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Lake Basin Management Initiative
Thematic Paper

Water Allocation and Environmental Flows in Lake Basin Management

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Introduction

This thematic paper is a contribution to a multilateral Lake Basin Management Initiative. It summarises and analyses the 28 lake basin management experience Briefs commissioned for the Initiative from the perspective of water allocation and environmental flows in lake basin management. The purpose of the analysis is to check the accuracy and adequacy of the treatment of the topics of water allocation and environmental flows in the 28 Briefs, and to develop a global picture of the topic based on the content of the Briefs. For the purposes of this paper water allocation and environmental flows have been defined as follows:

Water allocation is the process of specifying or quantifying the volumes of water available for, or used by, one or more "consumptive uses". In this lake basin management context this refers to volumes of water used in the contributing catchment, used from the lake or reservoir itself, or released from the lake or reservoir for downstream use. Consumptive uses are those which involve removal of water from a river, lake or reservoir, and thus include irrigation, hydro-electric power (HEP) generation (usually by controlled releases), industrial uses, and domestic water supply. A Brief was judged to deal with the topic of water allocation if it considered the absolute or relative volumes or water used, or proposed to be used, in any of these enterprises. Generally, this would also involve some level of the articulation of lake or lake basin water balance, for example, the relative or absolute values of water inflows and outflows.

Environmental flows are volumes of water purposefully left in or released into rivers, lakes or reservoirs, to maintain or restore particular ecological values. This involves the concept of providing an ecologically appropriate water regime. For a lake or reservoir the water regime is considered here as the depth and time variations in depth of the water body. Changes in depth change the nature and availably of different aquatic habitats, and are also expressed as changes in surface area and changes in shoreline length. Changes in depth also affect physical and chemical process within the water body, thus further affecting ecological character and condition. For rivers the water regime is considered here as discharge and time variations in discharge. Changes in discharge alter flow depths and velocities, which alter the nature and extent of aquatic habitats in rivers, as well as physical and chemical processes. A Brief was judged to deal with the topic of environmental flows if it considered the importance of the lake or river water regime to ecological values, either from a restoration or a preservation perspective. This included consideration of lake/reservoir releases for environmental purposes, environmental constraints on releases or lake levels, environmental constraints on downstream diversions/abstractions from lake/reservoir releases, or environmental constraints on diversions/abstractions from contributory rivers or their connected groundwaters, While temporal variability is an extremely important aspect of environmental flows, usually environmental flows have a volumetric flow consequence and hence can be considered a "water allocation". In cases where an environmental flow is actually determined and managed, the definitional boundary between environmental flow and water allocation can become blurred, since an environmental flow is not strictly a "consumptive use", and indeed, water released primarily for environmental purposes may be diverted further downstream for consumptive purposes. However, in the context this paper, the above definitions of water allocation and environmental flows are a sufficiently robust basis for analysis and discussion.

Analysis of the Briefs

Although lake basin management is concerned with both land and water management, the focus is always on the major water body and the goods and services that it supplies or could supply. All of these goods and services depend on both the water quantity and the water quality, however, for consumptive uses it is usually water quantity that is the limiting factor, while for non-consumptive uses it is usually water quality that is the limiting factor. The balance of consumptive and non-consumptive uses is thus very important in determining the stresses on a lake and hence determining the foci of lake basin management. In this paper this simple discriminator is used as a means to initially categorise the Briefs into: (i) those that deal primarily with water quantity (but also water quality), (ii) those that deal primarily with water quality (but also water quantity) (Table 1). The Briefs that primarily deal with water quality are those where a greater consideration of water allocation and environmental flows is to be expected. Overall water quality receives more attention (Table 1).

Category	Lake Basin Management Experience Brief
1. Primarily quantity	Aral Sea, lakes Baringo, Chad, Cocibolca, Issyk-Kul, Kariba, Naivasha, Nakuru, Sevan, Titicaca, Toba, Tonle Sap, and Tucurui
2. Primarily quality	lakes Baikal, Biwa, Champlain, Chilika, Constance, Dianchi*, Laguna de Bay, Malawi, Ohrid, Peipsi, Tanganyika, Victoria, Xingkai, The Great Lakes and Bhoj Wetland

Table 1: Categorisation of Briefs according to focus. An * indicates a border-line case.

In this categorisation a focus on lake sedimentation was a treated as a water quality issue as it is usually associated with increases in turbidity and nutrient loading. Over-fishing was also treated as a quality rather than quantity issue, as it relates to a non-consumptive use of water, and is often accompanied by pollution from fishing boats and the riparian population.

The availability of water for consumptive use is dependent on the regional balance between rainfall and evapo-transpiration (ET), the inter-annual variability in rainfall, and the capacity and morphometry of the lake/reservoir. Hence a consideration of the basin and lake/reservoir water balances is required to assess water availability. The adequacy with which this is dealt with varies between the Briefs. Where the balance between rainfall and ET is close there will be the less water available for consumptive use, and the importance of quantifying the water balance increases. Evaporation exceeds rainfall in the vicinity of the lake for the Aral Sea, and lakes Baringo, Chad, Chilika, Dianchi, Issyk-Kul, Kariba, Malawi, Naivasha, Nakuru, Sevan, Tanganyika and Victoria. However, in the cases of lakes Issyk-Kul, Kariba, Malawi and Tanganyika data are not presented in the Brief to make this apparent.

The natural lakes in this 'rainfall deficit' category are often closed lake basins – that is they have no natural outflow – an important consideration in the water balance. This is apparently the case for the Aral Sea, and lakes Baringo, Chad and Malawi, although not noted in their respective Briefs. It is noted to be the case for lakes Issyk-Kul, Naivasha and Nakuru. Of the above 'rainfall deficit' cases only lakes Dianchi, Tanganyika and Victoria have surface outflows; Lake Chad has a groundwater outflow (that caries a substantial salt load), and Chilika Lake has a seasonal connection to the sea. Of the seven naturally closed lake basin cases, all but the Lake Malawi basin have significant water abstraction and a consequent water quantity focus. These six cases are considered below as a sub-category of the cases where the primary focus is water quantity.

The second sub-category of water quantity focus cases is the naturally open lake basins that include lakes Cocibolca, Sevan, Titicaca, Toba and Tonle Sap. The final sub-category of water quantity cases that is the artificial water bodies of Kariba and Tucurui, that in spite of multiple uses, were constructed primarily for supply to downstream consumptive uses. The Briefs that deal primarily with water quality are considered as a single group and in less detail, as generally they have comparatively less to say on the topics of water allocation and environmental flows.

For all Briefs, the topic of water allocation is considered in terms of the degree of quantification of the lake and basin water balance and the degree of formalisation of water allocations. The topic of environmental flows is considered in terms of the degree of recognition of the importance of environmental flows, ranging from conceptual recognition, through planning/determination, to implementation and effectiveness monitoring. Because of their importance to successful water allocation and environmental flows, and indeed to integrated lake basin management, the following three aspects are briefly considered at least for the water quantity focus cases: (i) the strength of relevant institutional and legal frameworks, (ii) the degree of stakeholder involvement and empowerment, and (iii) the extent of transboundary issues.

