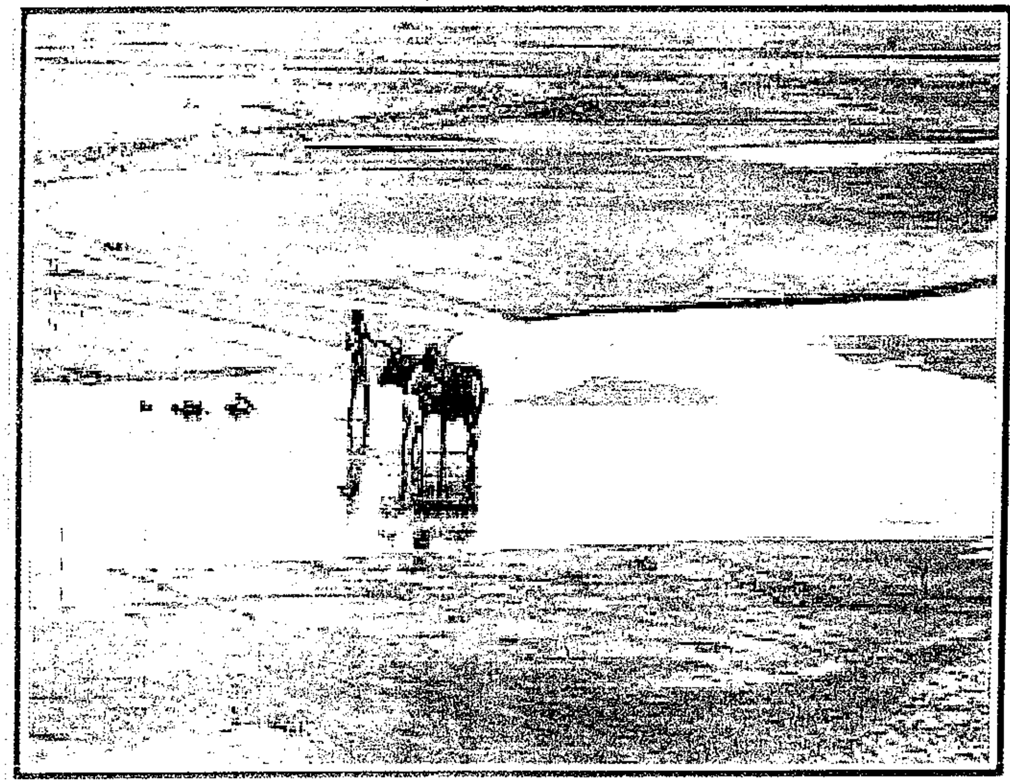
Report of Working Group to advise WQAA on the Minimum flows in the rivers



Government of India
Ministry of Water Resources
Central Water Commission

July 2007

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Working Group
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Contents

FOREWORD

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Provision for environmental flows is central to integrated water resources management. Environmental Flow Assessment (EFA) methods are still evolving and experience in addressing downstream biophysical and social impacts is limited. Successful mitigation, compensation, and restoration of biophysiology are more likely to be achieved if a thorough environmental flow assessment is undertaken during the planning of water resources development projects.

This report outlines the principles behind environmental flow assessments, provides a description of methods that have been used to assist with such assessments, and highlights the features that will enhance the chance of successful implementation of environmental flows.

Although the theory has developed rapidly in the last three decades, the practical application of environmental flows has been rather tardy due to lack of data and understanding of hydrology-ecology linkages and also on account of lack of legislative support. There is obviously a reluctance on the part of policy planners to accommodate these concepts due to rapidly increasing water demands for different uses. Provision of water for the environment will bring with it legal challenges from other potential users of water, yet the scientific knowledge base needed to defend environmental flow against such challenges remains poor. Much of this is changing, however, and flow assessments are becoming integrated with other tools such as environmental assessment and water allocation planning for guiding decisions on water resource development.

The environmentally sustainable development and management of water resources is a critical and complex issue for both rich and poor countries. It is technically challenging and often entails difficult trade-offs among social, economic, and political considerations. Typically, the environment is treated as a marginal issue when it is actually key to sustainable water management.

According to the World bank's recently approved water resources sector strategy, "the environment is a special 'water using sector' (World bank 2003 : 28). Being integral to overall water resources management , the environment is "voiceless" when other water using sectors have distinct voices. As a consequence, representatives of these other water using sectors need to be fully aware of the importance of environmental aspects of water resources management for the development of their sectoral interests.

While the need for maintaining certain minimum flows in the rivers has all along been felt, no guidelines are available in India for the purpose. With this background, it was decided to constitute a Working Group to advise the Water quality Assessment Authority (WQAA) on the minimum flows in the Rivers to conserve the eco-system.

The report on Minimum Flows in the rivers was prepared by the Working Group & presented in the 5 th meetingof WQAA held at New Delhi on 3rd August, 2006. The WQAA decided that "The Working Group" may carry out studies to include the Water Quality aspects as well.

In compliance with the above decision of WQAA, a team under the Chairmanship of Chief Engineer, EMO, CWC was constituted.The terms of reference was " to include water quality aspects in the study for fixing the minimum flows of the rivers in India". The report of thet team is enclosed at Annex-IV. Accordingly the final rcommendations have been suitably modified.

I would like to place on record the valutable contribution made by all the members of the Working Group in bringing out this report. Sh V.K.Jyothi, Chief Engineer (KGBO), CWC, Hyderabad and Sh A.K.Lohani, Scientist E1, NIH, Roorkee have provided very useful inputs by way of the studies conducted by them. Shri Shiv Nandan Kumar, Director, Shri Vijai Saran, Dy. Diretor, and Dr. M.C.Datta, Resarch Officer of River Data Directorate, CWC have made significant contribution in conducting various studies and prepration of the report. I do appreciate and acknowledge their efforts and contribution.

I also acknowledge the valuable contribution made by Shri M.K.Sharma, Ex Member (RM), CWC under whose chairmanship the work was started and the initial report was prepared. I would like to make a special mention of the commendable assistance provided and untiring efforts made by Sh. R.K. Khanna, Chief Engineer, EMO, CWC in compiling the material and bringing out the report in its present form..

