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Forest and Floods:
Moving to an Evidence-based Approach to Watershed and Integrated Flood Management

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Abstract*: Evidence is presented to show that there is a growing disparity between public perception and scientific evidence relating to the causes of floods, their impacts, and the benefits of mitigation measures. It is suggested that this disparity has arisen through the extensive promotion of certain land uses and engineering interventions by vested interest groups in the absence of any effective dissemination of the scientific evidence which may allow a contrary view. It is believed that this disparity may have resulted not only in the wastage of development funds (possibly to the extent of tens of billions of dollars per year) on unachievable targets, but also in the unwarranted blame of upland communities whose practices have generally had only marginal impacts on downstream flooding. It is recognized that the interaction of floods and society is a highly complex subject. What is recognized, with some certainty, is that simplistic and populist land management solutions, such as oft-advocated solutions involving commercial afforestation programs, cannot ever represent a general solution and will, in most situations, have at best marginal benefit and at worst negative impacts. Similarly, structural engineering interventions, although in the short term providing protection to flood-affected communities in one area may have the effect of transferring the problem downstream and may also introduce other unforeseen adverse environmental and economic impacts. An improved approach to watershed and flood management is proposed that integrates watershed and land-use management in the highlands with land-use planning, engineering measures, flood preparedness, and emergency management in the affected lowlands while taking into account the social and economic needs of communities in both the highland, often source areas, and also the lowland flood-prone affected communities. This approach should be based on our best available scientific knowledge of the causes and the environmental, social, and economic impacts of floods and the environmental, social, and economic effects of engineering interventions.*

Keywords: *forests and floods, watershed management, integrated flood management, public and science perceptions*

Introduction

Floods may be caused by natural events, by human activities, or by combinations of both. Regardless of their cause, floods have a profound effect on people and the economy. On an annual basis floods leave over 3 million people homeless and affect the personal and economic fortunes of another 60 million people (WCD, 2000). A single flood in a small, centrally-located province in Vietnam, Thua Thien Hue, in 1999 led to the deaths of 400 people and damage to property worth $120 million, or one-half of the annual provincial GDP. Such figures only grow in magnitude as the size of the basin concerned increases. Floods pose a particular threat in Asia, where flood-related economic losses exceeded those in North America and Europe during the 1987 to 1996 period (Berz, 2000).

How different actors have responded to floods – as individuals or as organizations – is determined by perceptions of the impacts of floods, whether direct or indirect, for good or bad. These perceptions may be influenced by many factors including first hand experiences, received and conventional wisdom, scientific observations and the expected gains and losses from staking out a position or taking a particular course of action.

To understand the history of responses to floods it is important to understand that there are many players and much at stake. Within a catchment, the lowland farmers and fishermen, as for example in Bangladesh, will often welcome the annual flood to bring down sediments rich in nutrients and water of sufficient volume to support their livelihoods. Too much may cause them problems, but too little will be a disaster. Elsewhere, where communities have encroached onto the floodplain and are not reliant on floodplain waters for their livelihoods, they will view the flood with distrust and as a danger, often as a plague to be blamed on any plausible external cause. Upland communities, who are generally affected less by floods, for good or bad, are usually the least vociferous players in the game.

But these are not the only players or the most powerful. Many of the technical specialties have tended to see solutions in terms of their own focused discipline. Many foresters have been early and effective players and have long promoted forests as being a key remedy for floods. By so doing they have ensured political support and funding for afforestation and reforestation programs. Similarly, engineers traditionally have seen floods as an opportunity to put in place expensive structures to either store and detain floods (dams) or to carry the water away (channels). More recently, under pressure from environmentalists, as well as a growing realization of the negative impacts of structural measures, engineers have secured more work by re-engineering or dismembering these structures in order to restore rivers, wetlands, or other waterways to their "natural" state.

Scientists are not disinterested players either. Hydrologists, agronomists, soil scientists, economists, and social scientists all have an interest in securing funding related to floods and have a vested interest in providing knowledge. When floods make a good story, inevitably a disaster story, the media appear repeating the conventional wisdom regarding cause and effect. These arguments, even where outdated and mistaken, are uncritically repeated by those NGOs who benefit from the message, underscoring the failure of scientists to convey their findings in a coherent and understandable fashion to the general public.

Meanwhile, politicians will interpret the (mixed) signals as best they can with an ear to where the votes and expenditures lie. Development organizations may try to take account of these disparate views but will usually settle for the solution that is most easily defended and causes the least disruption in budgetary allocations. Often this is the one supported by conventional (perceived) wisdom.

Despite this unflattering portrayal, advances have been made in reconciling competing views and interests, with recognition that most problems require integrated, rather than simplistic, solutions. The perceived wisdom of directly connecting forest cover and floods is increasingly questioned, as is the practice of seeing flood management as a matter of flood control using structural remedies. This paper attempts to outline the background behind this significant change in understanding of forests and floods and to summarize the emerging implications for watershed and flood management.

Forests and Floods – Contrasting Perceptions, Knowledge and Practice

"Contrary to the television images, the devastation wrought by [Hurricane] Mitch was no mere act of God but a far more human tragedy. Misguided government policies and poor farming practices - the two are interrelated - had already pushed the region to the brink of ecological collapse. The torrential rains only gave it a final push" (excerpt from letter to the Oregonian newspaper following Hurricane Mitch in 1998).

The public perception promoted by the popular press, the writings of some environmentalists and conservation agencies projects an unwavering, "stirring," and "evangelical" view of the relationship between forests, deforestation, and floods.

The Environmentalist's Concern

Lester R. Brown of the highly influential Worldwatch Institute, writing about the 1998 floods in China states:

"Over the last few weeks, the world has been following the floods in China's Yangtze basin, the worst in 44 years. […] The Chinese government is treating this disaster as an act of nature, and indeed it is. Floods during the monsoon season from June through September in southern China are a regular occurrence. But there is also a human hand in this year's floods in the form of deforestation and intensive land development. The Yangtze basin is home to 400 million people, making it one of the most densely populated river basins on earth. […] With such a density of population, the human pressure on the land is everywhere. To begin with, the Yangtze River basin, which originates on the Tibetan Plateau, has lost 85 percent of its original forest cover. The forests that once absorbed and held huge quantities of monsoon rainfall, which could then percolate slowly into the ground, are now largely gone (Brown, 1998).

