment aggradation downstream.	Reservoir may disrupt natural longitudinal sediment movement; downstream channel may degrade; downstream grain size distribution may change; depositional features (bars, islands, deltas) and channel morphology (width, depth, sinuosity) may change. These changes may result in habitat loss, streambank instability and impacts to water infrastructure.	Trap efficiency of dam, percentage of basin that contributes sediment to the dam.
BP5: Natural flow regime	Dam may reregulate altered flows (if dam is mostly downstream of a series of dams).	Dam may change historic hydrograph – magnitude, duration, timing, and frequency of high and low flows; may cause downstream degradation/aggradation or changes to channel morphology, migration or spawning cues, substrate conditions, condition of riparian vegetation. Because flow is considered the "master" variable (Poff et al., 1997) in regulating ecosystems, negative ecological impacts of flow modification are extensive.	Measured as changes to flood frequency and low baseflows when flow data available; alternately defined as by carryover storage – (0) run of river (1) seasonal storage (2) annual storage and (3) multiple year storage.
BP6: Climate change and air quality	Generation of hydropower may reduce emissions of greenhouse gases (GHG) and particulates; may improve local air quality.	Methane emissions due to decomposing organic material in some reservoirs may offset a portion of GHG saved by hydropower production.	Amount of GHG emitted from equivalent MW of coal power generation, energy density (MW/unit area of reservoir).

BP7: Landscape stability		Reservoir may induce seismicity, while road construction may increase landslide potential.	Weight and depth of reservoir, distance to faults, landslide hazard, grade of slopes, erosivity of soils.
Socioeconomic			
Impact name	Positive scope of impact	Negative scope of impact	Indicator
SE1: Social capital	Dams may facilitate transportation across rivers, integrating less accessible portions of communities with the rest of the community.	People from one community may be resettled into multiple new communities, disrupting social cohesion.	Buckner Scale, based on household surveys, qualitative interviews.
SE2: Cultural change	Dams may instil national pride.	Inundation of tombs, religious sites and other areas of cultural significance; loss of traditional knowledge regarding the ecosystem.	Index of impacts on material culture; knowledge of the local ecosystem; sense of place from household surveys and community surveys.
SE3: Local hydropower access	Communities that were once isolated or that relied on small hydro or alternative forms of electricity generation may be connected to the grid.	Prices of electricity may rise as the source of power may be further away.	Index of frequency and price from household surveys and community surveys.
SE4: Health impacts	Water treatment facilities may improve the quality of drinking water.	The prevalence of schistosomiasis and malaria and other water-borne diseases may increase as the breeding grounds for hosts increases.	Index of drinking water quality, water-borne illness, toxicity from household surveys and community surveys.
SE5: Income	Incomes may rise as off-farm opportunities working on dam construction arise; government transfers.	Inundation of agricultural land may imply reduced incomes for farmers.	Income share of watershed average from household surveys, community surveys and State Statistical Bureau data.

SE6: Wealth	The quality of housing and/or land in resettlement communities may exceed that in the affected area.	Evacuees may deplete resources while re-establishing themselves in resettlement communities.	Housing and land values, as a share of watershed average from household surveys, community surveys, and State Statistical Bureau data.
SE7: Macro impacts	New roads and other forms of infrastructure for dam development may have positive spillovers for tourism and other industries; money spent on dam construction may dramatically increase local economic activity; benefit of flood protection.	Resettlement of displaced peoples may be costly.	Index of the cost of resettlement, costs of infrastructure and present commercial value of hydropower produced from community surveys and State Statistical Bureau data.

Geopolitical

Impact name	Positive scope of impact	Negative scope of impact	Indicator
GP1: Basin population affected	Dam provides benefits to basin residents such as hydropower, irrigation, navigation, water improvements and employment.	Dam creates costs to basin residents such as loss of cropland, forced resettlement, damage to fisheries or loss of livelihood.	Share of basin population affected either positively or negatively as a percentage of entire basin population.
GP2: Political complexity	Basin-wide management may increase dialog that fosters improved inter-jurisdictional relations.	Basin-wide management may lead to greater tensions among riparians and reduce efficiencies.	Number and type of boundaries crossed.
GP3: Legal framework	Strong laws help mitigate the impacts of change; existing basin agreements and associated river basin organisations help reduce vulnerability throughout basin.	Laws and other institutions are weak or non-existent and insufficient to mitigate negative impacts or reduce vulnerability.	Administrative level of highest legal framework governing dam site (e.g. international, county-level).

GP4: Domestic governance – civil society (Democracy Index)	Decision processes are open and transparent; governmental management capacity is robust; civil dialogue is open and active.	Decision processes are closed and obfuscated; governmental management capacity is limited; civil dialogue is limited/constrained.	Democracy Index.
GP5: Political stability (intra-national)	Cooperation during planning, construction and operation phases leads to the establishment or strengthening of internal institutional arrangements, and promotes improved relations among relevant administrative areas.	Lack of cooperation during planning, construction and operation phases, or other conflicts related to project, increases tensions in relations among relevant internal administrative areas.	Internal BAR scale.
GP6: Political stability (international)	Cooperation during planning, construction, and operation phases leads to the establishment or strengthening of institutional arrangements, and promotes improved relations among relevant international administrative areas.	Lack of cooperation during planning, construction and operation phases, or other conflicts related to project, increases tensions in relations among relevant international administrative areas.	International BAR scale.
GP7: Impacts on non-constituents	Dam construction provides positive impacts for individuals and communities outside the immediate area of the dam.	Dam construction causes negative impacts for individuals and communities outside the immediate area of the dam.	Index of spatial extent and magnitude of impacts based on reports from media, hydropower companies, government and NGOs.

Because hydropower and other objectives of dam construction can be met in various ways – for instance, by building large dams across the main stem of a river or multiple smaller dams on tributaries – the second survey was designed to capture the perceived salience of impacts for many small hydropower stations relative to one large station. Thus, we were able to not only evaluate differences in the perceived benefits and costs of dams across stakeholder groups, but also to evaluate how the perceptions of impacts differ for one large dam relative to the cumulative impacts of many smaller dams. Finally, the surveys provided an opportunity to investigate the application of the IDAM for various dam scenarios. The results below derive from an analysis of the survey data collected at this meeting of experts.