20/7/07

(R.N.P. Singh)
Member (River Management)
Central Water Commission &
Ex-officio Additional Secretary to
Government of India
Chairman of Working Group

EXECUTIVE SUMMARY

Executive Summary

The flows of world's rivers are being modified by impoundments such as dams and weirs for various purposes. In many cases, these modifications have adversely affected the flows and consequently the ecological and hydrological services provided by the eco systems. A need has, therefore, been felt to provide certain minimum flows in the river to take care of the environmental and other considerations. However, what constitutes 'minimum flows' has been extensively debated all over the world.

Both water quality and water quantity characteristics have effects on ecosystems, and in some areas these are strongly inter related. Although the minimum flow guidelines focus on water quantity, water quality factors should not be ignored.

The four components that constitute the minimum flows are low flows, flushing flows, special purpose flows and maintenance of impoundment levels. However, for the purpose of present study, only requirements for low flows and flushing flows have been considered. The other two components of minimum flows are specific to a particular reach and not a general requirement.

The main difficulties in quantifying the minimum flows are absence of an acceptable definition of ecological needs and, also, the absence of an agreement on the priority of Environmental Flow Releases (EFR). Moreover, while the domestic and agriculture requirements are easily quantified, it is difficult to decide as to what comprises the legitimate ecological needs.

Extensive work has been carried out in this area in many countries viz; South Africa, Australia, United States and United Kingdom and more than 200 methodologies have been developed. However, no significant work has been done in other parts of the world including Eastern Europe, Latin America and Asia. In India too the consideration of minimum flows has started attracting attention recently and no guidelines have been formulation as yet.

Various difficulties have been experienced in implementation in many countries where guidelines have been developed for minimum flows. These difficulties are likely to be faced in India also, in addition to many problems peculiar to the Indian conditions such as most of the rain fall and, therefore, 80 to 90% of the natural flow occurring in just four months, inadequate treatment of the sewage discharged into the rivers and most of the major rivers being interstate. Moreover, enough data is not available for implementation of some sophisticated methodologies. It was therefore, decided by the Working Group that, to begin with, we may adopt a methodology similar to the Tennant method wherein certain percentages of the annual flows are prescribed as minimum flows as well as flushing flows during the monsoon. This has, also, been corroborated in the recommendations(Annexure 2) of the Workshop on Environmental Flows recently organized in New-Delhi by the National Institute of Ecology(NIE) and The International Water Management Institute(IWMI)

Certain studies were undertaken for the Indian conditions and recommendations of the Working Group are based on the results thereof. The recommendations are as under:

Naturally occurring minimum flows with 99% excedence can be taken as the minimum flows required for maintaining the in-stream environment. A range of minimum flows may be recommended as flushing flows during the flood period.

It was also felt that since the Himalayan rivers carry large snow melt component during summer months the recommendations may be different for the rivers originating in the Himalayas and for others.

From the studies carried out, it is seen that in the case of Himalayan Rivers the virgin flows are very high due to snow melt contributions. However, in Himalayan rivers where utilisation is mainly through diversions and not through storages, it is felt that the minimum flow should be a function of lean period flow keeping in view the committed utilisations.

Himalayan Rivers

Minimum flow to be not less than 10% of average virgin lean period flow (1st Dec. to 31st May) expressed in cubic meters per second.

One flushing flow during monsoon of not less than 250% of 75% dependable Annual Flow expressed in cubic meters per second.

Other Rivers

Minimum flow in any ten daily period to be not less than observed ten daily flow with 99% excedence. Where ten daily flow data is not available this may be taken as 0.5% of 75% dependable Annual Flow expressed in cubic meters per second.

One flushing flow during monsoon of not less than 600% of 75% dependable annual Flow expressed in cubic meters per second.

Measures for maintaining River Water Quality

Extensive efforts on augmenting wastewater collection, enhancing treatment facilities and ensuring proper operation and maintenance of these facilities.

Use of wastewater after required treatment for irrigation, horticulture and other purposes.

The Working Group feels that there is a need to carry out further detailed studies on the subject in collaboration with various other organizations such as The World Bank, International Water Management Institute, UNEP, International Commission on Irrigation & Drainage etc. The Officials of World Bank and IWMI have already shown interest in this area during discussions.

REPORT

1. INTRODUCTION

The flows of the world's rivers are increasingly being modified through impoundments such as dams and weirs, abstraction for agriculture and urban supply, maintenance of flows for navigation and structures for flood control. These interventions have significant impacts, reducing the total flow of many rivers and affecting both the seasonality of flows and the size and frequency of floods. In many cases, these modifications have adversely affected the ecological and hydrological services provided by water ecosystems. There is now an increasing recognition that modifications to river flows needed to be balanced with maintenance of water-dependent ecological services. The flows needed to maintain these services are termed environmental flows or EF and process for determining these flows is termed "environmental flow assessment" or EFA.

A debate has been going on as to what exactly constitutes the environmental flows. And, also, whether the correct term is "minimum flows" or "environmental flows". Broadly speaking, 'environmental flows' indicate the flows required to meet the ecological needs while 'minimum flows' indicate the flows required for the environment plus flows needed for other purposes viz. human uses such as bathing, washing, religious needs etc. Incidentally, the terms of reference of this Working Group include "Recommend criteria to be followed for minimum flow in different types of rivers from environmental and other considerations". However, the terms 'minimum flows' and 'environmental flows (EF)' or 'environmental flow requirements (EFR)' are generally used to convey the same meaning (just as ecology and environment) and that is the way these have been used in this report.

Recognition of the escalating hydrological alteration of rivers on a global scale and resultant environmental degradation, has led to the establishment of the science of environmental flow assessment whereby the quantity and quality of water required for ecosystem conservation and resource protection are determined.