A very similar message is contained in the writings of the well-known environmentalist Norman Myers about the consequences of deforestation in the Himalayas: "The Himalayan forests normally exert a sponge effect, soaking up abundant rainfall and storing it before releasing it in regular amounts over an extended period. When the forest is cleared, rivers turn muddy and swollen during the wet season, before shrinking during drier periods… Flood disasters are becoming more frequent and more severe" (Myers, 1986).

These views seem so plausible to us, perhaps because we have heard them so many times, that we think they are incontrovertible truths. But when we consider more critically and listen to the views of hydrologists, we might arrive at a different conclusion.

The Hydrologist's Critique

Thomas Hofer of the University of Berne's Geography Institute, referring to the "environmentalist's concern" states: "The hypothesis regarding the impact of human activities in the Himalayas on the ecological processes in the lowlands can be explained by the following, superficially convincing sequence; population growth in the mountains ® increasing demand for fuelwood, fodder and timber ® uncontrolled forest removal in more and more marginal areas ® intensified erosion and higher peak flows in the rivers ® severe flooding and siltation on the densely populated and cultivated plains of the Ganga and Brahamaputra. The apparently convincing conclusions have been subscribed to carelessly by some scientists and adopted by many politicians and journalists in order to identify the so-called culprits" (Hofer, 1998a).

Hofer (1998a) goes on to give examples of the "stirring statements" laden with "sensation and conflict potential" which are the usual lifeblood of many environmental journalists and many conservation organizations.

It is clear that this certainty of cause and effect is not reflected in the critique nor are such statements as "Flood disasters are becoming more frequent and more severe" in the Himalayas in harmony with the scientific analysis of the hydrological record carried out by the Berne Institute. In the light of the scientific studies such as Hofer's where he states that in the Ganga-Brahmaputra-Megha lowlands neither the frequency nor the magnitude of flooding has increased over the last few decades, or those of Marston and colleagues who claimed that "results demonstrate that… variation in bank-full discharge [i.e. flood flows] can be explained as a function of drainage area alone; forest cover did not add explanatory power" should we still accept these popular perceptions uncritically? (Hofer, 1998a; Marston et al., 1996).

A review of where we stand on the science of the issue should help to clarify the disparity in views.

The Science of Forests and Floods

Knowledge of the bio-physical processes by which land use, and particularly forested land uses, can affect floods has increased markedly over recent years. This knowledge, gained from studies in many parts of the world: America (Hewlett and Helvey, 1970); South Africa (Hewlett and Bosch, 1984); United Kingdom (Kirby et al., 1991; Johnson, 1995); New Zealand (Taylor and Pearce, 1982); and Asia (Bruijnzeel and Bremmer, 1989; Ives and Messerli, 1989; Hofer, 1998a; 1998b; Ives, 2004) and involving many disciplines including hydrology, soil science, and climatology, demonstrates a great complexity in the way in which the bio-physical processes affecting flood response interact; a complexity unimagined in most popularist accounts of land use and flood interactions.

In broad terms, we might expect land use to affect the severity of floods in two ways, through affecting channel flow, or channel form, either of which may cause rivers to overflow their banks. The flow rate, and peak flow rate, in the river may be affected both by the total quantity of runoff produced during a flood event and also by alteration of the timing of the flood peak, particularly as these flood peaks arrive and are "added together" from tributary rivers. Channel form changes may occur as a result of alteration of the channel network through, for example, construction of drainage ditches or road drains or through "obstruction" of the river channel through processes such as sedimentation of the channel and catastrophic landslips and through debris blocking culverts and bridges.

The complexity of land use influences on evaporation, on surface runoff generation, and on erosion, which affect channel flow and channel form, prohibits simple generalization of impacts. But the evolving new science perception does allow the derivation of guiding principles which have been identified and reviewed by a number of authors (Lull and Reinhart, 1972; Hewlett, 1982; Bosch and Hewlett, 1982; Hamilton, 1987; Bruijnzeel, 1990; Swanston, 1991; Calder, 1992; Bonell, 1993; McCulloch and Robinson, 1993; Calder, 1999; 2000; 2005).

The growing consensus associated with the science perception appreciates that forests generally evaporate more water than other land uses which tends to lead to a general reduction in catchment flows. From theoretical considerations it would be expected that interception of rainfall by forests reduces floods by removing a proportion of the storm rainfall and by allowing the build up of soil moisture deficits. These effects would be expected to be most significant for small storms, where the soil moisture or interception "deficit" might be a significant proportion of the storm rainfall but relatively insignificant for the largest storms (Lull and Reinhart, 1972).

Soils under natural forests tend to be relatively porous with high infiltration rates and consequently low rates of surface runoff and generally exhibit low rates of erosion. This is not necessarily the case for plantation forests, particularly where no natural understory of vegetation is maintained or where management activities involving site preparation, cultivation, drainage, road construction, and logging may have detrimental affects (Anderson et al., 1976). Forest management activities involved with drainage and planting, road construction, road use, and logging may not only contribute to increases in rates of surface runoff during storm conditions but also increase the transport of sediments into watercourses. The benefits of forests, whether natural or plantation, for preventing land slips and catastrophic erosion events are likely to be site, and possibly event, specific. For example the binding effects of roots and the generally drier conditions under forest will tend to stabilize slopes in storm conditions whereas wind throw of trees, when it occurs, can be particularly devastating in terms of debris transport into rivers with the added potential of not only blocking watercourses but also fouling bridges and culverts and causing added flood damage.