Water Quantity Focus– Closed Lake Basins

Aral Sea

Water allocation is clearly a central theme in this Brief, although surprisingly little quantitative data is presented on the basin or sea water balance, and the description of the sequence of upstream reservoirs and their associated HEP generation infrastructure is poor. As is typical in closed basins the water diversions are from upstream of the sea. Surprising, while figures for irrigation withdrawal and lake evaporation are cited, actual inflow volumes are not.

Clear messages relevant to water allocation include:

- Irrigation accounts for over 90% of the basin water withdrawal, leading to reduced river flow and the rapid shrinking of the sea.

- Water use efficiency is low in all sectors, especially irrigation, losses in on-farm delivery account for 37% of supply, and on-field wastage accounts for 21% of supply.
- Disputes over the seasonality of water delivery occur every year between riparian countries, because of the different requirements of upstream HEP generation and downstream irrigation.

Water allocation is the prime focus of transboundary negotiations in the region. However, in spite of extensive international attention and aid, little progress has been made in achieving equitable and sustainable water allocation. This is partly because in spite of some interstate cooperation, the institutions and legal basis for progress are poorly developed. Furthermore, the costs of the technical, economic and institutional reforms required for sustainable irrigation in the region are beyond the willingness and ability to pay of the basin states and international donors combined.

Environmental flows are hardly considered in this Brief. Clearly, the sea is shrinking with catastrophic ecological consequences. However, it seems the consideration of what might be an ecologically appropriate water regime for albeit a vastly modified sea is inconceivable in the political climate of the region. A passing mention is made of the major alterations to the contributory river flow regimes, including the river flows "falling below minimum discharge levels that have been recorded in the last hundred years". However, once again a consideration of what might be ecologically appropriate flow regimes for the rivers appears to fall in the 'too hard' basket. While there is recognition of the ecological character and associated goods and services of the sea, this recognition does not extent to the contributory rivers, let alone any ecological connections between the rivers and the sea.

While a strategic basin-wide approach to water resource management is being attempted, the magnitude of the problem, and the lack of the institutional and legal frameworks necessary to achieve transboundary cooperation mean little progress is being made. Additionally, there is little involvement, education or empowerment of stakeholder groups, with the majority of negotiations being at the inter-governmental level.

Lake Baringo

Although not yet as dramatic as the Aral Sea case, Lake Baringo is also shrinking due to the damming of the contributory rivers and upstream diversions for consumptive use, particularly irrigation. Again, there is a lack of quantitative data in the Brief describing the basin and lake water balance and how it has been altered. In spite of problems with data gaps and quality that are acknowledged in the Brief, it seems as though there are adequate data available to at least reasonably characterise these water balances. Two aspects of the lake water balance change that are poorly understood and require further investigation are the impacts of catchment clearing on river flow volumes and variability, and the affects of regional climate change.

There appears to be no basin-wide planning of water allocations in the Lake Baringo Basin, and no explicit efforts to manage or control further water diversions. Rather, there is a focus on local level initiatives in water harvesting and groundwater use as alternative supplies, and other community-based water projects. It is not clear the extent to which these will have any affect on the water balance of the lake.

While there is no articulation of environmental flows from a planning or management perspective for the either the lake or the contributory rivers, there is a recognition of some of the ecological consequences of reduced lake inflows in that "only a limited number of aquatic animals could survive under such conditions" and the recognition that the "fish community…has been very much disadvantaged". Although there is not a similar recognition of the impacts of changed flow regimes in the contributory rivers, there is a recognition of the ecological connections between the lakes and the contributory rivers in that "fish species…. which migrate upstream to spawn are today close to extinction in the lake".

Although there are some institutional and legal frameworks in place, these appear partial and ill-coordinated and have not led to the development of any strategic basin-wide planning. Limited stakeholder involvement has occurred, but again this has not occurred within any coordinated planning framework.

Lake Chad

Lake Chad is another shrinking, rainfall deficit, closed basin lake. In this case the Brief presents a quantitative water balance for the lake for both the recent drought decades and the period prior. It is clear that decadal climate variability is a major determinant of the lake size – indeed it is noted that the lake dried completely four times in a historical 500-year period. The lake ecosystem is therefore characterised by "boom and bust" cycles that affect all trophic levels from phytoplankton up to fish-eating waterbirds. This level of variability and the apparent lack of data on irrigation abstractions (amounts and location), makes it difficult to assess the extent to which water resource development in general, and irrigation in particular, have exacerbated lake shrinkage. Indeed, in spite of the good overview of the water balance, the Brief does not provide a good description of the upstream water resources infrastructure nor the amount and spatial distribution of the irrigation demand. It does note however, that new irrigation proposals are "studied very carefully", and that realisation of the "irrigation potential" of the basin would require 80% of the lake inflows. Presumably this assessment of "irrigation potential" was made in isolation of any environmental water requirements!

In spite of the establishment of the Lake Chad Basin Commission (LCBC) – an inter-governmental agency with the responsibility to "regulate and control the utilisation of water" that binds member states to "refrain from adopting any measures likely to alter the lake's water balance", and the signing of a convention that "forbids any unilateral exploitation of the lake water", the failure of the LCBC convention to prescribe any allocation rule, and lack of an integrated river basin management strategy, mean that water allocation is a continuing problem. The Brief notes "improperly designed dams and poor, uncoordinated operation of the dam reservoirs have led to numerous conflicts within and between member countries", and further that "communal uprisings (downstream versus upstream riparians) have become more frequent in recent times". Several examples are cited of large-scale inefficiencies in water use, and conflicts arising due to a lack of regional planning. The overall picture that emerges is one of a lake system that hydrologically is naturally highly variable, being placed under stress due to consumptive water use that suffers from inefficiency, poor coordination, inadequate planning and a lack of any guiding management or development strategy. Existing water allocations have not been formalised into water rights, and there is no clear basis for managing emerging water demands.

There is clear recognition in the Brief of the ecological importance of the water regimes of the lake and contributory rivers: "annual floods, which used to inundate large areas that served as breeding grounds for fish as well as other wildlife…became drastically reduced by …regulation…coupled with unsustainable reservoir operation"; "it is therefore not difficult to appreciate the disappearance of many valuable plant and fish species"; "fish species… whose pattern of migration and spawning is triggered by the rising flood are more severely affected by the change in the flood cycle"; and "the minimum annual flooding extent required to sustain the fish ecosystem and fishing industry in the Hadejia-Nguru Wetlands is 800 km^2".