Dam scenarios: Hydropower policy in China

China is a world leader in small and large hydropower projects, and is home to the planet's largest hydropower potential at approximately 384 GW. The country has a rich dam building history, with roughly 20,000 large dams (half the world's total), a staggering number of smaller dams and numerous research and design institutes for hydropower development. Depending on factors such as size, generating capacity or location, a particular project may fall under the jurisdiction of different levels of government or multiple bureaucracies at the same level. Thus, while large-scale projects requiring significant capital investment, complex financing, multiple layers of contractors and subcontractors and long construction periods will likely necessitate national-level oversight throughout the planning, bidding, construction and operation phases, smaller projects might only require approval at the county, municipal or province level.

Thus, policies designed to support hydropower development in China are formulated at different levels and target projects of different scales in order to address a wide array of needs. Here, the 'scale' of a project refers both to the technical scale of a dam (e.g. its installed capacity or height) and the reach of its impacts (e.g. how broad an area or large a population will receive irrigation, hydropower or flood control benefits, or experience fisheries or water quality declines). For example, proposed and existing large dams on the Lancang and Nu Rivers in south-western China are supported by a number of national-level policies. Chief among these is the Western Development Campaign (*xibu dakaifa*), officially instituted in 2001 and ostensibly designed to help reduce the disparity in levels of development between interior western provinces and coastal China. Included among the infrastructure prioritised by the campaign are numerous large-scale electrification projects, including hydroelectric dams (National Development and Reform Commission, 2009). Similarly, policies such as Send Western Electricity East (*xidian dongsong*) and Send Yunnan Electricity to Guangdong (*Diandian Yuesong*), which fall under the overall Western Development framework, call specifically for the development of generation sites in the west, where potential hydroelectric stocks are the greatest yet least developed. Power generated there can be sent to load centres in the east via long-distance ultra-high-voltage transmission lines. Other policies include the Rural Electrification Program (*nongye dianqihua*), in place in one form or another since the beginning of the reform period in 1979, which promotes smaller and more local hydropower development. Such policies are articulated by the provincial- and lower-level offices of central ministries.

Simultaneously, local governments in China also formulate their own economic development policies, including those regarding hydropower. According to interviews with officials at the Ministry of Water Resources in Beijing, overseeing local projects is left up to the relevant local authorities in the geographic and administrative jurisdictions affected. For example, if a particular dam is designed to be built entirely within one jurisdiction, then the project must be approved only at that level. If, however, a project involves two jurisdictions of the same bureaucratic rank (e.g. two counties or county-level municipalities), then the project must be approved by the relevant bureaucracy (-ies) at the next highest administrative level (in this case, at the municipality or province level). One important exception to this general rule involves large dams on important (*zhuyao*) rivers, of which both the

Lancang and Nu are examples given their transprovincial and transnational courses. For these two rivers and others like them, even though all planning, design and impact studies are supposed to be overseen by the relevant basin commission (in this case, the Yangtze River Water Resources Commission), final authority to approve or reject a dam rests with the State Council and the National Development and Reform Commission (NDRC) (Magee, 2006).

In theory, any dam built in China is subject to a final check by one of the seven basin commissions, in order to ensure that the dam fits with the comprehensive plans for that particular basin. In practicality, though, it is not always feasible to provide this kind of careful, multi-layered scrutiny for the thousands of dams proposed and built on the countless smaller rivers and tributaries in the seven basins. And while broad directions for hydropower development may be set at the national level, local authorities retain a great deal of latitude in building smaller projects that they deem to fit within those guidelines, and which do not fit the 'large dam' or 'primary river' criteria described earlier.

We developed two hypothetical scenarios to represent this continuum of governance and project scales. The first of these is a single large dam scenario that would receive higher-level approval, while the second involves a series of small tributary hydro development projects that together provide a comparable amount of energy relative to the large dam scenario, yet would be evaluated at a much lower governance level. That is, the large dam scenario (table 2) would be reviewed at the national level by the relevant basin commission and just as likely by the NDRC and the State Council (especially in the case of a transboundary river). The multiple small dams scenario (table 3), would likely be reviewed at the very least by county-level authorities, and at most by their provincial-level counterparts.

The purpose of comparing the scenarios is thus not to equate them, but instead to evaluate stakeholder perspectives on their magnitude and salience, and to explore the challenges of evaluating the impacts of the two scenarios, including interdisciplinary and cumulative impacts. In addition, we also surveyed stakeholders prior to defining the scenarios to capture perspectives on the salience of dam impacts in general and to evaluate how knowing details about the projects influences stakeholder views. For this general contexts survey, experts were asked only to rate the salience, as no magnitude information was provided.

To compare directly perspectives on the two hydropower development policies, stakeholders were provided with specific information about the objective magnitudes for the 21 impacts of dam construction for each of two scenarios – a single large dam across the main stem of a river or several small dams on the river's tributaries – as shown in tables 2 and 3. Based on this information, stakeholders categorised the magnitude of each impact. Using a scale similar to salience, magnitude of potentially negative effects were scored from 0 (no negative effect) to -4 (maximal negative effect), while potential positive benefits were scored from 0 (no positive effect) to +4 (maximal positive impact). The scores were summed for each participant; the figure reports the average summation for participants in each stakeholder group.

Table 2. Large dam scenario. Data in distilled format as presented to stakeholders.

Biophysical impacts	Objective measure
BP1: Water Quality (retention time)	One-year retention time.
BP2: Biodiversity (habitat quality for rare/endemic species)	Four migratory fish species affected, 3 diversity hotspots inundated, increased habitat for amphibians and Asian carp.
BP3: Impact Area (habitat quantity)	300 km² and 160km river impounded
BP4: Sediment (trap efficiency and percent of basin contributing to dam)	99% trap efficiency, 30% of basin blocked.
BP5: Natural Flow Regime (change to floods and baseflows)	Flows over 6 RYI trapped, baseflow increased by 400%.
BP6: Climate Change and Air Quality	Net 2.4 million tonnes of CO_2 'saved'.