The science perception also recognizes that although land use change effects on floods may be detectable on small catchments the "signal" is likely to be weaker on large catchments. Three reasons have been suggested for this weakened signal:

1) Processes which may reduce the "time to peak" and thereby increase the magnitude of the peak of the flood in small catchments may have less effect, proportionately, in large basins because the flood peaks arriving from the small catchments are not likely to arrive together, they will not be in synchrony.
2) The proportionate change in land use is likely to be higher on small catchments.
3) Storms of sufficient spatial scale to saturate large basins are likely to be of the largest magnitude and for these extreme event storms the effects of land use change on flood response are expected to be least pronounced. Extreme even storms have a low probability – The magnitude of extreme flood and storm events has traditionally been characterized in terms of the "return period", where the longer the return period the larger is the flood. Neither hydrologist nor the general public find this concept particularly easy to understand and a probability index is now preferred (see Institute of Civil Engineers, 2001). For a 100-year (return period) flood we would say that the odds are 100 to 1 against such a flood, or a greater flood, occurring in any year (100 to 1 chance flood) or alternatively this could be expressed as the 1 percent annual probability of flooding. Casting magnitudes in probability terms avoids the apparently nonsensical situation of a number of 100-year floods occurring within a short period of time – as has happened recently in the UK. It also avoids sending out the potentially dangerous message that once a large flood has occurred, say a 100-year flood, it will be another hundred years before another one happens).

The "emerging consensus" of opinion from the scientific community on these issues is illustrated by an informal internet debate which was stimulated by the writings of Kaimowitz (1998), published in the CGIAR's influential Polex newsletter. This newsletter was instrumental in drawing attention to the disparity between the science perception of the causes of floods, to which attention had been drawn by a number of papers prepared for a wider, policy-making audience (Chomitz and Kumari, 1998; Calder, 1998; 1999), and the public perception as reflected by national and development organizations' response strategies. The debate involved representatives of the World Bank, CGIAR, international consultants, and educational and research organizations. A summary of these discussions was reported in the FAO Electronic Workshop on Land-Water Linkages in Rural Watersheds in October 2000. Two excerpts are presented below relating to forest and sediment linkages and scale issues:

Deforestation-Sediment Linkages to Flooding

A discussion on the relationship between land use and flooding in the case of the recent disaster in Central America due to Hurricane Mitch drew on observations from China where the accumulation of sediment and other deposited material (channel aggradations) may have led to the need to raise dikes (or build the Three Gorges Dam) to maintain the same level of flood control. Observations from Honduras suggest that a rough estimate of level of sediment carried by floodwaters running through Tegucigalpa at their height is 15 to 17 percent. Participants also noted the question of how to assess the relative importance of channel aggradations due to deforestation and the problem of human encroachment in flood plains (reported by Calder, 2000).

Scale Issues

Discussions on efforts to collect data and develop computer models of water and sediment runoff, including those undertaken by the USDA Forest Service on experimental watersheds, highlighted the problem of scale. At small scales, increased water and sediment runoff due to deforestation can be identified and incorporated into hydrological models. At larger scales, increases in flood flows are not so easily discerned or modeled. A participant noted that this may be due to the integration of the cumulative effects from an entire watershed, of which only a relatively small percentage may have been affected by deforestation. More centrally, however, participants felt that the increase in scale reduces the likelihood of coincident peaks (in flows) far downstream. This "hydraulic attenuation," which tends to result in decreased flood peaks but longer timed base hydrographs, may mask an overall increase in flow during storm events in large basins. It was felt that more hydrologic modeling at these larger scales was necessary in order to develop some sense of the magnitude of increased runoff in relation to the size, intensity, and movement of large storms. Such work would test the working hypothesis that as the size of the flood event increases the effects of land use would become less important. Given that most of the larger flood disasters occur at such large scales such information would be important for decision-making (reported by Calder, 2000).

Since the FAO electronic workshop of 2000, a number of studies, reporting experiences in the UK, America, and India at the small to medium catchment scale, have provided further important information on the role of forests and floods.

In Chapter 5 of the UK Forestry Commission's report, "Climate Change: Impacts on UK Forests," Nisbet (2002), recognizing the public perception, states, "Forestry is viewed by many as having an important role to play in reducing flood risk." In consideration of some of the scientific arguments reviewed in this paper he concludes that "the scope for forests to reduce the severity of major floods that are derived from an extended period of very heavy rainfall is rather limited" (Nisbet, 2002). He also gives examples of circumstances where afforestation programs in the UK may actually have increased flood risk: "Cultivation and drainage practices can exert a strong effect on the timing of run-off from forest catchments. Deep plowing and intensive drainage have the greatest impact since they increase the density of water channels by 60 times or more. This can increase flood flows by up to 20 to 30 percent and decrease the time to peak by about one-third for completely drained catchments. The effect is long lasting, although it declines through time with soil subsidence and the infilling of drains. Badly designed drainage systems and the diversion of run-off from one catchment to another can also cause local flooding problems" (Nisbet, 2002).

From America, La Marche and Lettenmair (2001) have described the results obtained from comprehensive field experiments and a modeling study of the extensively logged 149 km^2 catchment of the Deschutes River, Washington, USA.

Through the use of a calibrated model they showed that at this experimental catchment scale, forest removal (without introducing any road effects) would increase the mean annual flood by about 10 percent. For floods of greater magnitude (longer return period) the model predictions indicated a decreasing (percentage) effect. The effects of forest roads (without any forest removal), which effectively increase the density of the stream network, were predicted to increase the mean annual flood by a similar amount (approximately 10 percent). But unlike the forest removal effect, the "road" effect was shown to increase with increasing flood magnitude. While the effect of forests in flood amelioration decreases as the size of the storm event increases, the road network is a feature which will not only generate surface runoff through providing a relatively impermeable surface but will also intercept and convey surface runoff quickly to the stream channel through its associated gutters and drains, factors which may proportionately increase in importance as storm inputs increase. It is critical to differentiate between the effects of removal of forest cover and the effects of roads used to help remove that cover. Timing of water runoff can change as roads and related drainage structures intercept, collect, and divert water. This accelerates water delivery to the stream, more water becomes runoff, which increases the potential for runoff peaks to occur earlier, be of greater magnitude, and recede more quickly than in unroaded watersheds (Wemple et al., 1996).

