FLOOD MANAGEMENT FROM THE PERSPECTIVE OF INTEGRATED WATER RESOURCE MANAGEMENT

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Introduction

From the Dublin conference (ACC/ISGWR 1992) onwards, it has been accepted that sustainable development requires the integrated management of land and water across each catchment. However, this leaves two questions:
1. How can we actually do it? And, in the case of the risk of flooding,
2. What are the implications for flood management?

Here, I will concentrate upon the second question.

Integrated Water Resource Management

The Associated Flood Management Programme of the World Meteorological Organisation and Global Water Partnership (2002) has suggested that there are a number of implications for flood management. he first of these is to recognise that the catchment is a system. If we consider the functioning of the catchment; it is a dynamic system in which there are exchanges and movements of sediment, water and pollutants between the land and water bodies that make up the catchment (**Figure 1**). As a system, it is dynamic across both the spatial and the temporal dimensions as it responses to the various disturbances that affect the system. Because it is a dynamic system, we should be concerned with the catchment's response under the whole range of conditions and not just to the characteristics of its response under some conditions: those that give rise to a risk of flooding. Just for the moment looking only at the variations of water quantity, we have to avoid arbitrarily partitioning this variation into 'droughts', 'water resources' and 'floods' (**Figure 2**). In particular, in arid climates, floods are the water resource. Instead, we have to decide how best to manage the overall functioning of the catchment, with the added complication that the response of the catchment in terms of water quantities necessarily also affects the flows of sediment and pollutants. Rather than reacting to perceived local problems, 'floods', we will move to looking for opportunities to improve, in the widest sense, the functioning of the catchment.

Figure 1 Flows and exchanges within a catchment
(Source: Green et al 2002)

The extreme flows that we deem to be floods have to be managed in this wider context because we have a food crisis. There are no unresolvable problems with supplying the quantities of water needed for domestic purposes; there are, however, major problems with supplying the water needed for food, whether this water is provided directly as rainwater or indirectly through rainwater harvesting or irrigation. Potable water demand presents no critical problem for three reasons:
1. The amounts required are so small: 40 m^3 of water per person per year is adequate for domestic purposes whereas producing the food for that person requires 1,000 to 2,000 tonnes per year, depending upon their diet.
2. We get most of the water supplied for domestic purposes back and so it is available for reuse or recycling. Conversely, most of the water used by crops is lost through evapo-transpiration.
3. Towns and cities are very effective systems of rainwater harvesting so that we usually get more water out of cities than we supply to them. Indeed, this is the difficulty – we have both urban surface water drainage and pollution problems as a result of their efficiency as systems of rainwater harvesting.

Figure 2 Managing variation in water quantities
(Source: Green et al 2002)

We have to take a dynamic perspective because the system is subject to dynamic disturbances and responds accordingly. Some of those disturbances are natural; for example, climate variability and seismic activity; we induce others, notably climate change and changes in the land uses across the catchments. Equally, many of the actions that we take are intended to change that dynamic response; however we provide it, the purpose of storage is to change the pattern of flow over the year. In turn, ecosystems develop around the prevailing water regime and hence whatever we do will almost inevitably affect biodiversity.

Some of those disturbances appear to be random (but might, for example, be the result of chaotic processes) but others are cyclical (e.g. climate cycles such as El Niňo), and yet others are trends. When thinking about risks, we need therefore to take a dynamic perspective and look for changes. So, one problem is that if we have fifty years of records of streamflows, the catchment has probably changed significantly over that period.

We need also to take a similar systemic approach to development; the sustainable livelihoods model (Ashley and Carney 1999) offers one way of thinking in these terms (**Figure 3**). Households seek to improve their quality of life by deploying the personal, social and financial resources available to them. At the same time, they are subject to disturbances including floods, droughts and economic depressions. We can then define 'vulnerability' in terms of their capacity to cope with these disturbances, the extent to which they can mobilise sufficient resources to cope with the disturbance. Hence we can reduce their vulnerability either by reducing the challenges they face or by increasing their capacity to cope with those challenges. In consequence, on the one hand, floods may so diminish their resources as to result in a reinforcing cycle of deprivation, or, on the other, they may be vulnerable to floods simply because they are poor; they lack access to resources. In turn, the problem may not be the floods but their general vulnerability, and the most effective way of reducing the effect of floods on those households may lie in reducing their poverty. Thus, Rogers et al (1989) argued that the problem in Bangladesh was less one of floods than of poverty and the way to reduce vulnerability was to increase incomes through expanding irrigation. Equally, people choose to live on flood plains because, on balance, the advantages of so doing outweigh the risks of flooding.