On top of this recognition of the importance of the water regime is the experience of the "dry season test releases in 1996 from Tiga and Challawa Dams (which control over 80% of the flow of the Hadejia River)" that can be considered as trial environmental flow releases. In fact, "virtually no water from the Hadejia River leaves the Hadejia-Nguru Wetlands due to weed blockages…and siltation in the riverbed in the zone of the wetlands". Nonetheless, "the test releases flooded most of the floodplains along the Hadejia River systems, simulating perfectly the wet season condition, and proving that the dam outlets and Hadejia Barrage are adequate to generate artificial flooding in most wetlands." Such releases would not only help sustain the floodplain ecology along the downstream river, but the traditional floodplain agriculture than depends upon this ecosystem.

Although environmental flows have not progressed beyond concept and trial in the Lake Chad basin, this is much further than in most such basins. The first objective of the recently articulated lake Chad Vision for 2025, namely "maintenance of Lake Chad and other wetlands of the region at sustainable levels for economic security of the freshwater resources, sustained biodiversity and aquatic resources of the basin and their equitable use and alleviation of poverty", embodies a strong environmental flow vision that may provide the incentive for future efforts, presumably in conjunction with improved water allocation planning and management. A recently proposed restoration project is based around a large inter-basin water transfer that is seen as "an opportunity to rebuild the ecosystem, rehabilitate the lake, reconstitute its biodiversity". In this is the clear recognition of the importance of the water regime to the aquatic ecology. However, as with all such grandiose projects, the lack of robust science to underpin regional-scale ecological engineering suggests a high degree of uncertainty as to the outcome, and careful cost-benefit and environmental impacts assessments are required to ensure it is not a case of "robbing Peter to pay Paul".

The relevant institutional and legal frameworks appear reasonably strong with a multi-laterally negotiated basin commission established with the mandate and power for resource management and control. However, this has not yet led to a strategic basin-wide approach to water allocation. Only limited stakeholder participation has occurred in the basin, and these efforts have largely focussed on local capacity building.

Lake Issyk-Kul

With a mean depth of 280m, Lake Issyk-Kul is only deep lake in this closed basin sub-category. The lake is feed by surface runoff and glacial meltwater; evaporation from the lake is substantial as is irrigation development within the basin. In recent years the net result has been nearly a 2m-drop in lake level. The lake experiences a seasonal cycle of depth variation associated with snowpack and glacier melt. Aspects of the water balance appear well quantified, however, irrigation withdrawals are not quantified in the Brief, nor is the apportionment of inflow between runoff and meltwater. Significant changes in both runoff and meltwater have been noted and partial future projections are provided. These projections include reasonable stable inflows from the northern tributaries for the next 5-10 years until glacial volumes are depleted due to regional warming, and a growth in inflows from southern tributaries for similar reasons until 2020 or 2030. However, the net, long-term projection for the lake water balance is unclear from this information.

There is little evidence of strategic water allocation planning or management. Rather, the general acknowledgement of the "long and consistent decline in lake levels" has led to proposals for "supplementary feeding of Lake Issyk-Kul over and above its natural water resources" by inter-basin transfers. This is stated to be "necessary to maintain development of irrigation in the basin". The problem is seen not as one of over-allocation that is beyond the sustainable limit of the system, but rather one of the "unfavourable natural tendencies" of the lake! In the longer term, climate change may indeed reduce lake inflow and affect water allocation, however, to-date it seems that while the source glaciers are being depleted, this has not yet substantially affected inflows. Rather, water abstraction appears causing lake level drop. There are differences of opinion regarding the appropriateness of the proposed inter-basin transfer, revolving around the water resources demand in the source basin. As always, careful cost-benefit and environmental impact assessments should be the foundation for proceeding with such potential solutions.

There is some recognition of the relationship between the water regime of the lake and its ecology and biogeochemistry, for example "fall in lake level bring with it a reduction in the volume of biogenic elements entering the lake from littoral silts, and thus an increase of the biological productivity of the lake", and "with the drop in water level also comes a certain increase in salinity". Beyond this elementary conceptual understanding, environmental flows for the lake or the contributory rivers are not considered. There is no mention of the ecological importance of the seasonal patterns of flow and water level change, and no consideration of the levels of water regime change may be environmentally acceptable.

The Brief gives little information in the institutional and legal frameworks for integrated basin planning and management. However, it appears as no clear frameworks exist, with only a very general resource management charter residing with an Environmental Protection Authority. There is no evidence of stakeholder consultation or involvement.

Lake Naivasha

Lake Naivasha is a shallow, closed basin, rainfall deficit lake. As a shallow lake it is sensitive to the high inter-annual variability of rainfall of the region and displays considerable natural variation in size and depth, with its dependent ecosystem being likewise highly dynamic. Importantly, there are complex connections between the lake and a productive groundwater aquifer. The dynamic water balance of the lake has attracted attention for several decades, and is comparatively well quantified by a monthly simulation model that includes consideration of groundwater aspects. As water abstractions are not monitored, the modelling has provided the best estimate of the total upstream water abstractions. The effects of water abstractions on the lake have been separated from the effects of rainfall variations. Currently, consumptive water use (predominantly high-value horticulture) accounts for about 30% of the natural mean lake inflows, and has translated into a 2.5m reduction in mean lake depth.

Water allocation is being considered very seriously in the Lake Naivasha basin. The Brief notes that “a water abstraction permit has always been required but in practice every request was honoured”, and “many users are abstracting either without a permit at all, or above the limit set by the permit”. Recently however, two new laws have been passed, and relevant authorities established with the mandate to implement and enforce these laws, which should improve many aspects of water management. The Government “has carried out a detailed water abstraction point survey, has stationed a hydrologist and a water bailiff in Naivasha to monitor resources and demand, and is training a water police force to prosecute illegal abstractors”. Furthermore, the Government is currently “seriously assessing abstraction permits, and the pricing of water is being seriously considered”. The Brief clearly recommends the introduction of water charges. On the production side, horticulturalists are promoting “water conservation” and “the importance of water abstraction monitoring”. Overall, water allocations are now being dealt with comprehensively, although there is still some way to go formalise allocations, and regulate the system sustainably.

Surprisingly, given the detailed hydrologic understanding of the lake and much of its drainage basin, and seemingly detailed knowledge of the ecology of the lake, there is no parent recognition of the importance of environmental flows for either the lake or the contributory rivers. The naturally dynamic nature of the lake’s water regime is acknowledged. However, only passing reference is made to the ecological implications of this water regime, and there is no consideration of the resilience of the lake ecosystem to additional imposed fluctuations in water level and hence shoreline changes.

Lake Nakuru

Lake Nakuru – the final lake in this sub-category of closed basin rainfall deficit lakes, is another shallow lake, with a mean depth of only 2.5m and a maximum of 4.5m. However, Nakuru is a relatively small lake, and without a subsurface outlet to remove salts, it is strongly sodic, and characterised by seasonal changes in water chemistry depending on whether “a dilution or evaporative cycle prevails”. Given its sodicity, the lake water itself is unsuitable for consumptive uses, however, the lake water balance has been greatly impacted by “an increase in water abstraction along the upstream parts of the rivers for irrigation, domestic and factory use”, with “over 350 registered and unregulated water intakes in the catchment streams”. “Prolonged dryouts of the lake have occurred in 1993, 1994, 1995 and 1996”. In additional to surface water abstractions, substantial catchment deforestation has altered the catchment hydrology, “manifested in higher runoff rates, higher and more destructive peak discharges in rivers and other water courses, marked seasonality in steam flow and significant declines in the stable yields of wells and boreholes". This latter change being also related to the direct groundwater demands of 156 registered and a few unregistered boreholes.