This study helps disentangle the "road" and "forest removal" effects associated with logging. The implication is that forest clearance per se would not increase average annual size floods by much more than about 10 percent. For the largest, most damaging floods we would expect considerably less than a 10 percent increase and less again at larger spatial scales. The USDA publication, "Forest Service Roads: A Synthesis of Scientific Information," (USDA Forest Service, 2000) summarizing the results of a number of recent American studies on the effects of roading and timber harvest on hydrologic regimes states "Collectively, these studies suggest that the effect of roads on basin stream flow is generally smaller than the effect of forest cutting, primarily because the area occupied by roads is much smaller than that occupied by harvest operations. Generally, hydrologic recovery after road building takes much longer than after forest harvest because roads modify physical hydrologic pathways but harvesting principally affects evapotranspiration processes."

Sikka et al. (2003) have reported on the impacts on both flood flows and low flows of converting natural grassland to eucalypt plantation in the Nilgiris region of south India. Fast-growing Eucalypt plantations are highly efficient in terms of plot water use efficiency (i.e. the amount of above ground biomass produced per unit of water evaporated), but have long been recognized as disproportionately large consumers of water and thus are expected to reduce catchment flows (Calder, 1996). The studies of Sikka et al. (2003) confirm these expectations. The detailed and long term (1968 to 1992) paired catchment experiments in the Nilgiris, where the responses from a "control" catchment under natural grassland were compared with those from a catchment with 59 percent eucalypt cover, which were monitored over a period encompassing two rotations of the eucalypt crop show, from the point of view of hydroelectric power generators, very serious reductions in low flows during the dry season. Expressed in terms of a "Low Flow Index" (defined as the ten days average flow which is exceeded for 95 percent of the time of the flow record) the low flows were reduced by approximately one half during the first rotation and by one quarter during the second rotation of the eucalypt crop.

Flood flows were also reduced but very significantly, the authors concluded, from analysis of probability plots of peak discharge from the two catchments, that the "effect of blue gum plantation (*Eucalyptus globulus)* on peak flows becomes insignificant for the largest floods," i.e. those with a low annual probability of flooding (high return periods). Any small gains the plantations achieved through reducing peak flows were therefore obtained at the expense of very serious reductions (for hydropower generation) in low flows.

Again from the UK, Robinson and Dupeyrat (2003) have reported studies of the changing flow regime following logging on the Plynlimon experimental catchments in mid Wales. They report changes in annual yield, low flows and peak flows in nested catchments at scales from about 1 to 10 km^2. Although these authors were primarily investigating changes in flows following logging, whilst in Sikka et al. (2003) were investigating the changes in flows as the trees grew, the conclusions drawn from both studies were similar. Robinson and Dupeyrat (2003) conclude "somewhat surprisingly, and in marked contrast with much of the extensive literature on the subject, there was no evidence that forest felling had a significant influence on peak flows." They did qualify this result by saying that "it should be noted that peak flow increases have often been attributed to soil compaction and disturbance reducing infiltration. Following modern forest management guidelines, care was generally taken during the felling to reduce soil damage and hence surface runoff by the use of brash mats" Robinson and Dupeyrat (2003). They also reported that forest cutting increased annual flows and augmented low flows, a result also consistent with the studies reported by Sikka et al. (2003).

Robinson et al. (2003) investigated under the FOREX (Forestry and Extreme Flows) project, funded by the European Commission's FAIR program, the impacts of forest on peak and low flows through analysis of data from 28 small basins across Europe. The conclusions were that: "Overall, the results from these studies conducted under realistic forest management procedures have shown that the potential for forests to reduce peak and low flows is much less than has often been widely claimed. Consequently, other than at a local scale, for the particular cases of managed plantations on poorly drained soils in NW Europe and Eucalyptus in Southern Europe, forestry appears to probably have a relatively small role to play in managing regional or large-scale flood risk or influencing drought flows across Europe." The authors also reported that while the effects of forests and forest management on the extreme flows of rivers may often be thought uniquely site-specific the FOREX study found relatively consistent results between regions and sites which gave confidence to the generality of the results.

The science perception of land use (particularly forest) impacts on floods has generally been developed from research directed at understanding the individual processes at the small spatial scale, often tree or plot scale, together with research at the experimental catchment scale (as described above). Because of the complexity of the interacting processes which will be affected by land use change the net effect, or "integrated effect," becomes increasingly difficult to predict at increasing spatial scales. All the more important then are the results from studies that have investigated impacts at large basin scales.

Arguably the most important and illuminating in this respect are the aforementioned University of Berne, Institute of Geography's detailed and comprehensive studies (Hofer, 1998a; 1998b) of the flood regime of the Ganga-Brahmaputra-Megha river system. Based on a detailed analysis of the hydrological records of the past 40 years Hofer states, "it can be inferred that floods are a normal process in the Ganga-Brahmaputra-Megha lowlands. Neither the frequency nor the magnitude of flooding has increased over the last few decades. Consequently there is no reason to believe that floods in the lowlands have intensified as a result of human impact in the highlands."

Earlier Marston et al. (1996) had arrived at a similar conclusion, but working at a smaller spatial scale. They recognized that "monsoon season floods in the central Nepal Himalaya have been difficult to predict with any precision, reliability, or accuracy." Using field data at 22 stream crossings, together with drainage basin morphometric data and forest cover data to determine the dominant controls on bank-full discharge from monsoon storms, they claimed that "results demonstrate that 82 percent of the variation in bank-full discharge can be explained as a function of drainage area alone; forest cover did not add explanatory power."

Thus, the evolving science perception suggests that the role of forest cover in flood mitigation or management is circumscribed. Perhaps the most salient point is that as the severity of the flood increases the marginal impact of land use change appears to be reduced. Still, this perception is evolving. There remains a need to better understand the interrelationship between different hydrological functions that are impacted by land use change, such as between sediment, the build-up of river channels and flood heights. In addition, as scientists improve their ability to disaggregate the linkages between forest and non-forest cover (such as roads) impacts associated with particular economic activities, the alternatives for minimizing associated flood risk will become clearer.

Consulting the state of scientific knowledge clarifies the factual basis for understanding forests and floods. And indeed there exists a clear gulf between this knowledge and public perception. On the one hand we have science, which admits complexity, incomplete knowledge, uncertainty qualified by caveats, and sadly a very unexciting story: a story that the media and popular press are unlikely to consider even on the "worst of news days," and on the other hand the simplistic, yet highly dramatic, public perception.