Figure 3 Sustainable livelihoods
(Source: after Ashley and Carney 1999)

Problems with IWRM

Integrated Water Resource Management is not enough; indeed, it could become a snare. Water and land management needs to be integrated with other local, regional, national and international policies (**Figure 4**) with which they overlap. Most rivers also reach the sea and there is also general agreement that integrated coastal zone management (OECD 1993) is as important as integrated catchment management, where the coastal zone certainly includes the estuary but also a substantial hinterland. Groundwater is a critical element in water management, including surface water/groundwater exchanges, and land-groundwater interactions are similarly important. But aquifers and catchments do not necessarily coincide, a catchment therefore not being a logical geographic area over which to manage an aquifer. That there should be a national energy policy seems to be an almost self-evident truth; similarly, a coherent national policy for transport is also logically necessary.

In China, 70% of the population is rural. Decisions about the use of water for agriculture will impact on food prices, as well as on rural unemployment and migration to urban areas, and to ignore these linkages might have consequences that outweigh the gains from an integrated catchment management approach. Similarly, the adoption of 'best environmental option' approaches to pollution management results in an 'all media' approach being adopted, as opposed to one that considers only water pollution. In turn, a catchment based approach is not appropriate when considering air or soil pollution.

All these different areas both impact on water management and are impacted by water management. We have therefore to integrate across a whole series of policy areas and not simply land and water management within catchments. It would be fair to describe this as a challenge: it is much easier to call for integration than actually to achieve it.

Figure 4 Integrating catchment management into the wider context

General principles of flood management

Taking such an integrated approach, a number of principles of flood management emerge (Green et al 2000).

Catchment efficiency

Since we are concerned with the functioning of the catchment as a whole, what we are trying to do is to improve the performance of the catchment as a whole; the ratio of the total benefits yielded from activities in the catchment to the total costs incurred to obtain those benefits, where we define both the benefits and costs in the widest sense to include, for example, both agricultural output and biodiversity. It is dangerous, therefore, to look at flood losses in isolation; reducing flood losses does not necessarily mean that performance has improved and annual flood losses should not be used as a performance indicator (Green et al 2000). Indeed, it is relatively easily shown that increases in flood losses are entirely consistent with improvements in efficiency (**Table 1**).

Table 1 **Economic efficiency and floodplain development**
(based upon Green et al 1993)

	Now	**With project**
Gross annual outputs	25	40
loss from flooding	2	4
Net annual outputs	**23**	**36**
Inputs required		
basic	12	14
annual losses from flooding	2	3
cost of adaptations to reduce flood losses	1	4
Total required inputs	**15**	**21**
total annual flood losses	4	7
total annual flood adaptation costs	1	4
ratio of outputs to inputs	**1.53**	**1.71**
net gain (outputs - inputs)	**8**	**15**
ratio of basic outputs to basic inputs	2.08	2.86
incremental change in flood losses	-3	
incremental change in flood adaptation costs	3	

Managing all floods and not just some

The concept of designing to some 'design standard of protection' is a dangerous snare; we have instead to think about how we will manage all floods, even the most extreme floods. The probability that there will be a flood with a return period of 1,000 years somewhere in the country in a given year depends upon the number of catchments and sub-catchments. In a country of the size and hydrological complexity of China, the likelihood that there will be at least one such flood in any year is significant; the only question is: in which catchment? In an extreme flood, one decision that is necessary: is which areas will be sacrificed, as emergency flood storage, in order to protect the most critical areas?

This means that we also need to design for failure (Green et al 1993): to examine how the strategy adopted will fail, either because an extreme flood occurs or because of some defects, what will then happen, and how we will manage the consequences. Using the conventional loss-probability curve (**Figure 5**), what is then important is the region to the left of the design standard of protection; in more extreme floods, the different options perform very differently. For example, if a dike fails, then the resulting flood can be more severe than if there were to be no dike at all. Conversely, with a channel improvement such as a bypass channel, widening or deepening, there will always be less water out of bank however extreme the flood. Similarly, if a reliable forecast can be made of nature of the expected flood, then controlled storage can be used to reduce the flood peak of even the most extreme flood. The result of adopting the 'managing all floods and not just some' principle is then likely to be the sort of layered system (source control, upstream storage, dikes, emergency detention basins) found here in China. The problem is most difficult when we have to manage flooding across a large catchment; here, the problem is often to avoid the flood peaks from different tributaries coinciding on the main stem of the river.