While the Brief presents a qualitative understanding of the basin and lake water balances, no quantitative descriptive is given. There appears to be little quantitative basis for water allocation planning or management, and current abstractions appear to be poorly quantified. There is therefore a poor ability to distinguish the relative contributions of climate variability and water abstraction to the recent fluctuations in lake size. While there is little apparent strategic basin-wide approach to water allocation, local efforts in water conservation and water harvesting are being promoted as ways to lessen or manage water demand.

There is apparent conceptual recognition of environmental flows for the lake in that "waterfowl counts…show a progressive decline in species diversity and numbers over the last 5 years, this can be attributed to the frequent and protracted dryouts that have occurred in the lake over the last 7 years". However, the acknowledgement of the exacerbating influence of upstream abstractions is not explicit, in that "the resilience of the lake ecosystem appears to have been compromised as evidenced by the changes in the lake ecology particularly after the perturbation caused by the El Nino rains in 1997". The importance of environmental flows, for the lake and presumably for the contributory rivers, is also recognised in the stated management challenge to "restore the water balance…. of the catchment basin through better land use practices and water management". Recognition of the importance of environment flows has apparently not progressed beyond this conceptual level.

A reasonably strategic basin-wide approach is being taken to water resource management, backed up by relatively robust institutional and legal frameworks, and active, self-organised community participation. However, there is a wide array of bodies with varying degrees of responsibility and power for natural resource management that do not appear especially well coordinated. Some level of coordination is provided by the lake Naivasha Management Implementation Committee, however, this committee doe not have official status or legal power, nor has it a formal budget.

Summary

The closed basin rainfall deficit lakes are those where water resources are the most limited and generally under the pressure from consumptive use. This is especially true for the shallow lakes where reductions in volume are expressed in marked changes in lake extent and hence littoral habitats. Attention to water allocation and environmental flow issues is therefore in lake basin management is therefore most important in these cases. The Briefs for these cases reflect a varying level of planning management attention to these aspects, ranging from none or very little to reasonable. Similarly, whether not these issues are being given adequate attention in lake basin management, there is considerable variation in the adequacy of the treatment of these topics in the Briefs, ranging from partial to adequate but not comprehensive. The issues discussed in the sections above are qualitatively summarised in Table 2.

Lake	Depth	Water Balance Quantification	Formalisation of Water Allocations	Recognition of Environmental Flows	Transboundary Issues	Institutional and Legal Frameworks	Stakeholder Involvement
Aral	shallow	good?	limited	poor	major - international	poor	poor
Baringo	shallow	poor	none	limited	minor - inter-district	reasonable	limited
Chad	shallow	good	none	Reason able	major - international	reasonable / strong	limited
Issyk-Kul	deep	moder ate	none	poor	none	very poor	none
Naivas ha	shallow	good	Reason able / improving	limited	minor - inter-district	reasonable / strong	good
Nakuru	shallow	poor	none	limited	minor - inter-district	reasonable	reasonable

Table 2: Qualitative summary of water allocation and environmental aspects in the closed basin, water quantity focus Briefs. The question marks indicate an assessment assumed in the absence of sufficient information in the Brief.

Water Quantity Focus – Open Lake Basins

Lake Cocibolca (Nicaragua)

Lake Cocibolca is a large, moderate depth (maximum depth 45m) lake that while not currently greatly impacted by consumptive water use, is the focus of several development proposals. Regional studies have "lead to the conclusion that the freshwater in the Lake Cocibolca-San Juan River Watershed is the only source capable of the meeting the foreseeable development needs of the semi-arid Pacific slope of Central America, the region's most populated area". The proposals are predominantly for HEP generation and large-scale irrigation development – far beyond the existing level of irrigation. Inherent in many of the HEP proposals are conflicts with the existing irrigation demands.

The Brief presents a quantitative water balance for the lake, and it appears that the water resources of the basin are reasonably well quantified. This suggests a reasonable technical basis for water resource development planning. However, there is an apparent lack of any strategic approach to the development planning, due to a lack of basin-wide planning and administrative institutions. The legal frameworks to underpin such institutions appear reasonably strong –

except in the area of bilateral cooperation (between Nicaragua and Costa Rica), however, a lack of necessary resources means implementation and compliance are weak.

There is a clear conceptual recognition of the importance of environmental flows in the Brief, for example "the construction of any of these projects will mean substantive changes in the average flow rate of the San Juan River, reducing it by some 36%.... aspects to be considered if these projects are implemented should be their effects on the aquatic life in the San Juan River and Lake Nicaragua, the flora and fauna existing in the area to by inundated by the proposed dams, and the environmental impact that will result from all the associated construction work". However, because of the lack of clear institutional arrangements for basin-wide water resource planning, it seems unlikely that environmental flows are being seriously considered by the respective Governments.

The exception to the generally poor basin-wide planning appears to be the Costa Rican "PROCUENCA" Project with the objective of formulating a strategic action plan for the integrated management of water resources and the sustainable development of the San Juan river basin and its coastal zone. The lack of geographical and other detail in the Brief makes it unclear the extent to which this project could deal with entire basin including the catchment of Lake Nicaragua. In spite of apparently not being bilateral, this project may strengthen the legislative and institutional frameworks for long-term basin management, and lead the way to wider stakeholder involvement.

Lake Sevan

Lake Sevan is a large, moderate depth, rainfall deficit lake. The water balance of the lake is well quantified and has been substantially altered by several large scale engineering projects beginning in the 1930s, and intended to "intensively use the water resources for irrigation and hydropower generation". Artificial increases in lake outflow for irrigation and HEP have lowered the lake level by nearly 20m. It has been recognised that " the consequence of long-term water balance disturbance is deterioration of ecological characters of Lake Sevan", and that the River Vaerdenik that is vital importance for particular fish species is completely drained in drought summers due to irrigation diversions. Clearly in this case, good quantification of the water resources has led to excessive exploitation rather than careful management. Water allocation has been simply demand driven, with no consideration of sustainability or environmental impact.

In 1980 the decision was made, based on scientific advice, to raise the lake level by 6m over 25 years to bring "environmental conditions to near natural". No details of this underpinning science are presented in the Brief, and issue of environmental flows in the contributory rivers themselves is not mentioned. Five years after the above decision was made, it became clear that this ambitious goal had not been met. Subsequent options were considered for 3m rise over 15-34 years and 6m over 31-85 years, in spite of no evidence that a 3m rise would lead to substantial improvement in environmental conditions in the lake. Reflected in this history is a clear *a postiori* recognition of the need for environmental flows for the lake, attempts at determination, but no success in implementation. It seems that in spite of the long list of codes, laws and treaties listed in the Brief, the lack of a strategic approach to sustainable water resource management stems from generally weak relevant institutional and legal frameworks. Stakeholder involvement occurs in the basin, but is ineffective, and treated as a necessary formality.