Why have we arrived at this disparity of perceptions? It would be facile to blame this on the media, who are often as much a reflection – as a driver – of public perception. How has this public perception developed? What do we need to do to reconcile the two differing views on this issue given that popular wisdom appears to be largely inconsistent with the findings of hydrological research? Until there is reconciliation, there remains the danger of not only the wastage of development funds (possibly to the extent of tens of billions of dollars per year) on unachievable targets, but also the unwarranted blame and castigation of upland communities whose land use practices may have had only marginal impacts on downstream flooding.

To answer these questions we need to explore not only the history and the "narrative" that has led to these perceptions on forests and floods, but also the historical response on the ground to the threat of floods. Interestingly what we find are two competing narratives.

The Forests and Flood Narrative

A particularly illuminating study and interpretation of the narrative relating to linkages between deforestation and intensified flooding is provided by Saberwal (1997) of the Institute for Social and Economic Change, Bangalore, India. Saberwal (1997) proposes a number of theses and argues that the institutional context in which the discourse has taken place, has, in a sense, shaped or directed the discourse. Over time, Saberwal (1997) claims, "one observes a two way process, whereby bureaucracies may use science to inform a particular rhetoric; at the same time, bureaucratic rhetoric comes to influence the scientific discourse itself, and, thereby the very nature of science."

Saberwal (1997) shows that the narrative influenced Indian foresters as early as the 19th century and argues that the discourse (narrative) of today has emerged from a diversified set of views amongst European, American, and Indian foresters and environmentalists in the 1920s, into the "uniform and alarmist rhetoric that characterizes forester and environmental positions today". Saberwal (1997) claims that since the 1930s the ideas within Indian and American forestry have diverged, being more quantitative in the former and more qualitative and rhetorical in the latter, due, he believes, to differences in the nature of opposition to forester viewpoints. A synopsis of the understanding of floods by foresters in the early 20th century comes from Pinchot (1905), a leading conservationist of the times and the force behind the creation of the US Forest Service. From the observation that infiltration rates vary from bare ground to forest, inference is made to the (non-quantitative) conclusion that forests protect against floods. How much protection forests offer is not made explicit, nor does Pinchot take into account important downstream variables such as hydraulic attenuation. "Rain which falls over a bare slope acts differently. It is not caught by the crowns nor held by the floor, nor is its flow into the streams hindered by the timber and the fallen waste from the trees. It does not sink into the ground more than half as readily as in the forest, as experiments have shown. The result is that a great deal of water reaches the streams in a short time, which is the reason why floods occur. It is therefore true that forests tend to prevent floods. But this good influence is important only when the forest covers a large part of the drainage basin of the stream. Even then the forest may not prevent floods altogether. The forest floor, which has more to do with the fallen rain water than any other part of the forest, can affect its flow only so long as it has not taken up all the water it can hold. That which falls after the forest floor is saturated runs into the streams almost as fast as it would over bare ground. […] in mountain countries, where floods are most common and do most harm, the forests on the higher slopes are closely connected with the prosperity of the people in the valleys below. […] Water in motion was nature's most powerful tool in shaping the present surface of the earth. In places where the slopes are steep, the structure of the ground loose, and the rainfall abundant, water may work very rapidly in cutting away the heights and filling the valleys. The destruction of the forest in such a region exposes the surface to the direct action of falling rain and is certain to be followed by the formation of torrents" (Pinchot, 1905).

It is important to note that the discussion over the effect of forest cover removal and the resultant increase in flood damage resulted from decades of poor land stewardship in the United States from its early settlement period until the late 1800s. Uncontrolled logging, wildfires, grazing, and farming denuded millions of acres with resulting increases in soil loss, sedimentation, and flooding. The science of watershed management was in its infancy and there were many opinions concerning both the cause and solution to flooding and related impacts. It seemed obvious to many that the loss of forest cover and increased flood damage were closely linked and the return of forest cover was important to the amelioration of flooding.

In America the vigorous debate over the environmental consequences of deforestation was related to interagency competition over appropriate methods of flood control. Engineers involved in flood control programs criticized the non-quantitative basis claims by the US Forest Service regarding the importance of forests as a tool in flood control. Efforts by the US Forest Service to counter these charges through empirical research led to the Wagon Wheel Gap experimental catchment research program that began in 1910 and ran through until the late 1920s. The work at Wagon Wheel Gap did not provide all the answers to the forests/flood question but opened the door to additional studies in forests around the nation. This led to the establishment of numerous long-term forest watershed research facilities, including the Coweeta Hydrologic Laboratory (North Carolina), Hubbard Brook (New Hampshire), Parsons (West Virginia), H.J. Andrews (Oregon), Beaver Creek (Arizona) and others.

Unfortunately the quantitative results of the program did not fully support the active hypothesis of the USFS that forests acted as a sponge and thus would not assist USFS in its on-going budgetary battles with the Army Corps. Undeterred, the Forest Service published the experiment with a front- and back-end that supported forests role as a "sponge" that reduced flood flows (Bates and Henry, 1928). While this is just one such case, it provides an example of how a perception can be traced back to a substantive source. The difficulty is that the source may not warrant the confidence with which it is entrusted and, in any event, should yield to the results of further studies. As detailed in the next section the Army Corps, as well as the Department of Interior's Bureau of Reclamation, went on to become the dominant federal agencies in flood control efforts, particularly related to channels and reservoir systems. The Forest Service grew over time to include over 191 million acres of National Forests and Grasslands in 45 states and territories, with a mission of proper land management of uplands as well as related streams, lakes and wetlands. The lingering legacy, however, is that the public, and even many foresters, still subscribe to the simplistic intuitive notion of the forest as sponge and flood protector. They do not understand the subtle differences between the effect of runoff from forests or from other land uses as modified by a wide variety of storm inputs, antecedent soil moisture content, and related scientific detail.

By contrast, in India the opposition to the forester's view came from non-technical officials of the revenue department. Saberwal (1997) indicates that the narrative developed as "Indian foresters were drawing on the writings of American foresters, and a wider international scientific context, doing so in a highly selective fashion to bolster their case for the introduction of more stringent conservation measures." The same lingering legacy remains in India as in America, a legacy which has underpinned the promotion of forestry as an effective means of reducing flood risk (and as a means of improving water resources) in a multitude of watershed development programs, funded by both national and international agencies, throughout India.