The quantum of flow in a river and its quality are interrelated. Impact on river water quality resulting from discharges of treated or untreated waste water into the river will depend upon the dilution offered by the quantum of flow in the river. Even in the most optimistic programme for treatment of waste waters prior to their discharge into a river, certain minimum flow in the recipient river would be required in order to maintain the desired water quality. The in stream uses of water, special to our country, such as religious mass bathing, regular bathing and washing also require adequate flow to be maintained so that the pollution of the rivers caused by such uses can be kept within acceptable limits. Rivers should be looked upon as components of the total environment. Rivers support a chain of life which has to be conserved. Conservation is possible only if adequate flow of acceptable quality is maintained in the rivers.

2. EXTENT OF PROBLEM

For some time a strong need has been felt for a consistent process for determining flow regimes, one that the various communities of interest perceive to be fair, accessible, and transparent.

Central and state water resource management agencies are the primary agencies that are often faced with making contentious water management decisions. States have responsibilities for setting river flow and water levels, and deciding on the flow regimes to be put in place to try and manage and allocate water resources. Ultimately, the objective of water managers is to set flow regimes that will maintain certain values identified in a river system.

The individuality and complexity of each river system highlights the importance of decision-makers setting clear and appropriate policy goals. In other words, determining as far as possible what the community wants from its river. Only then will it be possible to set a flow regime that both sustains the values of the river and meets the needs of its community in a way that accords with the efficient management of water resources.

While there is no disagreement on the need to maintain a certain minimum flow in the river for ecological objectives, there is no agreement on how to quantify this minimum flow. The main difficulties in doing this are:

a) Absence of an acceptable definition of ecological needs and
b) Absences of an agreement on the priority of Environmental Flow Releases (EFR).
c) Entry (in the debate) of a few activists who take ultra-romantic positions – bordering on utopia – thus ensuring sustainability of the debate.

Domestic requirements are easily quantified, based on population data and lifestyles in the concerned area. Agricultural needs are also easily quantified based on the area to be irrigated, intensity of irrigation, cropping pattern, and crop water requirement. But there is no basis to decide what comprises legitimate ecological needs. At one extreme the environmental activists demand that there should be no interference with the natural flow pattern in the river and even the needs of the estuaries should be taken in to account. (In the same breath they also demand that every drop of rain should be captured and conserved in situ, without realizing that if that was done, nothing would reach the river.) At the other extreme the basin managers want to supply every human need before supplying water for EFR. This practically reduces the EFR to what is "left over".

3. NEED FOR MINIMUM FLOWS

Our economic well-being depends on rivers whose waters are crucial for irrigation, power generation and industry, besides recreational and aesthetic values. It has, therefore, been felt that there is a fundamental need for guidelines for minimum flows for various Indian rivers.

Water Requirements

In the modern society, water is put to a variety of uses for the benefit of human population. The following are the important uses.

i) Domestic and municipal supply,
ii) Irrigation ,
iii) Thermal power and Industrial requirement,
iv) Generation of hydro electric power,
v) Navigation,
vi) Requirement to maintain natural eco system of the water stream, and the pollution control,
vii) Growing of fish, crabs and other aquatic animals for food, oil and other purposes,
viii) Growing of aquatic plants for food and other applications,
ix) Swimming, boating and other recreational uses and
x) Cattle bathing and washing.

In some of the above uses like irrigation and domestic supply, water has to be abstracted and transported from its source while in others it is used in its natural receptacle itself e.g. fish and plant growing, navigation and recreational uses. Each of these uses can be categorized as non consumptive or consumptive. In the case of navigation and hydro power generation, no water is consumed in the use as such while in the case of thermal power, industrial and urban water supply with planned waste water disposal system 80 to 90% of abstracted water is returned back and thus again available for use. The returned water may in most of the cases need some treatment and upgrading of its quality for the reuse. Application of water by irrigation to agricultural crops also generates the return flow although on a much reduced scale. While low flow requirement may be fulfilled in some cases by the resulting return flows from various uses, in certain cases it may impose restriction on the use, particularly in the summer months when the stream flow dwindles. An integrated water resources planning calls for attention to all the future needs of these uses including the possibility of flood management as well as the control of ground water levels to cover the various purposes that a water development plan may have to serve. If any one of these is attended to without regard to its effect on the others, serious conflicts and non-optimal use may result.

Since a large population is to be and will have to be supported, its basic needs of food and fibre in the first instance have necessarily to be provided for. Further, around seventy percent of the population depends upon agriculture directly for their living and, therefore, agriculture has always been and continues to remain the main industry of our country.

Pollution Loads

The minimum flow in a river for different purposes including maintenance of water quality in the river is going to be different at different places depending upon the actual requirement due to population concentration, industries established and the effluents likely to be discharged in the river. It is, therefore, generally not possible to fix any minimum flow for the entire reach of the river. Ideally, the minimum flow required in the river can only be fixed for a particular stretch. However, as explained subsequently in Section 7 & 8, simple recommendations based on the Tennant Method are being proposed in this report. Moreover, the sewage and effluents from the industries have to be treated under the provisions of the Environmental (Protection) Act, 1986, to the specified level before discharging into the river so that the water quality of the river water may be maintained.

Augmentation of River Flows

About 85% to 90% of annual rainfall occurs during the short period of 3 or 4 months of monsoon season. As a result, the river flows are also unevenly distributed over the year causing floods and wastage of the large portion of the resource as it goes into the sea concentrated during the monsoon period. During the remaining major portion of the year, the river flows become meager and scarce. The situation becomes more critical during April and May when the river flows are minimum. It is necessary to find ways and means to augment the river flows so as to meet the vital requirements.

There is a general consensus that certain amount of minimum flows should be maintained in a river from ecological and other considerations. However, as of now, there are no established methods or guidelines available to assess the requirement of minimum flow in the river from various considerations.

4. REQUIREMENT OF MINIMUM FLOWS FROM VARIOUS ANGLES

Environmental flows are the amount of water that is needed in streams (rivers, lakes and marshes) to meet the requirements of aquatic flora and fauna. Insufficient water, or water at the wrong time, can result in a loss of habitat, breeding failure and even death for some species. The need for developing environmental flow guidelines has arisen as both rural and urban communities have developed and there is increased utilization of water as a resource.