Lake Titicaca

Lake Titicaca is a large and relatively deep (mean depth over 100m) lake. It is included in the water quantity focus category because the Brief states that "the main conclusion of the assessment is that the available current hydrological resources do not meet the demand in the system", and that there are "large problems arising from the poor regulation of its waters". Indeed the terms of reference for this thematic paper note that with respect to water allocation "Lake Titicaca is among the best-documented shortfalls". It is surprising therefore that the Brief documents these shortfalls very poorly. Within the Brief the water balances of the lake and its catchment are not quantified, neither are current water allocations. Even more surprising perhaps is that the actual consumptive uses that give rise to current water allocations are not mentioned. A fairly vague picture is painted of "deficient regulation of the water resources" and of the recent history of severe floods and droughts affecting the region.

Environmental flows are not mentioned in the Brief – even from a conceptual standpoint. From the Brief it is apparent that a bilateral (Bolivia and Peru) strategic approach to water resources planning and management has been adopted. Beyond this however, it is not clear what institutional and legal frameworks exist to facilitate implementation of such an approach. There is recognition of a moderate level of stakeholder involvement.

Lake Toba

Lake Toba is a moderately large, and deep lake (maximum depth over 500m). Consumptive use is dominated by downstream HEP generation and upstream industrial use that have seen a substantial drop in lake levels in recent decades. As wastewater from the latter use is returned to the river and thence to the lake the actual water balance impacts from industrial are unclear. Indeed the Brief notes considerable disagreements over the main causes of change to the lake water balance. Overall however, the lake and basin water balance are well quantified and articulated in the Brief. The inflows, evaporation and consumptive uses are quantified, in a current and historical sense. The lack of rainfall data is acknowledged as constraint on determining the relative roles of water allocation and climate change on the lake levels, and the role of land use change on the basin water balance is unquantified.

The drop in lake level is acknowledged to be "a great threat to the biophysical environment", and " the aquatic plants and shrubs in the shoreline which forms the fish habitat wilt and dead (*sic*) due to lack of water". This drives fish into the deeper parts of the lake that are less accessible to traditional fishing methods. To improve this situation the lake levels are regulated by a government authority within a prescribed range, to prevent both excessive drawdown and inundation of riparian villages. There appears to a degree of self-regulation by industrial use to meet the prescribed volumetric allocations.

Overall, it appears that a reasonably strategic approach is being taken to water allocation planning and management. It is not clear from the Brief just how strong the institutional and legal frameworks to implement this approach are, but the reasonable level of stakeholder involvement that is reported and the actual implementation of lake level regulation suggest these frameworks are at least reasonable.

Tonle Sap

Tonle Sap is a shallow lake with a unique and extremely dynamic seasonal hydrological regime that drives its ecological functioning. The water balance of the lake and it seasonal dynamics are surprisingly well quantified considering the current lack of consumptive use, although the Brief acknowledges that "neither (the) lake's exceptional hydrology nor the driving forces behind the high aquatic production are yet fully understood and analysed". Tonle Sap is recognised to be an integral part of the Mekong Basin that needs to be managed in a basin-wide context, and the perspective is very much one of prevention rather than cure in the face of potential impact. It is noted that "the possible building of upstream dams can result in serious reduction of the water flow to the river as well as decrease the amount of sediments in the lake".

Environmental flows are recognised in a conceptual sense, especially in terms of hydrologic connectivity: the "majority of the lake's waters originate from the Mekong River making the river of extreme importance to the lake", "migration of different fish species between Tonle Sap and the Mekong River is extensive and diverse"; "during the inflow…there is mostly a passive migration of eggs, fry and fish to the Tonle Sap lake and its floodplains. Later fish follow the receding floodwater back to the lack and finally to the Mekong River". The fish resources of Tonle Sap are fundamental to the vast majority of people living in its vicinity.

There is a complex array of institutional and legal frameworks for natural resource management in the wider Mekong basin from the local to the international. These should provide the basis for objective resource use and planning both for the Mekong and Tonle Sap, however, transboundary negotiations (particularly upstream-downstream) are usually difficult and protracted. Various international organisations have been actively promoting stakeholder involvement in resource planning and management in the region. It is recognised in the Brief that greater scientific understanding of the system is also required for effective planning and management.

Summary

Although generally under less water allocation pressure than the closed lake basins, the above open lake basins are characterised by substantial actual or potential consumptive water demands Surprisingly their water balances are generally better quantified in the Briefs than those of the closed lake basins. In most cases however, water allocations appear unformalised, although there is scant detail on this aspect in most of the Briefs. The conceptual recognition of environmental flows is variable: from none at all to considerable. The issues discussed in the section above are qualitatively summarised in Table 3. The issues discussed in the sections above are qualitatively summarised in Table 4.

Lake	Depth	Water Balance Quantification	Formalisation of Water Allocations	Recognition of Environmental Flows	Transboundary Issues	Institutional and Legal Frameworks	Stakeholder Involvement
Cocibolca	shallow	good	none?	limited	minor - international	reasonable	limited
Sevan	moderate	good	none?	limited	none	poor	limited
Titicaca	deep	poor ?	none?	none	moderate - international	reasonable ?	moderate
Toba	deep	good	Reason able	Reason able	none	reasonable	reasonable
Tonle Sap	shallow	good	n/a	good	major - international	strong	reasonable

Table 3: Qualitative summary of water allocation and environmental aspects in the open basin, water quantity focus Briefs. The question marks indicate an assessment assumed in the absence of sufficient information in the Brief.

Water Quantity Focus – Man-made Reservoirs

Lake Kariba

Kariba Dam was built in the early 1960s for HEP generation. The impoundment is of moderate size and depth (mean depth about 30m). The water balance for the reservoir is not well quantified in the Brief with no mention of average inflow volumes or of the reservoir release regime. Presumably some water resource assessment preceded construction, although the Brief notes two revisions in spillway design during construction due to the occurrence of large floods that altered estimated flood recurrence intervals. The reservoir is managed predominantly for HEP generation. In the variable climate of the region this means maximising live storage to protect against droughts, thus leaving minimal capacity for flood mitigation. Downstream flooding is already, and will increasingly become, an economic and humanitarian problem.

There is no clear recognition of the importance of environmental flows in the Brief, although it is noted that the changes in downstream flow patterns have forcibly altered the livelihoods of riparian communities. There is no discussion of the options for mitigation of these impacts or downstream ecological impacts. Any ecological studies have been directed at the artificial lake itself .

A strategic approach is being taken to basin management, with institutional underpinning provided by a bilaterally (Zambia and Zimbabwe) negotiated and established river authority. It is noted in the Brief, however, that at the operational level there are contradictory approaches to water and other resource management. The politically weak communities of the basin have not been involved to any significant extent in resource planning or management.