(CO_2 equivalent of coal)	
BP7: Landscape Stability (distance to faults, landslide hazard)	27 active and potentially active landslides >20m³, 4 km from faults.
Socioeconomic impacts	**Objective measure**
SE1: Social Cohesion (Buckner Scale)	30% of people are resettled from villages into towns, disrupting social networks (including labour sharing and money lending).
SE2: Cultural Change (index of impacts on material cultural; knowledge of the local ecosystem; sense of place)	40 villages will lose cultural sites, including tombs, archaeological sites and present temple site.
SE3: Local Hydropower Access (index of frequency and price)	Availability increased to 24 hrs/day, but price increased 20%.
SE4: Health Impacts (index of drinking water quality, water-borne illness, toxicity)	10% more cases of schistosomiasis and malaria; 40% of people must walk 2 km for drinking water.
SE5: Income (as a share of watershed average)	Income inequality increased 20% because some people work at dam site, while farmers' land quantity and quality decreased.
SE6: Wealth (housing and land values, as a share of watershed average)	Liquid wealth has increased to exceed provincial average, because of compensation from government and hydro companies.
SE7: Macro Impacts (index of the cost of resettlement, costs of infrastructure and present commercial value of hydropower produced)	(Value of hydropower + increased mining access) – (cost of resettlement and infrastructure) = +4%.
Geopolitical impacts	**Objective measure**
GP1: Share of basin population affected	1%
GP2: Political boundaries	Basin crosses five international boundaries, two provincial and ten county boundaries within the country of interest.
GP3: Share of watershed covered by treaties or River Basin Organisation (RBO)	80% but not the two upstream countries.
GP4: Domestic governance – internal (Democracy Index)	Standard decision-making process in China.
GP5: Historical stability/tensions	Concern expressed and organised over environmental and social impacts. Support from provincial and national interests for hydropower.
GP6: Domestic governance – international/other riparians (Democracy Index)	Downstream neighbours vary in level of democracy, from military government to constitutional democracy.
GP7: Impacts for non-constituents	Potential hydropower market, greater transportation network and flood control. Some concern over loss of nutrients, fisheries and vulnerable hydrology.

Table 3. Small dams scenario. Data in distilled format as presented to stakeholders.

Biophysical impacts	Objective measure
BP1: Water Quality (retention time)	No change in retention time.
BP2: Biodiversity (habitat quality for rare/endemic species)	No migratory fish species, no biodiversity hotspots directly affected but possibly affected, no clear benefits to natural value.
BP3: Impact Area (habitat quantity)	4 km^2 and 1km impounded.
BP4: Sediment (trap efficiency and percent of basin contributing to dam)	0% trap efficiency, 20% of basin blocked by each structure.
BP5: Natural Flow Regime (change to floods and baseflows)	No flood flows stored, baseflow essentially zero below dam.
BP6: Climate Change and Air Quality (CO_2 equivalent of coal)	Net 2.6 million tonnes of CO_2 'saved'.
BP7: Landscape Stability (distance to faults, landslide hazard)	64 active and potentially active landslides <20m^3, 1 km from faults but little potential for seismic activity.
Socioeconomic impacts	**Objective measure**
SE1: Social Cohesion (Buckner Scale)	5% of people are resettled from villages into towns, disrupting social networks (including labour sharing and money lending).
SE2: Cultural Change (index of impacts on material cultural; knowledge of the local ecosystem; sense of place)	20 villages will lose tomb sites.
SE3: Local Hydropower Access (index of frequency and price)	Availability increased to 24 hrs/day, price decreased by 15%.
SE4: Health Impacts (index of drinking water quality, water-borne illness, toxicity)	No direct health impacts.
SE5: Income (as a share of watershed average)	Reduction in irrigation water for 60 villages, decreased crop yields.
SE6: Wealth (housing and land values, as a share of watershed average)	Lump sum payments for appropriated land.
SE7: Macro Impacts (index of the cost of resettlement, costs of infrastructure and present commercial value of hydropower produced)	(Value of hydropower) – (cost of resettlement and infrastructure) = +5%.
Geopolitical impacts	**Objective measure**
GP1: Share of basin population affected	Negligible.
GP2: Political boundaries	Basin crosses five international boundaries, two provincial and ten county boundaries within the country of interest.
GP3: Share of watershed covered by treaties or River Basin Organisation (RBO)	80% but not the two upstream countries.
GP4: Domestic governance – internal (Democracy Index)	Standard decision-making process in China.
GP5: Historical stability/tensions	Good communication with other riparians, some downstream concern about dam operations.
GP6: Domestic governance – international/other riparians (Democracy Index)	Downstream neighbours vary in level of democracy, from military government to constitutional democracy.
GP7: Impacts for non-constituents	Little awareness of issue outside of local impacts.