Forsyth (1998) argues very cogently that resolution of the narratives and the "so-called problems, such as Himalayan environmental degradation" will require the integration of social and natural science. He argues that we will need to find ways to allow critical debate about biophysical processes at the same time as acknowledging social constructions of the environment if we are to avoid the uncritical acceptance and propagation of the environmental "myths."

The Engineering Flood Control Narrative

As alluded to above, the reality is that in the early to mid-1900s engineers prevailed in the argument over what were the best mechanisms to tame the awesome power of floodwaters. With flood control as their explicit objective engineers around the world have spent over 50 years creating structural approaches such as dams and dikes (levees) to prevent floodwaters inundating the flood plain together with, in many situations, the straightening and deepening of the natural channel. In the US alone the federal government spent $38 billion on flood control between 1960 and 1985, largely through its Army Corps of Engineers.

According to the International Committee on Large Dams some 13 percent of large dams or over 3,000 worldwide have a flood control function. As can be seen from Figure 1, North America and Asia have been the biggest proponents of large dams for flood control. According to the World Commission on Dams, China has more large dams with a flood control functions than any other country and Japan is number three on the list.

These accomplishments both spring from an engineering "narrative" and feed into its continuing development. The engineering culture of the western world, developed and molded by the industrial revolution, was one of pioneering advance, of conquering previously insurmountable barriers to progress, and of ever-greater feats of engineering scale and excellence. Career development for engineers has traditionally been seen through association with large engineering projects – the larger the better.

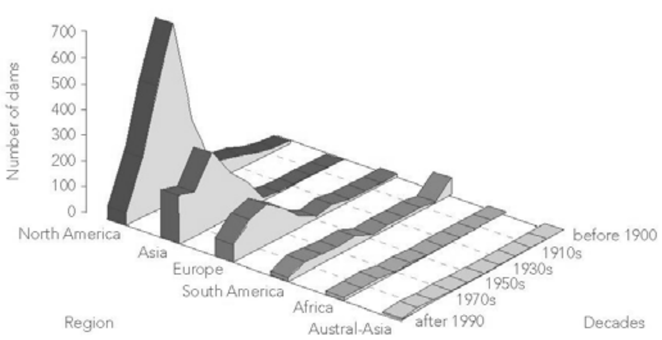

Figure 1. Number of flood control dams built in each decade and by each region, 1900 to 2000; Source: International Commission on Large Dams in WCD (2000)

That society has been transformed, and generally for the better, by engineering efforts, is undeniable. No more so than from the efforts of our water engineers who, in Victorian times, laid the basis for the improved health of nations through recognition of the need for, and through making available, adequate and wholesome supplies of water to meet the needs of households as well as many businesses.

In the 1900s the water engineer turned his attention to "taming the river" in order to reduce the damage to societies who had chosen to live and work in flood plain areas. As discussed above it is here that the Forests and Floods Narrative and the Engineering Narrative intersect. For foresters and environmentalists the outcome was less than ideal. For engineers the outcome was the unleashing of the full power of man's ability to modify his environment to suit his own ends. However, the narrative is still being written, and even for engineers there is a downside.

The culmination of this engineering tradition with respect to flood control is perhaps best exemplified by the efforts of the US Army Corps of Engineers, which, in 1954, started the engineering works which changed the natural 166 km winding path of the Kissimmee River, in Florida, into a 90 km long, 9 m deep, 100 m wide canal. But this amazing feat of engineering, completed in 1960, also illustrates many of the difficulties often associated with engineering solutions to flood control. The project also illustrates the turning point in our perceptions of the benefits of engineering interventions.

Before the engineering works for flood control were put in place the extensive 18,000 ha floodplains of this Florida River provided a wide range of wetland habitats with over 35 species of fish, 16 species of wading birds, 16 species of waterfowl, river otters, and many species of invertebrates, amphibians, and reptiles. The project hugely altered the hydrology and ecology of the river basin, which was widely seen as an environmental disaster, and efforts to restore the river were being contemplated, even before the project finished. The engineering works caused between 12,000 and 14,000 ha of wetlands to drain and dry up, with the consequent loss of the wetland flora and fauna. The changes in the flow regime also created conditions suitable for invasive plant and animal species, many of which were regarded as pests.

Traditionally, flood defenses were provided as individual local schemes with little consideration as to their cumulative impact across the wider river catchment, their impact on the aquatic and coastal environment and, indeed, their economic impact. These engineering interventions have now been recognized as having other, unforeseen at the time of construction, negative impacts which are not necessarily those applying just to the environment. There is a danger that engineering structures designed to transport the water quickly away from one flood area will, through removing the natural storage function of the floodplain, exacerbate flooding downstream. In developing regions, account has now been made of the reliance of flood plain dweller livelihoods on flood recession agriculture and in-stream fisheries. Flood defense works have often effectively ended natural floods and flood cycles, putting these communities at risk.

It now seems self-evident that individual flood alleviation schemes cannot be considered in isolation and that what happens in one part of the catchment will have effects on other areas some distance away. Returning to the Kissimmee example, environmental concerns were raised at the time of authorization but governmental water resource management processes were, at that time, relatively single-purpose-minded. The aim was simple: flood damage reduction in the most cost-efficient fashion. With increasing environmental awareness, and as the negative environmental impact of the project became increasingly apparent, the state and federal government introduced in 1976 initiatives and research programs aimed at gaining the knowledge required to restore the integrity of the river and retrieve some of the lost environmental benefits. In 1992 Congress approved the Corps of Engineers recommendation to undertake a river restoration program, which was aimed, essentially, at getting the Corps to fill in the canal they had originally dug and this, perhaps the world's first major watershed restoration project designed to reverse the impacts of earlier engineering works, is now underway.

Integrated Flood Management and Watershed Management

We are left then with two narratives. On the one hand, we have the engineering flood control narrative – not without being pushed and pulled from all sides, which is still evolving and making progress. On the other, we have the forest and floods narrative where, in many countries and in many institutions, the public perception and environmental concerns remain unchanged and apparently out of touch with the last 50 years worth of scientific research. How these narratives currently intersect and how this intersection may provide for future progress on all fronts can best be seen by examining the two practical and policy manifestations of these narratives: integrated flood management and watershed management.