Tucurui Reservoir

Tucurui Reservoir is a relatively recent, large impoundment of moderate depth (mean depth 19m, maximum 75m) constructed for HEP generation. The water balance of the reservoir is partially described in the Brief, while that of the basin is largely overlooked. The geography and climate of the region are poorly described, as are series of dams upstream of Tucurui. A second phase to the Tucurui Project is referred to that will "take advantage of the hydrological periods and excess water available in the rainy season". It is not made clear to what use the water will be put, although it is noted that "changes will occur in the hydrological system downstream". The Brief notes existing downstream impacts: "decrease in fisheries, the proliferation of mosquitoes and the high exploitation of natural resources of the area with the lack of alternatives".

The Brief does recommend cost-benefit and environmental impact assessments for any future HEP projects. For the Tucurui project environmental impacts assessments apparently focussed on the constructed reservoir, as "less importance, at least at the initial stages of the environmental impact assessment was given to the watershed and the downstream environment". Beyond this there is little recognition of the importance of environmental flows in the Brief, that notes "when….construction started very little experience existed concerning such large hydropower impacts on the terrestrial/aquatic and socioeconomic environments of the Amazon region".

The Brief contains few details on the relevant institutional and legal frameworks for water resources planning and management (some may be in the missing Figures); the impression gained is they are not particularly strong. There is no reference to stakeholder involvement.

Summary

The above two Briefs provide scant detail on water balances, water allocation or environmental flows. This is consider surprising as water allocation is common focus in reservoir management, and internationally, environmental flows assessment predominantly deal with the regulated rivers downstream of reservoirs.

Lake	Depth	Water Balance Quantification	Formalisation of Water Allocations	Recognition of Environmental Flows	Transboundary Issues	Institutional and Legal Frameworks	Stakeholder Involvement
Kariba	moderate	reasonable?	none?	none	moderate - international	reasonable	none
Tucurui	moderate	poor?	none?	none	none?	poor	none

Table 4: Qualitative summary of water allocation and environmental aspects in the man-made reservoir, water quantity focus Briefs. The question marks indicate an assessment assumed in the absence of sufficient information in the Brief.

Water Quality Focus

The Briefs that focus on water quality issues have, in general, little information on water allocation or environmental flows. As a consequence these Briefs are not dealt with in the same detail as those that focus in water quantity. In spite of their water quality focus, consumptive uses are noted in these Briefs, including HEP generation (lakes Baikal, Biwa, Constance, Malawi, Ohrid and Victoria), irrigation (lakes Biwa, Chilika, Dianchi, Laguna de Bay, Ohrid, Victoria, Xingkai), and other uses (lakes Biwa, Constance, Dianchi, Laguna de Bay, Ohrid, Peipsi/Chudskoe Tanganyika, Victoria, Xingkai, and the Great Lakes and Bhoj Wetland). In the cases of lakes Constance and Malawi, water allocations for HEP were noted in terms of reference for this paper but were not referred to the respective Briefs.

Lake Baikal

In the case of Lake Baikal, no quantification of water balance is provided, and no formalisation of water allocations is apparent. Regulation of the lake for HEP has "raised the water level by 3-5 feet flooding valuable wetlands, depleting forests due to inundation, and depleted sensitive fish habitat", reflecting a recognition of the environmental importance of the lake water regime. 'In 1999 a law was passed that created a maximum and minimum water level to reduce environmental impacts". However, in spite of appropriate legislation there is a lack of a strong regulatory and enforcement agency.

Bhoj Wetland

The upper lake of the small Bhoj Wetland is used for drinking water supply. There are however, no apparent water allocation problems, nor any environmental impacts clearly associated with this consumptive use.

Lake Biwa

Although primarily impacted by water quality degradation, Lake Biwa does support multiple consumptive uses, including domestic supply to 14 million people, industrial use, irrigation and HEP generation. The lake is also used for flood control, which affects the water level regime and creates conflicts with consumptive uses. While the water allocations for most of the consumptive uses are quantified in the Brief, the overall water balance is not. Water levels in the lake and downstream flows are regulated by an outlet structure, however, water is also pumped directly from the lake. Although much of the ecological degradation of the lake has been linked to water quality, it is noted that a “hazard for the fishes is intentional lowering of the lake water level in June, when it happens to be their spawning season. Their eggs would thus dry up even if they succeeded to spawn”.

The relatively recent Lake Biwa Comprehensive Development Project had the primary objective of “additional supply of Lake Biwa water to the downstream region”. This was to be achieved by construction of levees, flow control structures, channelisation and irrigation pipelines. The project “triggered massive destruction of the lake shores and littoral ecosystems” leading to community-based legal action that while unsuccessful, highlighted the importance of the lake ecosystem and shifted the community focus from “comprehensive development to comprehensive conservation”. The Brief notes that the flood control measures of the project have been partially successful, with flood damages in the lake watershed and downstream declining significantly. However, adverse effects on the lake and its littoral ecosystems have become prominent, leading to wide stakeholder involvement in a process to review the rule of water level control. This has not reached a conclusion yet, but is an attempt to define an environmental water regime for the lake.

Lake Champlain

Although this Brief notes that “nearly everyone in the basin depends upon the lake for a wide variety of uses from drinking water and recreation to agriculture, industry and waste disposal”, the consumptive uses and water allocation receive essentially no attention in the Brief.

Chilika Lake

Chilika Lake is a brackish water body intermittently connected to the sea. Because of this brackish character there are no significant consumptive water uses from the lake itself. However, irrigation infrastructure in the upstream catchment affects the freshwater inflows to the lake, which are important in maintaining an appropriate salinity regime, particularly the seasonal dynamics of the salinity regime. The lake in fact receives two types of freshwater inflows – the entire unregulated flow from the adjacent western catchments, and a small fraction of the flows from the large northern basin, via one of its deltaic distributary channels. While the deltaic inflow that is affected by upstream regulation is naturally a small fraction of the total basin flow, it is a very substantial fraction of the lake water balance. Although this water balance has been well quantified it is not described in the Brief.

Increasing upstream irrigation demand, continued deltaic flooding and poor flow regulation control has led to the recent construction of new flow regulating infrastructure upstream of the lake that will further affect the freshwater inflow regime. The Brief notes that the cumulative impacts of these interventions on the freshwater inflows are currently being considered in an environmental flow assessment. While reasonable data is available to guide this assessment, these data are primarily for the recent period when the lake ecosystem underwent a dramatic restorative change following a management intervention that re-opened the lake's connection to the sea after a lengthy period of isolation. As this connection is prime regulator of the salinity regime, determining the smaller but important contribution of the freshwater inflow to salinity regime regulation is difficult. A confounding aspect of the freshwater inflows is that they carry a high silt load that leads to enhanced sedimentation of the lake. The relative merits of the possibility of using upstream flow regulators to control silt loads versus provide freshwater flows is a part of the environmental flow assessment.