Results

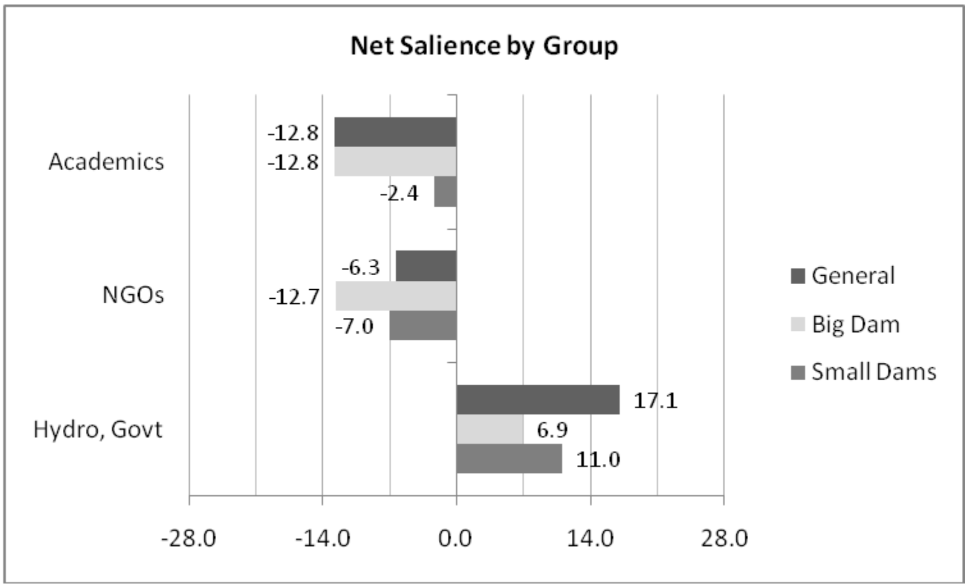
The results of the surveys are organised in a number of ways to illustrate patterns in stakeholder views of dam impacts. In addition, insights gained from the qualitative analysis of participants' comments during the workshop help interpret and contextualise these ratings.

Differences in salience across scenarios and stakeholder groups

Stakeholders evaluated the importance of 21 different impacts associated with dams; note that no details about the dams (e.g. size, number) were provided for the general scenario, such that these surveys reflect feelings about dams in general. Scores were summed for each participant; the figure reports the average summation for participants in each stakeholder group. The process was repeated for two more specific scenarios – a single large dam across the main stem of a river and for several small dams along tributaries.

Figure 1 displays 'net salience', derived by subtracting the salience of negative impacts from the salience of positive aspects. The combined results of all 21 indicators are averaged across all members of each group. Positive net salience indicates that the stakeholder felt the benefits of dams were more important than the costs, while negative net salience indicates that s/he felt the costs held more significance than the benefits.

Figure 1. Net salience of impacts of dams in general and two potential dam development scenarios by stakeholder group.



On average, academics and NGOs believed that the salience of the negative impacts of dams exceeded that of the positive aspects. In contrast, representatives from hydropower companies and government considered the salience of positive aspects of dam construction to be greater than the negative aspects. Further, academics and members of the NGO community viewed the negative impacts of one large dam to be more important than those from a series of small dams, while hydropower and government officials considered the positive impacts of small dams to exceed those of a single large.

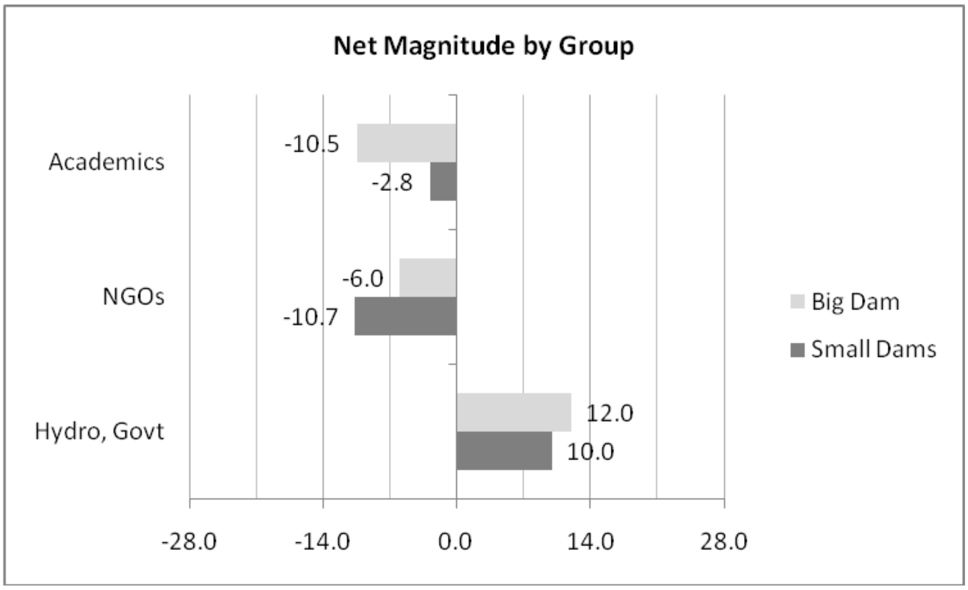
In comparing this general scenario to the Big Dam and Small Dams scenarios (figure 1), information about the magnitude of specific impacts had a varied response on modifying the importance of dam impacts. For academics, the large dam scenario was similar to the general scenario, while impacts of the small dams scenario were considered to be much less important. This suggests that the academics tended to think of large hydro development projects in considering dams generally. For NGOs, information about the large dam scenario greatly increased their view of the importance of impacts, with a smaller increase for small dams. In contrast, officials from hydropower companies and the government viewed the importance of dam impacts to be high in general, yet the net salience decreased as they considered context-specific scenarios, with the impacts of large dams being of less overall importance than those of small dams.

Comparing hydro development policies: Variability in magnitude and salience across stakeholder groups

As with salience, academics and members of the NGO community ranked the negative effects of dam construction, independent of importance, to exceed the positive effects, while the opposite was true for hydropower officials and government authorities (figure 2). Of the three groups, only NGO representatives found the small dams to have greater impacts than the large dam scenario.

Academics tended to view the magnitude of impacts for large dams to be much greater than those of small dams, whereas NGO representatives viewed the magnitude of impacts as being *smaller* for large dams than for the cumulative effects of smaller dams. For hydropower and government officials, large dams had a slightly larger positive impact than small dams.

Figure 2. Net magnitude of impacts of two potential dam scenarios by stakeholder group.



A more nuanced story is revealed by decomposing the overall impacts into biophysical, socioeconomic and geopolitical areas. Figure 3 disaggregates stakeholders' views of salience (top two panels) and magnitude (bottom two panels) from figures 1 and 2 according to the three pillars of sustainability, as well as the aggregate costs (left side of each panel) and aggregate benefits (right side of each panel) for each pillar.