The **National Water Policy** of 2002 suggests the following priorities in the planning and operation of systems:

- *Drinking water*
- *Irrigation*
- *Hydropower*
- *Ecology*
- *Agro-industries and non-agricultural industries*
- *Navigation and other uses.*

However, the priorities could be modified or added if warranted by the area/region specific considerations.

The National Water Policy has thus accorded due importance to the water allocation for ecology.

It is often difficult to isolate the individual factors that limit populations of biological communities in any given river. Many studies have attempted to link the stream fauna and its abundance to flow magnitude but most have failed to show any relationship. If the abundance of an aquatic species in a particular stream is limited by the naturally occurring low flows, then further reduction in flow would have a detrimental effect on that species. However, if the species is not limited by low flows; further reduction in flow will have minimal effect. However, intuitively there must be a point at which there is too little water in a stream for the continued survival of aquatic species.

No information/criteria are available for India regarding requirement of minimum flow from various angles such as ecology, environment, human needs such as washing and bathing, fisheries etc. However, the following table (ref: Technical Note C.1 of World Bank) indicates qualitatively the environmental flows required for various features.

EXAMPLES OF VALUED FEATURES OF RIVERS THAT COULD BE PROTECTED THROUGH ENVIRONMENTAL FLOWS

Feature	Explanation of value	Examples of environmental flows required
Aquatic animals	Freshwater fish are a valuable source of protein for rural people. Other valued fauna include: angling fish, rare water birds, or the small aquatic life that forms the base of the food chain.	• flows to maintain the physical habitat; • flows to maintain suitable water quality; • flows to allow passage for migratory fish; • small floods to trigger life-cycle cues such as spawning or egg-laying.
Riparian vegetation	Stabilizes river banks, provides food and firewood for rural people and habitat for animals, and buffers the river against nutrient and sediment losses from human activities in the catchment.	• flows that maintain soil-moisture levels in the banks; • high flows to deposit nutrients on the banks and distribute seeds.
River sand	Used for building.	• flows to transport sand and to separate it from finer particles.
Estuaries	Provide nursery areas for marine fish.	• flows that maintain the required salt/ freshwater balance and ocean connection to estuary.
Aquifers and groundwater	Maintain the perennial nature of rivers acting as sources of water during the dry season.	• flows to recharge the aquifers.
Floodplains	Support fisheries and flood-recession agriculture for rural people.	• floods that inundate the floodplain at the appropriate time of the year.
Aesthetics	The sound of water running over rocks, the smells and sights of a river with trees, birds, and fish.	• Sufficient flow to maximize natural aesthetic features, including many of the flows mentioned above.
Recreational and cultural features	Clean water and rapids for river rafting or clean pools for baptism ceremonies or bathing. Also features valued by anglers, birdwatchers, and photographers.	• flows that flush sediments and algae, and that maintain water quality -see also aquatic animals.
Ecosystem services	Maintain the capacity of aquatic ecosystems to regulate essential	• flows that maintain biodiversity and ecosystem

	ecological processes, for instance to purify water, attenuate floods, or control pests.	functioning.
Overall environmental protection	A wish to minimize human impacts and conserve natural systems for future generations.	• some or all of the above types of flows.

Incorporation of social data into flow assessments

In regions such as Africa, South America, and Asia, where large numbers of poor people rely directly on rivers for sustenance, flow assessments should include consideration of the social and economic implications of changes in river flow. In some cases these will be obvious, such as a loss of a food fish or plant, deterioration in the quality of potable water, or filling in of a pool used for ceremonies. In others, the impacts will be less obvious. Vitamins and minerals supplied by riparian plants may contribute to the overall health of a community, or certain levels of flow may dilute or aid decomposition of wastes entering the river, so that the water can be drunk without incurring health risks. So often externalized in water-resource planning, these indirect costs of deteriorating river condition are usually borne by the poorest members of the society.

5. PRACTICES AND GUIDELINES AT GLOBAL LEVEL

It must be acknowledged that quantification of EFR is one of the most vexatious issues now confronting the water sector and there is no easy way out of this conundrum of using the river water and having it flow in the river too.

Perhaps the single most important reason for the difficulties in quantifying EFR is ever expanding scope of EFR. Starting with limited objective of maintaining a reasonably good water quality and protection of fish population and their habitats, the scope has slowly moved to cover all aquatic life, riparian vegetation, sediment transport, nutrients transport, river morphology, flood plains, wet lands, estuaries, mangroves etc. and even the cultural, spiritual and aesthetic aspects, and the list does not seem to have stopped growing.

South Africa is one of the countries where an overriding priority is assigned to EFR Provisions in their National Water Act treats EFR as the "Ecological Reserve" and imposes not only restrictions on withdrawals but places demands on dams for release of water to meet EFR. To ensure compliance with the said act, they have developed methodologies to compute EFR but all these methodologies are project/ problem specific and cannot be applied for a basin level assessment. Also, the higher priority given to EFR is now being increasingly questioned as "water for whom, insects or humans?" and it is doubtful whether the policies aimed at sustainable use of water are themselves sustainable.

In Australia new approaches are being developed to study the flows required to sustain ecological processes and diversity of riverine ecosystems. Instead of treating them as separate need, environmental requirements are being gradually incorporated into water resource planning and management. Ecological risk assessment approaches are used to draw formal management plans for the environmentally stressed rivers.

In the United Kingdom minimum flow concept has been in use since the 60s primarily to protect the right of downstream users, including. water abstraction and navigation. After 1995 environment act, management seems to have shifted to the Environmental Agency which considers the impact of abstraction on environment before issuing of abstraction licenses. Mostly simple hydrological indices are used for not permitting abstractions below a critical level called the "hands-off flow" (usually Q95). In a few cases impact of the abstraction has been studied through modeling approaches e.g. habitat model of key fish species. A scenario based approach is used for conflict resolution. Information on the trade-off between different abstraction options and their habitat impacts generated through model is utilized for negotiations with water companies.