While there is a reasonably appropriate institutional and legal framework in place help carry environmental flow recommendations through to implementation, there are serious weaknesses in the system. There is a lack of awareness of some of the issues and a lack of technical capacity in the relevant government bodies. While a useful coordinating body – the Chilika Development Authority – has been established by state and central government funding, this authority has no statutory power over other state agencies whose activities impact upon the lake, and suffers from a lack of financial resources. Furthermore, in spite of this active and enthusiastic coordinating agency, no comprehensive lake management plan has been developed to guide and coordinate activities amongst government agencies. Because of the importance of Chilika to the livelihoods of so many of the people in the vicinity of the lake, community stakeholders have been pro-active, and several NGOs have contributed to facilitating stakeholder involvement in resource planning and management, community eduction and capacity building.

Lake Constance

Unlike many lakes in the foothills of the Alps, Lake Constance is not artificially regulated and so impacts on the water regime are minimal. The lake does supply drinking water to about 4 million people, and although this is not placed in the context of a quantitative water balance in the Brief, this is assumed to be a fairly small relative demand.

Lake Dianchi

Lake Dianchi's uses include water supply, HEP generation and flood regulation, all of which affect its water regime. Water scarcity is one of the lake's three major environmental problems, with demand exceeding supply in average and dry years – not accounting for irrigation return flows and urban runoff in the available supply. Overall the "development and utilisation of the water resource hits 60% in the basin, exceeding the international rational limit of 40% (the limit causing destruction of the ecological environment". This statement demonstrates the very high level of consumptive uses, which is why this case was indicted as a border-line case in Table 1, in spite of the Brief's strong focus on water quality. The above statement also reflects recognition of the need for environmental limits on such use. However, the spurious "international rational limit" that is cited, sheds an interesting light on the perceived appropriate balance of water use in this case.

While the Brief does present a quantitative water balance for the lake and has quantified gross consumptive use at least in a relative sense, there is no recognition of the importance of environmental flows for the lake itself or the rivers of the basin beyond the statement cited above. In spite of the recognition of the severe water allocation problem, a strategic basin-wide approach to water allocation planning and management has not been adopted. While some relevant institutional and legal frameworks are in place and efforts being made to involve stakeholders, the focus is on water quality management, and progress is hampered by a lack of awareness and technical capacity.

The Great Lakes

The North American Great lakes are a huge water resource, and the impacts of consumptive and non-consumptive uses have long been explicitly recognised – as cited in the Brief "there are two basic and quite different bilateral Great lakes issues: lake levels and water quality". The consumptive uses noted in the Brief include drinking water for two-thirds of the 40 million regional inhabitants, industrial uses and agriculture. Domestic and commercial uses are cited as using nearly four trillion liters per day. Beyond this, water allocations are not quantified in the Brief. It is noted that the "hydrology and water balance of the Great Lakes basin has been altered by human diversions, regulatory structures, urbanisation, dredging, filling and other human activities over the last 200 years or so". Some of the major diversions and associated structures are qualitatively described. Beyond this, the water balance and disturbances to it are not quantified. This is perhaps not surprising as given the size of the resource the volumetric water uses are relatively small. The Brief notes however, "various large scale proposals to remove water from the Great lakes have been around for almost a century, but received little attention". These proposals led to a bilateral Great Lakes Charter and provisions in the US Water Resources Development Act to deal with new or increased water diversions. Deficiencies in this management framework were revealed in the early 1990s when a company was issued a permit to abstract water for bulk overseas water export. This is turn led to amendments to the Canadian Boundary Waters Treaty Act to prohibit bulk water withdrawals and "set in place a licensing regime for dams and other public water works projects".

In spite of the relatively limited consumptive use, the various diversions and associated water regulation do affect the water level regime of the lakes. The nature of these changes however, is not described in the Brief, and no mention is made of the ecological impacts caused or potentially caused by these water regime disturbances. Indeed the Brief says almost nothing about the ecology of the lakes, beyond reference to invasive species. There is no reference to the consideration of environmentally appropriate water level regimes for the lakes, and no consideration of environmental flows in the rivers of the basin.

Laguna de Bay

Amongst the multiple uses of Laguna de Bay are the consumptive water uses of irrigation, and industrial cooling water. Although neither these consumptive uses nor the overall water balance are quantified in the Brief, they are apparently relatively minor. Consumptive uses are limited by water quality, particularly the brackish nature of the lake resulting from tidal exchanges with the sea that vary according to river discharge. It is this brackish nature and the natural water quality dynamics that sustain a highly productivity lake fishery – the dominant lake use. A regulating structure has been built to prevent saline tidal backflows from the outflow river. The intention being to reduce lake salinity thus improving water quality for consumptive uses. However, to-date the structure has not been operated in this way, and the saline backflows that maintain the important fishery continue. In spite of this situation there is an increasing interest in the lake's potential as a drinking water supply – again a consumptive use requiring low salinity that would compromise the main existing uses of the lake.

In the lake basin a river rehabilitation program has been in place since the mid-1990s. Although this began very much with a "physical clean-up" focus, it is now developing a broad vision for healthy rivers, which would provide an appropriate framework for the consideration of environmental flows in the basin. The Brief does not note whether consumptive water use from the rivers of the basin are significant.

Lake Malawi

Lake Malawi is a large, deep closed basin lake in the Rift Valley with a reasonably stable water level regime. While water allocations for HEP generation downstream of this lake are referred to in the terms of reference for this paper, these are not noted in the Brief. Indeed consumptive water use is not mentioned in the Brief at all except for passing reference to drinking water supplies for the inhabitants of the basin. No quantification of the lake or basin water balances is provided, and water allocation is not discussed.

Lake Ohrid

Lake Ohrid is a relatively small but deep lake with releases for downstream HEP generation. This and other lakes and rivers in the basin are sources of irrigation and drinking water. An overflow structure controls lake releases, and the river downstream has been diverted to allow these releases to be used for HEP generation. The lake water balance is not quantified in the Brief (although some aspects are qualitatively described), but water allocation does not seem to be a major issue. There is not a high level of demand and the demand is not growing substantially. While there are clearly issues of environmental degradation of the lakes and rivers in the basin, these relate more to a range of water quality problems (including eutrophication, bacterial pollution and heavy metal contamination), fishing pressure and sand and gravel extraction.

Lake Peipsi

The only consumptive water use noted in the Lake Peipsi Brief is the diversion from the river that drains the lake for drinking water supply for a town of 73,000 people. Water allocation and environmental flows are currently not significant issues. The lake has been considered as a potential water supply for northeastern Estonia, including the capital – Tallinn. Even this however, is a relatively trivial demand given the size of this and associated lakes, and the substantial and inter-annually consistent discharge of the major rivers.

Lake Tanganyika

Lake Tanganyika a very large and deep lake – volumetrically it is the largest of Rift Valley lakes. The Brief notes that the lake is "an important source of drinking and domestic water" but does not explicitly acknowledge any other consumptive water use in the entire basin. Indeed the Brief focuses strongly on the lake and provides little information about its watershed. No details of the lake water balance are provided. Given the low demand, water allocation is not a significant issue, and environmental flows are not considered in any way. Degradation of the lake is attributed to over-fishing and associated pollution, sedimentation due to catchment erosion, and habitat destruction.