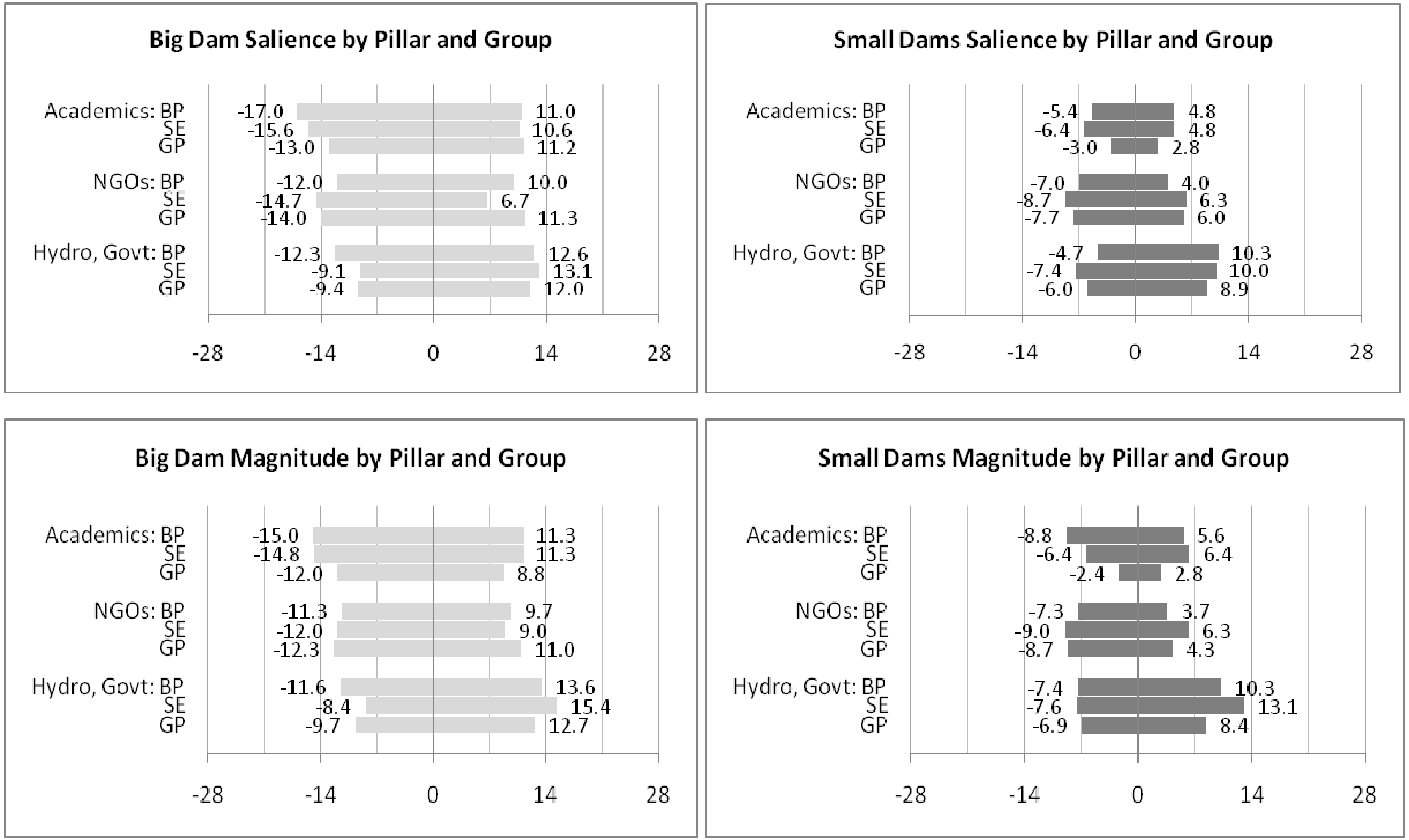
Regarding differences in perceived magnitude, all groups appear to be more concerned about all pillars of impacts for large dam construction (measured in net terms) than the cumulative impacts of many small projects. By pillar, academics tended to perceive biophysical and socioeconomic impacts to be greater than geopolitical impacts for both dam scenarios, with negative impacts perceived to be greater in magnitude than positive impacts for the large dam scenario. For both large and small scenarios, socioeconomic and geopolitical impacts of the small dam scenario were perceived to be smaller, both negative and positive, than biophysical impacts by academics. For both biophysical and socioeconomic pillars, NGOs found the negative and positive impacts of large dams to be smaller than academics, and the benefits to be smaller than perceived by hydropower officials. Socioeconomic impacts, both positive and negative, were perceived to be the greatest of the three pillars for the small dam scenario for NGO representatives. Of all groups, hydropower representatives and government officials perceived the greatest benefits and least negative impacts of the large dam scenario, but found some negative impacts of the small dams scenario to be of higher magnitude than academics. Notably, this group considered the net benefits and costs of both dam scenarios to generally accrue in the socioeconomic arena.

Regarding stakeholder views on salience, like magnitude, the importance of cumulative effects around many small dams was considered smaller than a large dam across all pillars and for all stakeholder groups. For all pillars in both dam scenarios, the negative effects were more important to academics and NGO representatives than the positive effects. Academics weighted the importance of the negative biophysical impacts of large dams most heavily, as well as the importance of the negative socioeconomic impacts of a series of small dams. The NGO community found the negative socioeconomic impacts of both large and small dams to be paramount in importance. Notably, this group also considered the importance of socioeconomic benefits to be lower than the importance of biophysical and geopolitical benefits. Representatives of hydropower companies and the government considered the negative biophysical impacts of large dams to be much more important than those of socioeconomic and geopolitical impacts. In contrast, this group rated the salience of biophysical impacts to be the least for the small dams scenario.

Investigation of the objective magnitudes described in tables 2 and 3 in the form of a 5-point scale demonstrates that different stakeholder groups view the objective impacts of dams very differently. For example, the average negative score for each of the seven geopolitical impacts of small dams among academics was 0.34 (between 'no impact' and 'low impact'), while representatives of NGOs assessed these GP impacts with an average score of 1.24 (between 'low impact' and 'moderate impact'). Similarly, hydropower representatives and government officials scored the socioeconomic costs of large dam development as 1.20 (between 'low impact' and 'moderate impact') in magnitude, whereas academics scored the same effects as 2.11 (between 'moderate impact' and 'severe impact') in magnitude.