Figure 5 Loss-probability curve

Avoiding the right solution to the wrong river

If we are to do better, then we have to learn and this involves applying what works in one place to another. Unfortunately, we can learn the wrong lesson and apply the right solution to the wrong river; what is appropriate in one context may be totally inappropriate in another context. We talk too much about alternative options (e.g. insurance, land use control) and too little about the contexts in which they are likely to be appropriate (Green et al 2000; 2002). The appropriate option is a function of the nature of the flood, the local context and the wider, national context. What we have to learn, therefore, is: what are the critical differences in the nature of the flood and in the two contexts that should determine the appropriate option?. It is then the similarities of the contexts that will result in the same option being appropriate for two different rivers. So, what is the right solution for the Mississippi can be the totally wrong solution for the Yangtze (Green et al 2000). Similarly, when I went out to Buenos Aires, I had an expectation that the resolving the urban drainage problem would involve source control. However, I discovered that there is virtually no public or private open space in the city and that the catchment is effectively 100% impermeable. Consequently, introducing source control would probably mean resettling 20% of the population. Since the city is supplied with drinking water from a river that is 90 kms wide, rainwater harvesting would not offer potable water benefits in addition to reducing the problems of urban drainage, so rainwater harvesting appears to be an uneconomic solution in the context of Buenos Aires.

Perhaps the biggest differences in contexts are: population density, economic reliance on agriculture, and the nature of farming. So, in North America and Europe, the logic is re-create the natural wetlands on the flood plains because since agriculture is heavily subsidised, wetlands are more valuable than arable land. In addition, there the farms are large and only about 4% of the population is engaged in agriculture. Again, in the ultra-low population densities of North America, 28 people per square kilometre, there are many more options than there are in China – so, urban source control is much easier in the low urban development densities found in North America and Australia than in Europe. But the implication is that as the economy of China expands and changes, so will the nature of the best options to adopt also change.

Institutions

In human terms, catchments are arbitrary and their boundaries rarely correspond to cultural, ethnic, political or religious boundaries. Moreover, I have argued above that Integrated Water Resource Management is not enough; IWRM has to be integrated into other policies for which quite different boundaries, especially those for integrated coastal zone management and groundwater management, are appropriate.

Our fundamental problem is then that decisions are made and implemented by institutions of different types and including county, city and provincial governments, but all institutions necessarily have both functional and geographical boundaries. For accountability, and also other reasons, institutions are defined by what they are not allowed to do, and where they are not allowed to perform those functions, just as much as they defined in terms of their powers to carry out certain functions within a particular area. No one set of boundaries is then likely to be ideal for all purposes or to perform every function. If we try to map all those institutions that will be needed, because of the powers and resources they have available, to implement an integrated catchment management plan, then we usually find a complex picture made up of different levels of government, along with individuals and companies. It will be a complicated picture because of the requirement to integrate catchment management into wider national policies, notably those concerning rural and urban development.

Figure 6 Possible institutional boundaries for a dike system

We have some scope to define particular boundaries for specific functions; **Figure 6** summarises the different functional and geographical boundaries that I have found in different countries for managing dike systems. But, none are ideal and, consequently, we have to develop better ways of co-ordinating and co-operating across institutional boundaries. If it is to be successfully implemented, then a catchment plan has to be a widely shared vision of the future, a vision that is shared by all of the stakeholders. Hence the process of developing that plan is the important phase, and a plan is not a document but a shared understanding of what we are trying to achieve and the role of each of the stakeholders in achieving that vision. This is extraordinarily difficult to achieve and it is difficult to find really successful examples of institutional structures that are actually delivering integrated water resource management. The Agence Bassin in France, although they are, as yet, only incidentally involved in flood management, is probably the best example (Barraque et al 1994). Their success appears to be the result of three things: firstly, the existence of a catchment ‘parliament’ made up of all of the major stakeholders; secondly, that this parliament develops the catchment plan; and, thirdly, that, in effect, the parliament has its own tax raising powers so ensuring that it has the revenue with which to implement the plan.

A second and important form of institutional boundary is that of the academic disciplines. There are some good reasons why universities should be organised on a disciplinary basis; the problems come in the real world where problems are not organised on a disciplinary basis. Here, we need engineers, economists, ecologists, sociologists, planners and those of other disciplines who are not only to be able to communicate with each other but also to think outside of the disciplinary frameworks in which they have been taught. In turn, reward system, particularly prestige which is the basic reward of academics, has to be shifted to rewarding the ability to work effectively in multi-disciplinary teams on inter-disciplinary problems, rather than only for advancing the discipline.