5.1 Evolution of Flow Assessment Methodologies

A global review of the present status of environmental flow methodologies revealed the existence of some 207 individual methodologies, recorded for 44 countries within six world regions. These could be differentiated into hydrological, hydraulic rating, habitat simulation and holistic methodologies, with further two categories representing combination-type and other approaches.

There was concerted development of methodologies for prescribing environmental flow requirements at the end of 1940s, in the western United States of America. Dramatic progress was achieved during 1970s, primarily as a result of new environmental and fresh water legislations and demands from the water planning communities for documentation of EFRs, in concert with the peak of dam building era.

Although historically, the United States has been at the forefront of the development and application of methodologies for prescribing environmental flows, using 37% of the global pool of techniques, parallel initiatives in other parts of the world have increasingly provided the impetus for significant advances in the field.

Application of methodologies is typically at two or more levels. (1) Reconnaissance-level initiatives relying on hydrological methodologies are the largest group (30% of the global total), applied in all world regions. Commonly, a modified Tennant method or arbitrary low flow indices is adopted, but efforts to enhance the ecological relevance and transferability of techniques across different regions and river types are underway. (2) At more comprehensive scales of assessment, two avenues of application of methodologies exist. In the developed countries of the northern hemisphere, particularly, the instream flow incremental methodology (IFIM) or other similarly structured approaches are used. As a group, these methodologies are the second most widely applied worldwide, with emphasis on complex, hydrodynamic habitat modeling.

The establishment of holistic methodologies as 8% of the global total within a decade, marks an alternative route by which environmental flow assessment has advanced. Such methodologies, several of which are scenario-based, address the flow requirements of the entire riverine ecosystem, based on explicit links between changes in flow regime and the consequences for the biophysical environment. Recent advancements include the consideration of ecosystem-dependent livelihoods and a benchmarking process suitable for evaluating alternative water resource developments at basin scale, in relatively poorly known systems. Although centered in Australia and South Africa, holistic methodologies have stimulated considerable interest elsewhere. They may be especially appropriate in developing world regions, where environmental flow research is in its infancy and water allocations for ecosystems must, for the time being at least, be based on scant data, best professional judgement and risk assessment.

Outside the United States the route by which environmental flow methodologies (EFMs) became established for use is less well documented. In many countries the process only gained significant grounds in 1980s (example Australia, England, New Zealand and South Africa) or later (example Brazil, Check Republic, Japan, Portugal). Other parts of the world including eastern Europe and much of Latin America, Africa and Asia appear poorly advanced in the field with little published literature that deals with environmental flow issues.

5.2 Minimum flow assessment methods

Many methods have been developed over the last 20 years-primarily in Europe, the United States, South Africa, and Australia- to establish environmental flows. Some techniques were developed for protection of specific species, while others were developed for broader ecosystem protection. These techniques have now been applied in over 25 countries, resulting in a considerable body of experience for temperate and semiarid rivers, but only limited experience in the application of these methods to tropical rivers.

Environmental flow assessment methods fall into two categories, prescriptive and interactive. Methods based on the prescriptive approach usually address a narrow and specific objective and result in recommendation for a single flow value or single component of the flow regime. Their outcomes tend not to lend themselves to negotiation, because effort is mostly directed to justifying the single value, and insufficient information is supplied on the implication of not meeting the recommended value to allow an informed compromise. Interactive approaches, on the other hand, focus on the relationships between changes in river flow and one of more aspects of the river. Once these relationships are established, the outcome is no longer restricted to a single interpretation of what the resulting river condition would be. Methods based on the interactive approach are thus better suited for use in negotiations. They do tend to be more complex, however, and have more onerous data and time requirements, than do prescriptive approaches. Several methods have been developed in each category.

RELATIVE DATA AND TIME REQUIREMENTS OF SELECTED FLOW ASSESSMENT METHODS

Output	Method	Data and time requirements	Approximate duration of assessment	Relative confidence in output	Level of Experience
Prescriptive	Tennant Method	Moderate to low	Two weeks	Low	USA/extensive
	Wetted-Perimeter Method	Moderate	2-4 months	Low	USA/extensive
	Expert Panels	Moderate to low	1-2 months	Medium	South Africa, Australia/ extensive
	Holistic Method	Moderate to high	6-18 months	Medium	Australia/ very limited
Interactive	IFIM	Very high	2-5 years	High	USA, UK/extensive
	DRIFT	High to very high	1-3 years	High	Lesotho, South Africa/very limited

5.2.1 HISTORIC METHODS OR HYDROLOGICAL METHODOLOGIES

Many historic flow methods based on hydrological data have been used to define minimum flows. They are often referred to as fixed percentage or look-up table methodologies, where a set proportion of flow often termed as minimum flow represents the EFR intended to maintain the freshwater fishery, other highlighted ecological features, or river health at some acceptable level, usually on an annual, seasonal or monthly basis. Occasionally, hydrology based EFMs include catchment variables, are modified to take account of hydraulic, biological or geomorphological criteria or incorporate various hydrological formulae or indices. Three variants of these are described below.

5.2.1.1 Exceedance methods

These include flows such as the mean annual, 1 in 5-, 10- or 20-year 7-day (or some other duration) low flow or percentages of those, or a percentage Exceedance flow (i.e. a minimum flow is defined as a flow that is equaled or exceeded for a proportion (e.g. 96 percent) of the time. The principles underlying this technique are very similar to those of the Tennant method but use naturally occurring low flows rather than mean flow to define minimum flow (Chaing, 1976).

5.2.1.2 Tennant method: Percentage of Average Annual Flow (AAF), required to achieve different objectives (AAF expressed as instantaneous flow)

Tennant (1976) recommended specific percentages of mean annual flow based on field observations of the wetted perimeter, cross-sectional area and velocity of North American rivers at a range of flows. The Tennant method (known in New Zealand as the Montana Method) was based on a study of cross-section data from 11 streams in Nebraska and Wyoming in the USA. The study found that stream width, water velocity and depth all increased more rapidly from zero flow to 10 percent of the mean flow, than at flows higher than 10 percent of the mean flow. Habitat for trout formed the basis for Tennant's assessment of minimum flow. He considered that an average depth of 0.3 m and velocity of 0.23 m/s, as provided by 10 percent of the mean flow, were lower limits for the well-being of trout, whereas an average depth of 0.46 m and velocity of 0.46 m/s, as provided by 30 percent of the mean flow were within the good to optimum range.