Some interesting contrasts emerge from these surveys. For example, in the large dam scenario, members of the NGO community tended to view socioeconomic impact magnitudes and importance to be lower than biophysical impacts, and lower than were ranked by academics; however, the opposite relationship appears to hold for small dams. This is interesting, particularly since most NGO representatives in attendance were from organisations that specialised in environmental conservation, not cultural preservation or a related socioeconomic mission. Further, the view of higher magnitude and importance for socioeconomic impacts in small hydropower development, over large mainstream projects, is not commonly expressed.

Figure 3. Salience and magnitude for big and small dams across disciplines.



In another example, hydropower and government officials viewed socioeconomic impacts to be of greatest importance, but tended to view the potential benefits associated with these impacts as more important than the potential costs. This may reflect the recent history of dam construction in China, which has led to the displacement of some 15 million people since 1949 and has been, in part, driven by policies that promote dam development as a key way to improve the socioeconomic conditions of people, despite the potential for negative outcomes. These officials are part of the overall development policy framework in China, which is fundamentally modernist in its outlook and seeks to provide high rates of economic growth and improve living standards through large-scale development projects. A common slogan from Deng Xiaoping, the architect of China's recent economic reforms, holds that "Development is the indisputable truth" (Tilt, 2010). However, massive resettlement and a limited legal framework for ensuring public participation in the decision-making process may be represented in the acknowledgement of negative impacts over large development projects.

Further, and taken together, these results show not only that different stakeholder groups view the importance of different dam impacts differently, but also that they evaluate the magnitude of the same objective data differently.

Qualitative findings

During the workshop, participants were encouraged to share their ideas both in public and in writing on survey forms. Qualitative analysis of participant comments yielded a variety of important viewpoints on: 1) the challenges of interdisciplinary cooperation; 2) the difficulty of standardising data and indictors; 3) accounting for the distribution and potential mitigation of impacts; and 4) evaluating and planning for the cumulative impacts of hydro development.

1. Challenges of integrated dam assessment. Most survey respondents stressed the value of an integrated, transparent process for evaluating dam impacts, such as that afforded by the IDAM tool. This approach is especially valuable in China, where the guidelines for environmental and social impact analysis are often poorly defined. As one workshop participant noted, "Some things are considered important [in EIAs and SIAs], and other things are not". Integrated tools can thus be important in establishing transparency in decision making and in documenting investigations of dam impacts on biophysical, socioeconomic and geopolitical systems.

While valuable, however, such research efforts can be extremely complex and daunting. One representative of an environmental NGO remarked that "Such an assessment is really difficult to do. It takes decades to do a thorough job, and that's why people ignore it".

For example, experts were uncomfortable evaluating impacts outside their area of expertise, inasmuch that geopolitical impacts were viewed generally by all groups to be of smaller net impact and importance than socioeconomic and biophysical impacts. This may reflect some confusion on the part of workshop participants about exactly how dams affect geopolitical systems. One participant, a scientist working in an academic institution, commented that "It's very hard to assess whether the effect [of a dam] on internal governance is good or bad, positive or negative". Another participant, a representative from a conservation-oriented NGO, remarked "I'm confused by geopolitical indicator 6 [governance in other countries]. What does this have to do with dam construction? It's strange". This illustrates how individuals are often influenced by their academic and professional backgrounds, and that salience may vary depending on the discipline of the individual. Furthermore, it suggests a need for a very thorough introduction to impacts and indicators prior to surveying stakeholders.

The comments of two workshop participants are indicative of the fact that many issues are now of primary concern. One official from a large hydropower development company said that "When we think about the effects of a dam, we've got to consider several areas. The first is inundation of land and relocation of people. The second is the effects on the environment". Another participant, an official from one of China's largest state-owned power generation enterprises, agreed that "On the socioeconomic side, the relocation problem is key. China is a country with little land and a huge population. It's difficult to give land to resettled people. Cultural protection, especially for minority cultures, is important. It's a national priority".

These comments serve to underscore the importance of conducting interdisciplinary dam assessments. Natural scientists and social scientists have traditionally used their own disciplinary training to study the effects of dam construction, yet dams lie at the nexus of biophysical, socioeconomic and geopolitical relations, and an impact in one area is thus likely to have repercussions for others. For example, the adverse effects of dams on ecosystems, hydrology and water quality (Salazar, 2000) often disrupt cultural conditions and economic institutions (Scudder, 2005; Cernea, 2003), and also influence relationships between communities, regions or nations (Wolf, 2003).

2. Standardising data and indicators. As with any model, the IDAM tool requires careful consideration of the reliability and validity of the data used, the assumptions required for the model structure and the most effective techniques for reporting results. Especially in China, compiling datasets can be problematic, as data, if available, is often collected from multiple locations or gathered by multiple agencies. One workshop participant, a representative from an environmental NGO, pointed out that "If you collect some data in one place and other data from another place, how can you standardise it"?

This question is particularly relevant to work in China, where data access and quality can be limited. In an ideal setting, a research team would collect all of the data themselves, using the IDAM framework as a template for minimal information to assess a project. However, that is rarely feasible, and thus data are developed from multiple sources, often at low resolution and/or with great uncertainty. It is therefore critical that some measure, qualitative or quantitative, of data reliability and uncertainty accompany the analysis.

Regarding model structure, some participants argued that the assignment of weights between each indicator was difficult to resolve. One social scientist in an academic institution noted that "Whether we should give different weights to the different components [biophysical, socioeconomic, and geopolitical] – that is the first question. And who decides the weight"?