Lake Victoria

There are no significant water abstractions directly from Lake Victoria, indeed the quantitative water balance for the lake that is presented in the Brief indicates that the small net balance of inflows over outflows is the reason for the 1m rise in lake levels over the last 50 years. Interestingly, over 80% of the inflows are from rainfall directly over the lake itself. However, over 90% of this rainfall is lost by evaporation from the lake, so the discharge from the lake that supports a range of consumptive uses downstream can be viewed as being primarily sourced from the lake basin. The downstream consumptive uses include extensive irrigation schemes in Egypt and HEP generation in Uganda – a portion of which is exported to Kenya. The outflows also maintain several downstream wetland systems including in Sudan. It is not noted in the Brief whether there is regulation of the lake outflows to help these downstream demands, nor therefore what the impacts of such regulation might be on the lake or the downstream rivers and wetlands. It is noted that there is "a tension between managing the lake to the benefit of the riparian communities and managing the lake to the benefit of the downstream countries of the Nile". However, this appears to be largely a water quality issue, and not one of water allocation or environmental flows.

Lake Xingkai

Lake Xingkai's uses include irrigation and drinking water supply. The Brief quantifies the lake water balance including these demands to imply that about 18% of the average inflow is allocated to consumptive uses, of which 94% is used by irrigation. The Brief notes the "draining of swamps" and " lowering of the lake's water level" as major reasons for the observed "biodiversity degradation in the Lake Xingkai drainage basin". The water resources of the basin do not appear to be under immediately increasingly pressure. Indeed, in the Russian portion of the Lake Xingkai drainage water consumption has been decreasing in recent years due to economic downturns. In the most water intensive district "the volume of water consumption for irrigation over the last 10 years has decreased by 80%". Although a reasonably strategic approach appears to have adopted for environmental management in general, there is little focus on water allocation planning or management – presumably largely due the lack of pressing need.

In this context, it is perhaps not surprising there is little consideration of environmental flows for the lake or the rivers of the basin in the Brief, beyond the above-noted connections between biodiversity degradation and induced water regime change.

Summary

Although as a group the water quality focus Briefs have less to say on water allocation and environmental flows, three cases should be especially noted. Firstly, Lake Biwa, because of the considerable consumptive demands, the clear impacts of consumptive use and associated lake regulation on the lake ecology, and the initial efforts to determine an environmentally appropriate water regime. Secondly, Chilika Lake, because of the recent successful management intervention to re-establish the lake's hydrologic connection to the sea, and because of the current attempt to rationally determine a freshwater inflow regime that balances the needs of the lake with the desire to better control river delta flooding. And thirdly, the border-line case of Lake Dianchi, because of the high very high consumptive demand and yet the absence of attention to environmental flows. These three cases, together with the others in the category, demonstrate uneven treatment of the topics of water allocation and environmental flows amongst the Briefs that does not simply reflect the relative importance of these issues.

Synthesis

Assessing the adequacy and accuracy of the treatment of water allocation and environmental flows in the 28 Briefs is difficult on the basis of the Briefs alone, which is the approach adopted herein. A lack of treatment of a topic in Brief may reflect the lack of importance of the topic in the particular lake basin or an under-estimation of the relative importance of a topic by the author(s). Inaccuracies in the Briefs are potentially difficult to discern without reference to independent information.

In spite of these difficulties some conclusions can be drawn on both adequacy and accuracy. The categorisation of the Briefs used herein is essentially based on the perceived degree of importance of water allocation and environmental flow issues across the case studies. Within the water quality focus group these issues are considered to usually be of greater importance in the closed lake basin cases, followed by the man-made reservoirs and then the open lake basin cases. Clearly of course, the actual levels of consumptive use in a basin can over-ride this importance ranking. Given this ranking, it is the man-made reservoir sub-category that has received the least adequate treatment of water allocation and environmental flows. As noted earlier, this is surprising given the usually attention to these issues in such cases. Within all the other groupings there are varying degrees of adequacy – that is, the treatment is uneven and does not simply reflect the apparent relative importance of the issues. The best treatment of the water allocation and environmental flow issues are found in the Briefs for lakes Chad, Naivasha, Toba and Tonle Sap. These four Briefs appear reasonably comprehensive across other issues.

Factual inaccuracies are difficult to ascertain, however a number of conceptual inaccuracies have been noted in the sections above. Overall these to no detract greatly from the Briefs, but perhaps reflect something of the awareness or and attitudes to these issues. While the Briefs do clearly deal with the same range of lake basin management issues overall, there are amongst the Briefs considerable biases towards hydrologic aspects, lake ecology aspects, watershed aspects, and institutional and administrative aspects.

Lessons Learned

Perhaps the clearest message from the Briefs is the rarity of environmental flows in lake basin management. Environmental flows is a relatively new concept in river basin management, and the adoption in lake basin management is clearly only just emerging. While many of the Briefs recognise elements of the concept underpinning environmental flows, only four Briefs refer in any way to past or current investigations to determine environmental water regimes (lakes Biwa, Chad, Chilika and Sevan), and only one of these is in what might be considered the high risk closed basin category. There are cases of restrictions upon water regime regulation or abstractions at least partially for environmental purposes (lakes Baikal, Toba and the Great Lakes), but these appear to have been imposed with little investigation of the specific environmental benefits.

The above cases have or are dealing with environmental flows from a restoration perspective. In the case of Tonle Sap there appears to sufficient awareness to initiate an environmental flow assessment from a prevention perspective. In no cases have environmental flows moved beyond the assessment or determination stage, exception in the case of the one-off trial dam releases in the Lake Chad basin. There are no cases of negotiated and implemented environmental flows for specific environmental benefits.

While many Briefs recognise the importance of lake water regime to lake ecology, this recognition is less evident for the contributory rivers (regulated or unregulated) and for outflow rivers or other dependent downstream ecosystems. The ecological importance of hydrological connectivities within a lake basin receives little attention. Overall there is much room for raising the awareness of the role of environmental flows in lake basin management, including ensuring they are considered in a whole-of-basin context.

With respect to water allocation, there is a wide range in the availability of the data and technical capacity that is necessary to provide a quantitative basis to water allocation planning and management. In spite of considerable international aid in many of these cases, there appears to still be many opportunities for technical capacity building in developing countries. Indeed, an awareness of the importance of a quantitative description of lake and basin water balances as the basis for objective water allocation planning and management does not appear to be universal. The enabling environments for improved water resource planning and management, including administrative and legal frameworks and institutions and a culture of stakeholder involvement, are highly variable. Water licensing and even abstraction monitoring were discussed in surprisingly few cases. While change in the administrative and legal aspects are perhaps the most difficult to affect, they are also probably the most critical changes for improved lake basin management. These issues are particularly important in the major transboundary cases.