From these observations, he recommended that 60-100 percent of mean annual flow would provide optimum flows for most forms of aquatic life, 30 percent would provide good habitat, and that 10 percent was a minimum below which only short-term survival of aquatic life could be expected. Tennant also recommended periodic flushing flows of 200 percent of the mean annual flow.

Change in width, depth and velocity (as a proportion of mean flow) for two channel types (single thread uniform and single thread non-uniform) is represented as a function of the percentage in mean flow. It can be seen that, in general the hydraulic conditions change at a high rate from zero to approximately 10 percent of the mean flow. However, this is variable and is dependant on the hydraulic parameter and geometry of the channel being considered.

Objective	Recommended percentage of AAF	
	Autumn-Winter	Spring-Summer
Flushing or maximum flows	200	200
Optimum range of AAF	60-100	60-100
	Percentage AAF required to maintain a river condition	
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair or degrading	10	30
Poor or minimum	10	10
Severe degradation	10-zero flow	10-zero flow

5.2.1.3 Modified Tennant method

Fraser (1978) suggested a modification of the Tennant method for New Zealand rivers as an interim measure only until a more defensible method was established. He recommended as an emergency "rule-of-thumb" that 100 percent of the mean flow for each month be considered "optimum", 75-99 percent "acceptable", 30-74 percent as "poor-fair", and 29 percent or less as "unacceptable". Fraser noted that this regime could reduce peak flood flows which may be important in maintaining the normal ecosystem in some rivers, and recommended that flushing flows be maintained for "optimum" and "acceptable" flow regimes.

5.2.2 HYDRAULIC METHODS OR HYDRAULIC RATING METHODOLOGIES

Hydraulic methods usually consider changes in simple hydraulic variables, such as river width or wetted perimeter. Hydraulic parameters such as width, wetted perimeter and velocity increase with increased flow. This increase is non-linear and a point is generally reached where the rate of increase in the value of a parameter reduces rapidly. This point is called the point of inflection and marks the point beyond which increased flow will have a diminishing effect on the hydraulic parameter being considered. Water velocity is not usually considered in hydraulic methods, possibly because it shows less clearly defined inflection points.

The wetted perimeter approach provides information on the effects of different flows on the area of wetted river-channel which is assumed to provide habitat for aquatic life. For both uniform and non uniform channel cross-sections, there is a rapid increase in wetted perimeter from zero discharge to the discharge at an inflection point, beyond which additional flow results in only minor increases in wetted perimeter. Minimum flows are set near the inflection point of the wetted perimeter versus discharge curve. Braided channels and some gravel bed channels have very flat cross-sections and ill defined banks. These channel types do not show a clear inflection point.

Fifteen or more cross-sections should be randomly chosen for the wetted perimeter method. Cross-sections are best placed in riffles and runs because these are areas of the stream most seriously affected by reduced discharges. This technique may be unsatisfactory for identifying minimum flows in uniform steep-banked channels. This is because a very small flow may just cover the bed of the channel between the banks. The shallow depth and low velocity at this point of inflection may be unsuitable for many biota. However, in rivers with non-uniform channel cross-sections, the irregular channel shape will tend to produce a variety of channel depths across the cross-section when the inflection point is reached.

5.2.3 HABITAT METHODOLOGY

Habitat is an encompassing term used to describe the physical surroundings of plants and animals. Some aquatic habitat features, such as depth and velocity, are directly related to flow, whereas others describe the river and surroundings. Habitat methods are a natural extension of hydraulic methods. The difference is that the assessment of flow requirements is based on hydraulic conditions that meet specific biological requirements rather than the hydraulic parameters themselves. Hydraulic models predict water depth and velocity throughout a reach. These are then compared with habitat suitability criteria to determine the area of suitable habitat for the target aquatic species. When this is done for a range of flows (flow increments), it is possible to see how the area of suitable habitat changes with flow. The resultants outputs, usually in the form of habitat discharge curves for the biota, or extended as habitat time and Exceedance series, are used to predict optimum flows as EFRs.

5.2.3.1 Habitat suitability

Instream habitat usually refers to the physical habitat water velocity, depth, substrate, and perhaps cover. Usually, animals are most abundant where the habitat quality is best, in lesser numbers where the habitat is poor, and absent from totally unsuitable habitat. Many aquatic species are commonly found in similar hydraulic conditions in a wide range of rivers. If the characteristic habitat occupied by a species is surveyed, it is possible to determine the relative quality of the different habitats from the abundance of animals in them. Preference curves are the measured variation in the frequency of animals with change in depth, velocity and substrate. Sampling and analysis techniques have been developed that allow preference curves to be developed easily and quickly. The locations of animals are found by electro-fishing for small benthic fish, bank observation for large trout and birds, or Surber sampling for invertebrates.

Habitat suitability curves for a particular section of river show the variation in the total quantity of habitat with change in flow for a particular species. Habitat suitability can vary from zero (unsuitable) to one (optimum).Providing preference curves for a species (or life stage of a species) has been determined, it is possible to quantify the area of suitable habitat available within a river for that species. This area is termed the useable area or weighted useable area (WUA).

5.2.3.2 Habitat retention method

Nehring (1979) described a method used by the Colorado Division of Wildlife in which minimum flow recommendations are based on retention of hydraulic characteristics in various habitat types (riffles, runs and pools). These criteria consist of average depth, average velocity and wetted perimeter, and instream flow recommendations are set when two or more criteria for the appropriate stream size and habitat are met.