This question carries important scientific and policy implications. One representative of an environmental NGO advocated for placing more weight on biophysical indicators such as Natural Value (BP2) when applying the model in ecologically sensitive areas:

> We know that Yunnan is such a small area, but the biodiversity is quite rich. It has as much biodiversity as the entire United States, so we have to pay attention to this unique system. In such a small area, once [biodiversity] is destroyed, you lose millions of years of evolution that you can never get back... Because the biodiversity is so high in a place like Yunnan, it should be rated much higher, because if it's destroyed, we'll never even know what was lost.

The development of weighting criteria in quantitative decision theory is challenging due to the subjectivity of the task. Utility theory (Chechile, 1991; Fishburn, 1968) and the Analytic Hierarchy Process (AHP) (Saaty, 2001; Schmoldt et al., 2001) are examples of multi-objective decision-making frameworks that require weighting of various decision criteria. While methods for weighting criteria in utility theory matrices are unspecified and may vary according to the preferences of the user, the AHP specifies a method for calculating weights, requiring that stakeholders rank decision criteria relative to one another. Expert opinion, for example the Delphi method (Gordon and Helmer, 1964), has also been utilised in weighting objective criteria for decision making (Armour and Williamson, 1988; Smit and Spaling, 1995). With the IDAM instrument, we have taken the philosophy that the weighting decision should be made on a case-by-case basis. For the analysis presented here, we applied an equal weighting of all indicator magnitudes. Weighting is instead represented by the assignment of salience to the indicators by the different stakeholders, which we believe is another weighting approach that also increases transparency. For example, if biodiversity trumps all others, then it will simply receive the highest salience weighting.

3. *Distribution and mitigation of impacts.* Finally, many workshop participants agreed with the need to capture both the distribution of costs and benefits, and the potential for mitigating certain impacts. In regard to impacts' distributions, one representative from an environmental NGO summed up the challenge by stating that "We're talking about impacts, but it's important to know who bears the impacts". Similarly, a scientist from an academic institution suggested that "We've got to consider the benefit-sharing arrangement, the distribution of benefits [from dams]. This includes doing a stakeholder analysis. Who loses and who wins when it comes to property rights, indigenous knowledge and so forth"?

Certain types of negative dam impacts may be mitigated, while the mitigation of others may be infeasible or impossible. An official from one of China's largest state-owned power generation enterprises commented that "We've got to consider how able we are to mitigate certain effects of dams, like ecological impacts. Also, who has the responsibility to mitigate"? This is a particularly difficult challenge in China, and one that varies based on the size and purpose of a given hydropower project. For example, large dams may arguably have a greater impact on local ecosystems, but national laws require at least a nominal environmental impact assessment of such large projects. Meanwhile, dozens of small hydropower projects exist on tributaries which, as a result of their small scale, mostly undergo scrutiny only by county-level officials. Under such limited oversight, mitigation of environmental and social impacts may be compromised. Given that the responsibilities for designing, constructing, operating and regulating hydroelectric dams may fall to literally dozens of agencies and companies, determining responsible parties and holding them accountable in cases of negative impact mitigation becomes acutely important.

4. *Cumulative impacts assessment.* The small-scale scenario supports calls (WCD, 2000; Yao et al., 2006) for the assessment of cumulative impacts of hydro development projects. During our surveys, challenges arose in considering how to aggregate impacts from 100 small tributary projects, and concerns arose among workshop participants around the validity of comparing large and small dams. At one level, this concern stems from uncertainty about when such comparisons are meaningful and relevant. Workshop participants expressed concern that large and small hydropower projects may be incommensurable in terms of benefits (e.g. provision and distribution of electrical power) and costs (e.g. displacement of human population, effects on ecosystems). As one participant, a scientist in an academic institution, noted, "You can't just add up 100 small hydropower projects to equal one large dam". In a similar concern regarding mitigation, a scientist in an academic institution noted that "There's no way to capture who's responsible for mitigation. Small dams look better than big dams on many indicators, but no one is accountable, so the actual outcomes can be worse".

Further, given the longitudinal connection of river systems and the fact that dams already exist upstream and downstream of new hydro development sites in south-western China, the need to reconsider that the definition of an environmental and social 'baseline' may be necessary to relate new projects to existing developments for hierarchical, additive and synergistic links is warranted (Wenger et al., 1990). Further, it will be critical to identify what jurisdiction is ultimately responsible for both basin planning and assessing cumulative impacts of hydro development, the benefits of which span multiple basins and jurisdictions.

CONCLUSIONS

Our experience in developing and applying the IDAM tool illustrates some of the important challenges that remain in comprehensively assessing the impacts of hydropower development. This is somewhat troubling, given the time that has elapsed since the WCD report and the rate of dam building around the world, much of which is occurring in data-poor environments. From complicated policies to interconnected and indirect impacts, scientists will need to continue investigating ways to meet the recommendations of the WCD. However, a few key conclusions are beginning to emerge.

First, regardless of which tool is used in the assessment of dam impacts, our results suggest there is an important need to consider stakeholder perspectives, as different groups view both the objective magnitude and subjective salience of impacts differently. This is an important element that should be considered in any decision support tool.

Second, some impacts (e.g. geopolitical) are not as well understood by stakeholders as other impacts. While the structure of the IDAM tool uses bins to provide context for the magnitude of impacts, it is still important to assess impacts, articulate views and document factors in decision making independently for stakeholders from different backgrounds. Further, in addition to this lateral variability in stakeholder views of impacts, we anticipate vertical variability in stakeholder views. That is, particularly in governments that are particularly hierarchical in organisation, such as China, higher level decision makers collectively are likely to have different views than lower level decision makers.

Third, some challenges remain in structuring models to assess and weight cumulative and management/mitigation impacts over space and time. A major challenge is over-structuring the assessment model; flexibility in the model is important to meet the various scenarios under which stakeholders need to articulate information and document decisions about dams.

Fourth, uncertainty due to the scarcity and reliability of information could play an important role in developing stakeholders' perceptions of impacts. Decision support tools can provide an important analysis framework that establishes minimum information requirements and techniques for expressing uncertainty in assessments.