Thirdly, if we are to do things better, this means trying new things. Not everything we do will be successful but if we don’t try new things, then we will make no progress. Therefore, we have to make some forms of failure acceptable; trying and failing must be acceptable if we learn in consequence of that failure. It has to be acceptable, therefore, for institutions to fail some times and also for individuals to fail. What is real failure is then to repeat some thing that has already been found to fail in the same circumstances, or to fail to seek to learn by trying new things.

Specific lessons

Since learning is so important, I want to turn to three things that I have learnt working for the World Bank on a series of missions in China. In turn, I suggest that the message in each case is the need to set up systems that formalise learning by institutions.

Operations and maintenance

Globally, there is commonly a gap between design and construction, and the operation of a scheme. Often one institution has responsibility for design and construction and another for operations and maintenance (O & M), with the two activities being funded from different sources. Consequently, many schemes then fail or need to be replaced prematurely because of inadequate maintenance. Equally, whilst the designers of a dike, for example, will prepare a priced schedule for construction works, it is very rare for them to also prepare a priced schedule of O & M. This needs to change: any proposal for new works should be accompanied by a priced schedule of the necessary O & M works: we need to adopt a life-cycle approach. The long term commitment to fund O & M works can also be substantial and it is necessary to determine how these works will be funded. Secondly, we need to learn what maintenance schedule will yield the best returns. Since the different options often have a different balance of capital to O & M costs, we need also to make the choice between the initial and continuing costs on a considered basis. In particular, many of the ‘softer’ engineering approaches, such as beach recharge on the coasts as a form of protection against erosion, may require significant O & M costs. Similarly, both the useful life and maintenance costs of permeable pavements as a form of source control are uncertain (Office of Water 1999). To learn, we need to compare what we predict will be the costs involved against actual costs involved. It may well be more important to manage the O & M efficiently than to make slight reductions in initial costs.

This comparison should not be limited to structural works; we need to apply the same approach to so-called ‘non-structural’ works. We have found, for example, that a simple test of an emergency plan is to call the various contact telephone numbers listed: often, the number has changed and even more often, the contact person has changed. So, a maintenance strategy must be developed and monitored for ‘non-structural’ as well as conventional approaches. There are grounds for suspecting that institutions are more difficult to maintain in an effective condition than physical objects, that a concrete wall or pump can survive neglect for longer than can an organisation. So, a flood warning system that is only required if the 100 year return period flood occurs is less likely to work when needed than one that is required for the 10 year return period flood.

Measuring success and failure

We need to learn how to do better; this means learning what works and what does not work. If we are to do better, then we must try new things and some of these will not succeed. We have to formalise learning if we are to do better.

However, it is much more difficult to learn what works and what does not work for flood alleviation schemes than, say, wastewater treatment. The real test of a flood alleviation scheme is the extreme event but such an event may not occur doing the lifetime of the scheme. Hence, we need some way of assessing the performance of a flood alleviation scheme through its performance under normal conditions. Two possible performance indicators are then:

- O & M costs and defects, and
- Defects reported during floods

When, for example, we replace an existing dike system then we should expect O & M costs to fall because the new dike will be in a better condition. Hence, monitoring the nature, frequency and costs of repairs and comparing these to those of the existing system is one possible performance indicator (**Figure 7**). Of course, this assumes that an appropriate level of maintenance was being given to the existing dike system.

Figure 7 O & M costs as a performance indicator

Secondly, in a flood, some problems and weak points are likely to be found in the scheme; a second performance indicator is then the number and severity of the problems (e.g. sand boils) found during a flood. We should expect these problems to increase with the severity of the flood but to be less frequent for a new scheme than for an existing scheme (**Figure 8**).

The limitation of both measures is that we don't have the data to compare different projects. Similarly, whilst the rate of change over time can be compared between different types of options in different places (e.g. dikes can be compared to flood warning systems), we cannot readily compare the absolute performance of the different options.