Towards Integrated Flood Management

According to the Institute of Civil Engineers (2001) "Within river systems, flooding is the natural way for the system to discharge the water arising from the occasional large rainfall event. There is no problem at all until man decides to use some of the natural flood plain for his own use, and chooses to protect against inundation. We then face the dilemma of protecting against a natural hazard for the benefit of mankind that has chosen to live and work in flood plain areas."

Increasingly, attitudes to managing flood risk are moving away from structural, engineering solutions to those which are consistent with working with natural processes and promoting biodiversity and sustainable rural development. According to the World Commission on Dams (2000) the impetus for this shift arises from a number of major destructive flood events in the last few decades, that subsequently led to significant changes in flood policy around the world including:

- coastal flooding of 1953 that led to the Delta works in the Netherlands;
- the 1988-89 floods in Bangladesh that led to the Flood Action Plan and the National Water Management Plan;
- the Upper Mississippi floods of 1993, the Rhone floods in 1993, the 1997 floods in the Rhine, and the 1998 flood in China that drew attention to the role of non-structural catchment measures.

The switch from flood control to integrated flood management recognizes the fallibility of engineers and engineering, at the same time that it recognizes the difficulty of controlling human behavior. In an ideal world, engineers would either build 100 percent effective flood control structures or no person or economic activity would be allowed to locate in a flood hazard zone. The reality of course is that neither is possible. In effect, by promoting the idea that floods can be or are controlled has led to no end of trouble as people and businesses consequently have moved into these "protected" areas. The costs of flood control rise rapidly if structural responses are to adequately cope with low annual probability, 50 to 1 or 100 to 1 chance floods (1 in 50-, 1 in 100-year return period) or even more remote events, so that the flood control that is provided often fails to provide protection against the "big one." The results of course are major natural disasters, costing business, taxpayers, and insurers massive amounts of money, which over time has led to a rethinking of flood control as a realistic objective.

The new approach recognizes intervention strategies in flood management and has led to a gradual shift from a focus on structural responses to flood control to introducing or expanding the role of non-structural responses as part of integrated strategies for floodplain management. The World Commission on Dams (2000) provided a straightforward summary of the components of an integrated approach to flood management (see Table 1) that grouped responses as acting to reduce the scale of floods, isolate the threat of floods or increase people's capacity to cope with floods.

This type of approach is also evident in the Mekong River Commission's (MRC) promotion of "Integrated Floodplain Management" which illustrates the "new engi-

Table 1. Complementary approaches of an integrated approach to flood management

Reducing the scale of floods	*Isolating the threat of floods*	*Increasing people's coping capacity*
Better catchment management	Flood embankments	Emergency planning
Controlling runoff	Flood proofing	Forecasting
Detention basins	Limiting floodplain development	Warnings
Dams		Evacuation
Protecting wetlands		Compensation
		Insurance

neering approach" to flood management. The MRC views Integrated Floodplain Management as an integrated and coordinated mix of four types of management measures that reflect the flooding, flood risk and flood hazard characteristics of the particular floodplain, the specific social and economic needs of the flood-prone communities, as well as environmental and resource management policies for the floodplain. The four management measures are:

- *Land-use Planning Measures* are aimed at "keeping people away from the floodwaters." Land-use measures on the floodplain aim to ensure that the vulnerability of a particular land-use activity is consistent with the flood hazard on that area of land, i.e. the objective is to keep people and vulnerable activities out of the most hazardous areas of the floodplain.
- *Structural Measures* are aimed at "keeping floodwaters away from the people." Typical structural measures include flood mitigation dams, embankments and flood detention basins. Development and Building Controls can be seen as a particular kind of structural measure for urban and settlement areas, aimed at reducing flood damage to buildings. Typical building controls include minimum floor levels to eliminate nuisance flooding, and the use of building materials and building designs that enable rapid and effective cleanup after a flood.
- *Flood Preparedness Measures* recognize that no matter how effective the above types of management measures are an overwhelming flood will always occur. They aim at "getting people ready for floods before they come." In a number of cases, Flood Preparedness and Emergency Measures may be the only type of management that is feasible or economically justified. Flood preparedness measures embody flood forecasting, flood warning, and raising the general flood awareness of the potentially affected population groups. The MRC Flood Forecasting System is now underway and three- to five-day flood forecasts are published on the web (www.mrcmekong.org) on a daily basis.
- *Flood Emergency Measures* deal with the aftermath of such an event by "helping affected people to cope with floods." Flood Emergency Management, like Floodplain Management, is a process that typically encompasses preparation, response and recovery. In addition to flood preparedness, the flood emergency management process embodies evacuation planning and training, emergency accommodation planning, flood cleanup planning with the restitution of essential services and social and financial recovery measures.

The Role of Watershed Management

As shown above, the WCD considers better watershed management as a means of reducing the scale of floods. However, the MRC measures presented above do not specifically refer to watershed management. It seems lost in the shuffle between structural measures to 'keep floods away from people' and the land use planning to keep 'people away from floods'. Generally-speaking, however, any discussion of integrated flood management today is likely to contain a reference to, or a component on, watershed management. Still, it is clear that from the perspective of flood managers, watershed management is one of many critical tools.

This is not surprising. From the perspective of watershed managers, flood management will be only one of the objectives worth satisfying. The control of sediment, nutrients, chemicals and water in a watershed provides a vast area of "hydrological services" to people and to the economy (Enters, 1996; Aylward, 2004). And given that the linkage between forests and floods may be a tenuous one at times, the savvy watershed manager may try to optimize land use and land management for purposes other than flood control.

Despite these caveats it is quite likely that there is room for improving the extent to which these two approaches are integrated one into the other and the other into the one. Water resource managers are unlikely to be fully cognizant with the science on forests and floods – and may simply hew to the conventional wisdom. Or they may be practical engineers, for whom watershed management seems a very messy affair. On the other side of the coin, those involved in watershed management are often singularly uninformed about the downstream consequences of the hydrological services they provide.