Finally, a key advantage of a decision-support tool like the IDAM is the introduction of more transparency into the decision-making process. When stakeholders and decision-makers are allowed to rate salience as well as magnitude, their value judgements become explicit rather than remaining implicit or invisible.

ACKNOWLEDGEMENTS

We gratefully acknowledge Professors HE Daming and YAN Feng and the Asian International Rivers Centre at Yunnan University for collaborating on the development of the IDAM tool and for planning and hosting the International Conference on the Impacts of Dams in Kunming, China in July 2009. We also would like to thank Francis Gassert, Ying Li, Eddie Schmitt, Qianwen Xu and Yong Zhang for their assistance with data collection and analysis. This work was funded by the National Science Foundation through awards # 0623087 and # 0826752.

REFERENCES

Armour, C. and Williamson, S. 1988. Guidance for modeling causes and effects in environmental problem solving. Biological Report No. 89(4). Washington, DC: Fish and Wildlife Service, U.S. Department of the Interior.

Brown, P.H.; Tullos, D.D.; Tilt, B.; Magee, D. and Wolf, A.T. 2009. Modeling the costs and benefits of dam construction from a multidisciplinary perspective. *Journal of Environmental Management* 90(S3): 3-11.

Cernea, M.M. 2003. For a new economics of resettlement: A sociological critique of the compensation principle. *International Social Science Journal* 55(175): 37-45.

Chechile, R.A. 1991. Probability, utility, and decision trees in environmental decision analysis. In Chechile, R.A. and Carlise, S. (Eds), *Environmental decision making: A multidisciplinary perspective*, pp. 64-91. New York: Van Nostram Reinhold.

Dingwerth, K. 2005. The democratic legitimacy of public-private rule making: What can we learn from the World Commission on Dams? *Global Governance: A Review of Multilateralism and International Organizations* 11(1): 65-83.

Dubash, N.K.; Dupar, M.; Kothari, S. and Lissu, T. 2002. A watershed in global governance? An independent assessment of the World Commission on Dams. *Politics and the Life Sciences* 21(1): 42-62.

Fishburn, P.C. 1968. Utility Theory. *Management Science* 14(5): 335-378.

Gordon, T. and Helmer, O. 1964. Report on a long range forecasting study. Santa Monica, CA: RAND Corporation.

Koch, F. 2002. Hydropower – The politics of water and energy: Introduction and overview. *Energy Policy* 30(14): 1207-1213.

Magee, D. 2006. New energy geographies: Powershed politics and hydropower decision making in Yunnan, China. PhD thesis. University of Washington, Seattle, United States.

McCully, P. 2001. The use of a trilateral network: An activist's perspective of the formation of the World Commission on Dams. *American University International Law Review* 16(6): 1453-1475.

Mokorosi, P. and van der Zaag, P. 2007. Can local people also gain from benefit sharing in water resources development? Experiences from dam development in the Orange-Senqu river basin. *Physics and Chemistry of the Earth* 32(15-18): 1322-1329.

Saaty, T.L. 2001. Fundamentals of the analytic hierarchy process. In Schmolt, D.L.; Kangas, J.; Mendoza, G.A. and Pesonen, M. (Eds), *The analytic hierarchy process in natural resource and environmental decision making*, pp. 15-36. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Salazar, J.G. 2000. Damming the child of the ocean: The Three Gorges project*. The Journal of Environment and Development* 9(2): 160-174.

Schmolt, D.L.; Kangas, J. and Mendoza, G.A. 2001. Basic principles of decision making in natural resource and the environment. In Schmolt, D.L.; Kangas, J.; Mendoza, G.A. and Pesonen, M. (Eds), *The analytic hierarchy process in natural resource and environmental decision making*, pp. 1-14.Dordrecht, the Netherlands: Kluwer Academic Publishers.

Scudder, T. 2005. *The future of large dams: Dealing with social, environmental, institutional and political costs*. London: Earthscan.

Simonovic, S.P. and Fahmy, H. 1999. A new modeling approach for water resources policy analysis. *Water Resources Research* 35(1): 295-304.

Smit, B. and Spaling, H. 1995. Methods for cumulative effects assessment. *Environmental Impact Assessment Review* 15(1): 81-106.

Tilt, B. 2010. *The struggle for sustainability in rural china: Environmental values and civil society.* New York: Columbia University Press.

Turner, B.L.; Matson, P.A.; McCarthy, J.J.; Corell, R.W.; Christensen, L.; Eckley, N.; Hovelsrud-Broda, G.K.; Kasperson, J.X.; Kasperson, R.E.; Luers, A.; Martello, M.L.; Mathiesen, S.; Naylor, R.; Polsky, C.; Pulsipher, A.; Schiller, A.; Selin, H.; Tyler, N. 2003. Illustrating the coupled human-environment system for vulnerability analysis: Three case studies. *Proceedings of the National Academy of Science of the United States of America* 100(14): 8080-8085.

UN Committee on Economic Development. 1993. *Agenda 21*. New York: United Nations Publications.

Ünver, O. 2008. Global governance of water: A practitioner's perspective. *Global Governance: A Review of Multilateralism and International Organizations* 14(4): 409-417.

van der Zaag, P.; Kunstmann, H.; Rosbjerg, D.; Uhlenbrook, S.; van de Giesen, N. and Mul, M. 2009. Integrated water resources assessment, with special focus on developing countries. Special issue. *Physics and Chemistry of the Earth* 34(4-5): 209-340.

Wenger, R.B.; Wang H. and Ma X. 1990. Environmental impact assessments of the People's Republic of China. *Environmental Management* 14(4): 429-439.

Wolf, A.T.; Yoffe, S.B. and Giordano, M. 2003. International waters: Identifying basins at risk. *Water Policy* 5(1): 29-60.

WCD (World Commission on Dams). 2000. *Dams and development: A new framework for decision-making*. London: Earthscan.

Yao, Y.; Zhang, B.; Ma, X. and Ma, P. 2006. Large-scale hydroelectric projects and mountain development on the upper Yangtze river. *Mountain Research and Development* 26(2): 109-114.