Figure 8 Problems experienced in a flood as a performance indicator

Risks

Flood management is all about managing risks; changing either the probability of a flood of a given magnitude or changing the consequences of that flood. But we have to view risks from a dynamic viewpoint rather than a static one: the critical characteristic of these risks is that they are changing, not only as a result of climate change but also as a result of changes to the catchment and in the nature of the economy. In some respects, highly industrialised economies are more vulnerable to floods than simpler economies: industry is becoming more specialised, so that the closure of a single factory may disrupt the entire economy, and more concentrated so that there is less scope for transferring production to another factory. At the same time, modern technologies are more susceptible to flood damage: whereas if an electro-mechanical machine tool was flooded, it could be cleaned and the coil of the electric motor rewound, if a robotic machine tool is flooded, then at a minimum all the specialised electronic components will require replacing.

Although flood management is risk management, and the risks are changing, we typically do not know what are the risks except in qualitative terms. For example, the benefits of the Yangtze dike strengthening and raising project (World Bank 2000) largely resulted from the reduction in the risk that the dikes would fail before they were overtopped. Although the theory for applying quantitative risk assessments to dikes is quite straightforward (Wolff 1997), and there are several million kilometres of dike around the world, there is virtually no statistical data by which to calculate the probability that any given dike will fail before it is over-topped. The engineers at the different design institutes therefore had to make subjective assessments of the probabilities of failure of the different dike sections both now and after they had been strengthened and raised (**Figure 9**).

Figure 9 Reductions in the probability of dike failure
(Source: World Bank 2000)

Similarly, over-runs in construction time can have a very serious effect on the benefit-cost ratio of projects because the benefits are delayed. The main options considered for an urban drainage strategic plan for Buenos Aires were new large tunnels, varying between 2 and 4 metres in diameter. In principle, therefore, a critical question was: what is the probability of a time over-run for each of the different options? For example, if an option would give annual benefits of 37 million at a capital cost of 160 million spread over 2 years, the Net Present Value of the option is 50 million. If, however, the project takes five years to complete, then the Net Present Value is – 3 million. Again, although the theory for calculating the probability of a time over-run for different tunnelling methods is relatively straightforward (Isaksson 1998), there is no statistical data with which to calibrate that model (Isaksson 2001).

Similarly, our flood forecasting models are generally static models that assume the future will be like the past and focus on the rivers rather than the conditions that result in floods. Rather than analysing flows in rivers, I suggest that we look more at meteorological events, including the pattern of movement of these events, and also take a dynamic perspective. For example, the Taihu Basin

Authority has shown that three different meteorological events had quite different consequences in the Taihu Lake area, depending upon where the rain actually fell (Taihu Basin Authority 2002). Similarly, antecedent conditions are known to have a major influence on the proportion of precipitation that becomes runoff. Antecedent conditions and precipitation are often highly correlated so that time series modelling (Calver 2001) is likely to be a more useful tool for modelling the conditions that give rise to flooding. As an aside, let me note that engineers often reassure those people who were flooded that, since the flood had a return period of 100 years, they are unlikely to be flooded again in the near future. This is not actually true; we usually use the Annual Mean series to assess the return periods of floods. This gives the number of years between a year containing at least one flood of at least the specified magnitude. If there are three floods of the specified magnitude in a given year, then it only counts as one flood year. So, it is unlikely that there will be another 100 year return period flood next year, but it may be quite likely that there will be another flood this year; the conditions created by the first flood leaving the ground saturated so that any further rainfall is likely to create another flood.

Uncertainty

Whilst I have stressed that we need to learn, and need to establish ways of improving what we can learn, I want to end by arguing that in making choices we have to recognise what we do not know, and what we cannot know. The role of economics in particular, and economics is no more than the application of reason to choice, is to help us understand what is involved in the choice we have to make, and the nature of choice itself.

We have to make choices whenever the options are mutually exclusive; a choice is, therefore, by definition about conflict where there are a variety of reasons why the conflict may arise (Green and Penning-Rowsell 1999). This means that real choices are always difficult because they involve conflict; in turn, we should not expect that choices can always be resolved by a consensus.

A second condition for a choice to exist is that we are uncertain what to do, which option to adopt. In turn, we can define ‘uncertain’ as an inability to differentiate between the alternatives, so that someone who does not know what to do is uncertain. Thus, uncertainty is not an inconvenience, it is a condition for the existence of a choice; once we are all agreed what should be done, then the choice has been made. So, choice is a process through which we seek to resolve the conflict that makes the choice necessary and to achieve some confidence that one option should be preferred to all others.

We can, however, be certain about one thing: that the future is uncertain. It is uncertain because generally we only have partial knowledge of the present, and even less understanding and knowledge of the processes of change. In addition, we make predictions about the future only in order to try to change it; in making a choice, we are trying to choose the future. The success or otherwise of all the other attempts at choosing the future will typically change the future in which our particular choice must be made. We seek to change the future when the future is constantly being changed.