More than forty years ago, McKinley used habitat requirements for salmon spawning in North America (McKinley, 1957). Osborn (1982) developed another habitat retention approach for assessing minimum flows for salmon in North America. He calculated the discharge at which maximum spawning area became available using velocity and depth criteria determined from existing information, and from calculations of bank-full discharge (similar to procedures in IFIM). The latter calculation required a single field trip to obtain measurements of channel geometry.

5.2.3.3 Instream flow incremental methodology (IFIM)

Once habitat suitability curves or criteria are defined, they can be applied to habitat survey data and the amount of suitable habitat calculated for a range of flows (flow increments). This is the basis of the instream flow incremental methodology (IFIM) (Jowett, 1989).

A fundamental criticism of IFIM has been that, although it seemed reasonable to assess in stream flow needs on the basis of the amount of suitable habitat, there was no evidence that there was any correlation between species abundance and the amount of suitable habitat (Scott, 1987). This is not an unreasonable criticism; assessments of habitat should be considered to represent the potential of a river to maintain a population of the target species.

Having said this, studies have found correlation between habitat availability and animal abundance for many species of benthic invertebrates and fishes. It is also necessary to consider all the requirements for a species' continued survival. For example, the primary requirements for salmonids are both space and food. Assessing instream flow needs for a river must therefore consider salmonids space and food production requirements. Requirements for reproduction (spawning) must also be considered in river reaches which are used for this.

5.2.3.4 Hydraulic modeling and prediction of habitat suitability

The standard step method, used to model non-uniform steady flow in natural rivers, is well established in engineering practice. This method is based on the principle of energy conservation and uses the flow, slope, hydraulic roughness, and the hydraulic properties of the cross-sections to calculate the longitudinal flow profile. An important assumption in the method is that the distance between cross-sections must be short enough that the hydraulic properties of the cross-sections approximate the hydraulic properties and slope between them. This means that cross-sections should be located sufficiently close that the cross-section area increases or decreases uniformly between cross-sections and that the change in slope is kept to a minimum. In practice this means decreasing cross-section spacing at the heads and tails of riffles, where water slopes and cross-section areas change rapidly, and increasing the spacing when the hydraulic conditions are uniform. This sampling procedure is consistent with those used to sample instream physical habitat.

The hydraulic roughness (Manning's n) is determined from field data on discharge, cross-section area, hydraulic radius, and slope. Manning's n can vary with flow in an unpredictable manner (Hicks and Mason, 1991), and this limits the range of flows for which the roughness calibration is valid.

The distribution of water velocities across a cross-section can be calculated from its conveyance once the water level and flow are known. Each velocity can be adjusted for site-specific features, such as an upstream obstruction which might cause a reduction in velocity or a current on a bend increasing local velocities. Each measurement point represents a cell of the total river area for which the suitability of the velocity, depth, and substrate is evaluated on a scale of 0 (unsuitable) to 1 (optimum).

5.2.3.5 Habitat mapping

Until recently, applications of IFIM involve surveying and hydraulically modeling habitat across a series of contiguous cross-sections over a range of flows in representative reaches of river. An alternative approach that requires less knowledge of hydraulic modeling is Meso habitat typing or habitat mapping. This approach better represents the physical habitat in the river over which the survey is intended to apply.

Meso habitat typing first requires that habitat is mapped over the segment of river under study so that the proportions of the different habitats of interest (e.g. pool, riffle, run, etc) can be calculated. Next, several cross-sections are chosen to represent each of the habitat types. At each cross-section, depths, mean column velocities and substrate composition and recorded at approximately 0.5-1 m intervals, or with enough frequency to characterize the changes in depth and velocity across the section, as for hydraulic modeling. Flow and water level is recorded for each cross-section and repeated at two or more other flows to establish a stage-discharge relationship. Water velocities and depths over each cross-section can then be predicted for a range of flows, using the stage-discharge relationships and channel geometry. This prediction is usually more accurate than predictions made by water surface profile modeling. The area of suitable habitat (weighted useable area, WUA) can be calculated for each species of interest. The WUA at each cross-section is multiplied by the proportion of the total river length that each cross-section represents. The total WUA is then the sum WUA of all the cross-sections.

The computer programme RHYHABSIM has been extended to evaluate habitat surveys based on habitat modelling and includes useful tools for the derivation and comparison of rating curves at cross-sections.

5.2.4 HOLISTIC METHODOLOGIES

Holistic methodologies emerged from a common conceptual origin to form a distinct group of EFMs focused from the outset towards addressing the EFRs of the entire riverine ecosystem. In a holistic methodology, important or critical flow events are identified in terms of selected criteria defining flow variability, for some or all the major components or attributes of the riverine system. This is done either through a bottom up or a top-down or combination process that requires considerable multidisciplinary expertise and input. The basis of most approaches is a systematic construction of a modified flow regime from scratch (i.e. bottom up), on a month-by-month or element-by-element basis, where each element represents a well defined feature of the flow regime intended to achieve particular ecological, geomorphological, water quality, social or other objective in modified system. In contrast, in top-down, generally scenario-based approaches, environmental flows are defined in terms of acceptable degrees of departure from the natural flow regime, rendering them less susceptible to any omission of critical flow characteristics or processes than their bottom up counterparts.

5.2.5 HYBRID METHODOLOGIES

A diverse array of methodologies that bear characteristics of more than one of the above four basic types, including partially holistic EFMs which incorporate holistic elements, but within insufficiently developed methodological frameworks can be recognized. These methodologies are classed as 'combination' or 'hybrid' approaches alongside various other approaches not designed for EFAs from first principles, but adapted or with potential to be used for this purpose. These latter approaches are termed 'other' EFMs.

5.3 Conceptual differences between minimum flow assessment methods for habitat

The following sections explain the conceptual differences between the different assessment methods and the suitability of applying them to meet management goals.

5.3.1 Historic flow methods

Historic methods are easy to apply because they are based on simple hydrological calculations. Factors like food, habitat, water quality, and temperature are not considered explicitly, but are assumed to be satisfactorily provided for because the aquatic species have survived such conditions in the past. These methods attempt to produce a "low risk" approach to an minimum flows by specifying flows that are in the historic range. The methods also provide some choice of the level of protection in terms of flow. However, flow acts as a surrogate for biological response and cannot be quantified biologically.