Kaimowitz (2000) documents the "Useful Myths and Intractable Truths" related to practical attempts to implement watershed management project. His analysis reveals how grandiose schemes to manage watersheds are often devised in the absence of any real understanding of how such activities will affect their purported beneficiaries downstream – which are often large hydropower dams. Kaimowitz's (2000) case studies provide a window on the practical (and often convoluted) technical and political machinations of the watershed management "business." Indeed, Kaimowitz (2000) raises a rich set of questions and issues – to the point where some of the examples he cites could cause an anxious taxpayer to raise the question of what is the appropriate boundary between doing the right thing for the wrong reason and doing the wrong thing for the wrong reason.

Integrating Watershed and Flood Management

An improved approach to watershed and flood management would more effectively integrate watershed and land use management in the highlands with land-use planning, engineering measures, flood preparedness and emergency management in the affected lowlands. At the same time account would need to be taken of the social and economic needs of communities in the highland, often source areas, as well as the lowland flood-prone affected communities. This approach should be based on our best available scientific knowledge of the causes and the environmental, social, and economic impacts of floods and the environmental, social, and economic effects of engineering interventions.

Some movement in the direction of a more strategic, catchment based approach to flood risk management appears in the evidence presented to the UK Institution of Civil Engineers' Presidential Commission to review the technical aspects of flood risk management in England and Wales. The evidence highlighted the desirability of directing agricultural and forestry policies, practices, and grant regimes towards alleviation of flood risk and of restoring the role of undeveloped flood plains in storing water and reducing peak flows downstream. These ideas led to novel suggestions for flood storage to be a recognized land use in development plans which should be promoted to landowners through government incentives to make it an attractive complement to rural land use.

These suggestions have been taken up in the UK Forestry Commission's report: Climate Change: Impacts on UK Forests. In Chapter 5 of this report Nisbet (2002) states that "One location where forestry could make a net positive contribution to flood control is in the actual floodplain itself. The removal of river embankments in less sensitive locations would allow floodwaters to spread out and thus help to reduce downstream flood peaks at high risk sites." He also cautions that flood plain forest expansion is not totally without risk: "consideration needs to be given to sites that could be threatened by the backing-up of floodwaters, problems of restricted access to rivers and the impact of higher water use on water supplies during periods of summer drought."

Implications for Policy and Development

The science on the causes of floods admits uncertainty and imprecision in prediction of land use changes on floods. The interaction between forests and soils and how they co-evolved over different time periods ranging from years to thousands of years and how soil properties will ultimately change with changes of vegetation cover remains a particularly "grey" area in our knowledge. In these circumstances and taking account of the precautionary principle, we should be wary of advocating new courses of action which alter the present situation when we are not sure of the precise outcome. For example, we should be wary of allowing deforestation to occur on steep slopes or on soils that are recognized as being easily erodible.

On the other hand, it could be argued that we should be equally wary of investing significant proportions of very limited development funds in "remedial" programs (often afforestation programs) when the science perception is that, at best they will have marginal hydrological benefits, and at worst negative hydrological impacts. The "best" situation we might expect, from the studies in America's Pacific Northwest, is approximately 10 percent diminution in floods at the small (100 km^2) scale, while at larger scales we seem to have little evidence for any beneficial effect. Of particular concern would be reforestation programs, which involve extensive road construction, or other management activities involving extensive cultivation or drainage activities that might lead to negative effects on flooding.

The recognition in the US Pacific Northwest that the engineering management activities associated with forestry, particularly those activities involving road construction, can significantly increase flood peaks and modify runoff timing has resulted in a situation not entirely dissimilar to the Kissimmee example in that engineering works are now being reversed. Many National Forests are carefully analyzing their transportation needs, then decommissioning and re-contouring unneeded portions of the road network to halt continued environmental damage while restoring hydrologic function and ecological resilience.

In the UK the Forestry Commission whose ethos and working practices would traditionally have been expected to be associated with the "forester and environmental positions" has recently radically changed its position in relation to forest and flood issues to that of fully supporting the science perception. This is evidenced in recent publications (Forestry Commission, 2002) where not only is it admitted that "the scope for forests to reduce the severity of major floods that are derived from an extended period of very heavy rainfall is rather limited" but admit that forestry management practices such as those involving deep plowing and drainage practices can actually enhance flood risk. This recognition of the hydrological impacts has resulted in a move away from these forms of land preparation activities in the UK in recent years. Many forestry operations in the US are employing less intensive site preparation and management practices, both to limit environmental impacts as well as to reduce costs for practices which have little practical benefit.

The plethora of misinformation, misperceptions and myths surrounding the relationships between forests, trees and land-use activities on one hand and catastrophic floods on the other – is just as prevalent in Asia as it has been in the USA and the UK. Partly through the lack of a clear science message in relation to forest and water interactions many interest groups have selectively reproduced and propagated conventional wisdoms which best suit their purposes. Foresters have long been suspected of propagating many of the forest and water myths in "defense of their trees" and their agency agendas. More recently, environmentalists have picked up on the "forests protect against floods" message as a means of promoting forest preservation.

Foresters, of course, not only wish to plant trees they also want to log them. Ironically, the oversold "forests prevent floods myth" has contributed to the environmental case against deforestation in the tropics and has played a role in the introduction of logging bans and massive reforestation programs in many Asian countries. At the same time, gradual recognition that a purely structural approach to flood control is unworkable has lessened demand for dam and dike engineering in favor of softer engineering approaches such as flood warning systems, flood proofing, and watershed management.

At this juncture it is important that policy makers and development organizations rethink the potential impacts of these trends on not just watersheds and floods, but upstream communities. If it is true that the proposed remedies for watershed management (i.e. primarily reforestation) are unlikely to address the real problems and the needs related to flood disasters, then this needs to be clearly understood not just by watershed managers but by those agencies working on flood management. A number of the instruments of watershed management - logging bans, reforestation programs, resettlement of residents out of upper watersheds, restrictions on growing certain crops – may be highly detrimental to the livelihoods and food security of (typically poor) upland dwellers (Calder, 2005). Policy makers and development agencies need to ensure that regulatory and project approaches that are of questionable scientific validity do not put these communities at risk of further impoverishment. It is time for the narrative to change course.

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