In the context of these other changes, climate change is relatively minor. For example, at the current rate of economic growth, the economy of China will be more than seven times its present size in 30 years time. I have no idea what that economy will look like except that it will be radically different to the structure of the economy at present since it is impossible to simply scale up the present economy by a factor of seven. Against this, a change in runoff of perhaps 20% is lost in the error factor – although changes in the variability of runoff are more important that changes in the average quantity as the former are more difficult to manage. What is important is that we recognise that we have to choose in the knowledge that the future is inherently uncertain; we have both to decide how to choose and to select the particular option in this knowledge. In particular, in making choices we have to move away from the conventional approach of assuming certainty and then adding a bit of risk. Instead, we have to approach choices knowing that the future is necessarily uncertain.

Uncertainty is quite different to risk. For example, if we know that a dice is fair, that the probabilities of throwing 1, 2, 3, 4, 5 and 6 are identical, as well as known exactly, then there is no rational reason for expecting one outcome rather than another. In this case, that the risks are known with certainty is the reason why we should be uncertain what to do: on which outcome to bet.

In turn, we have to differentiate between uncertainty about the world and uncertainty about what to do. Since the future is inherently uncertain, there will always be uncertainty about the world; the critical question is whether this should make us uncertain as to what option to adopt. Fortunately, we can often be quite confident what to do even though we are very uncertain about the world; equally, it is better to know that rationally we should be uncertainty what to do than to be either irrationally certain or irrationally uncertain what to do.

Early in the decision process, we need to establish which are the critical parameters that influence the choice of the option. Conventionally, this is called 'sensitivity analysis' and undertaken at entirely the wrong time: at the end of the analysis. Instead, we need to establish these parameters at the beginning of the analysis because these are the parameters to which we should pay most attention. Fortunately, we know from experience that the most critical parameters are those benefits and costs that occur early in the project life cycle and occur most frequently.

At the end of the analysis, we need to determine whether the choice of the option is robust to all the inherent uncertainties. We already know from the benefit-cost ratio how far our estimates could be in error before the choice should be changed: if the benefit-cost ratio is 3.2, we know that we could have underestimated the costs by a factor of 200% or overestimated the benefits by more than a factor of three, without changing the choice. This also means that the appropriate interpretation of a benefit-cost ratio of one is not as a critical threshold separating desirable from undesirable options, but as the point of maximum doubt as to whether it is worthwhile undertaking the project. If a project has a benefit-cost ratio of 1.1, then we should suspect that there are better investments elsewhere in the country or look for a better option.

What we need to determine is whether it is plausible that our estimates of the critical parameters could be so far in error as to reduce the benefit-cost ratio below one. To test this, we need to vary the values adopted for the critical parameters that were identified in the sensitivity analysis. The technique can be likened to hitting the analysis with a very large hammer and seeing if it breaks. **Table 2** shows the results of the analysis that was conducted for the Yangtze dike strengthening and raising project. It shows both that changes in critical parameters can have radical effects upon the benefit-cost ratio and also that, in this case, the decision is robust to the uncertainties. It also brings out the importance of improving our understanding of bank protection.

Table 2 Robustness analysis: Yangtze dike strengthening and raising project

Case	**Hubei**			**Hunan**
	Jianan	**Wuhan**	**Babu**	
Base	**11.0**	**4.9**	**10.2**	**2.7**
Delay benefits by 2 years	8.4	3.0	5.9	1.8
Probability of failure by existing dikes is lower	1.7	2.3	6.3	1.5

CONCLUSIONS

The common thread in this paper is learning: what I have learnt from involvement in a number of World Bank missions in China, what we need to learn, and how we can learn. Indeed, I have argued that decisions are learning processes through which we seek to discover what the choice involves, to resolve the conflicts involved, and to determine what option we should adopt. At the same time, I have argued that a condition for a choice to exist is uncertainty; that we do not and cannot know the future. Thus, in taking decisions, we have to understand what is we do not know and cannot learn. In particular, we have to avoid designing projects using point estimates of parameters, then adding in some risks, and equating this to uncertainty.

Although, I have argued (Green et al 2000) that China has one of the two best flood management policies in the world, it has to: the problems of catchment management in China are arguably more difficult, more complex and larger in scale than in other countries. Both learning and recognising that uncertainty is a condition for choice are, I have argued, critical to making further improvements in catchment management in any country.

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