5.3.1.1 Exceedance flows

Use of an exceedance flow (e.g. annual, 5-year or 10-year 7-day low flow) will tend to preserve the status quo. The level of protection given by these methods is clearly associated with the recurrence of the minimum flow under natural conditions. That is, there is a higher level of protection to the biological community if the minimum flow is the same as a frequently occurring natural low flow. The choice of exceedance period should therefore reflect the significance of the biological community at risk, with communities of higher significance being afforded greater protection by setting more frequently occurring natural low flows as minimum flows.

5.3.1.2 Tennant methods

The Tennant and modified Tennant methods also attempt to maintain the status quo. The assumption that a proportion of the mean flow will maintain the instream environment is reasonable and the use of these methods is well established. The modified Tennant method offers a range of minimum flows with a descriptive measure of their acceptability. This offers some ability to consider the significance of the biological community at risk and level of environmental protection offered. For the same aquatic community, small streams will be more "at risk" than large streams, because velocity and depth are already relatively low.

5.3.2 Hydraulic methods

The aim of hydraulic methods is to describe how "full" the river channel is for given flows. It is assumed that a "full" channel will maintain the food producing capacity of the river. If the inflection point method is used as the flow requirement, the resulting water depth, velocity, and ecological response will depend on channel geometry. For example, in uniform channels only a small and shallow flow is required to maintain water across the full stream width. Under such conditions, the water depth and velocity may be unsuitable for many species. However, in many non-uniform channels, the water depth and velocity will be characteristic of those at natural flow, thus retaining both the "character" and ecology of the natural system.

5.3.3 Habitat methods

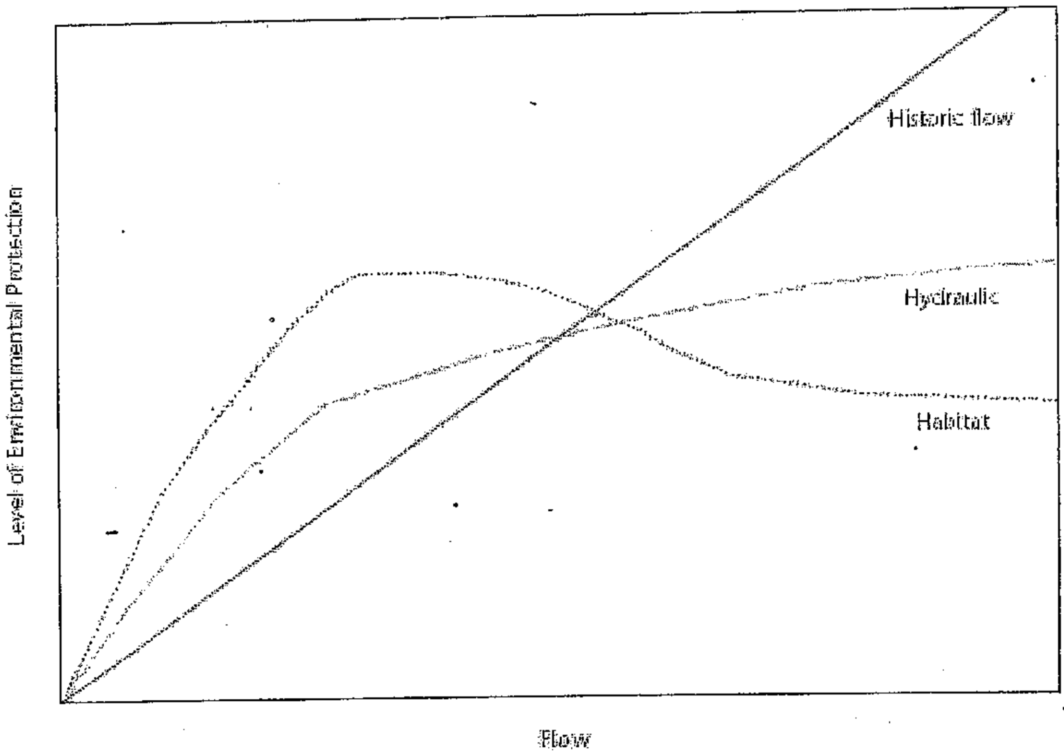
The ecological goal of habitat methods is to provide or retain a suitable physical environment for the aquatic organisms that live in a river. With the focus of habitat methods on "target" species, there is a risk of failing to consider other essential components of a stream ecosystem. The selection of appropriate habitat suitability curves and consideration of other factors, such as food, temperature, and water quality is crucial. The key to successful minimum flow recommendations is to provide sufficient habitat for the maintenance of all life stages of the target species and to consider the requirements of the stream ecosystem as a whole (Jowett, 1996).

Habitat methods aim to preserve, or even improve, habitat, in terms of depth and velocity, rather than river "character". For example, a swift flowing river may contain large areas of deep, high velocity water that are not utilized by most aquatic species. A minimum flow based on habitat would suggest that the area of suitable habitat could be increased by reducing flows so that water velocities and depths were in the range of those preferred by a "target" species.

This would result in a loss of the high velocity areas that lend "character" to a river. Flow assessments based on habitat tend to reduce rivers to a common denominator the habitat used by the "target" species (Jowett, 1996).

Habitat methods provide the most flexible approach to minimum flow assessments, but can be difficult to apply and interpret. Because of this, the outcome depends critically on how the method is applied: what species or uses are considered and what suitability curves are used. When using habitat methods, there are more ways of determining flow requirements than in either historic flow or hydraulic methods. The relationship between flow and the amount of suitable habitat is usually non-linear (Figure 36). Flows can be set so that they maintain optimum levels of fish habitat, retain a percentage of habitat at average or median flow, or set so that they provide a minimum amount of habitat. Flows can also be set at the point of inflection in the habitat/flow relationship. This is possibly the most common method of assessing minimum flow requirements using habitat methods. While there is no percentage or absolute value associated with this level of protection, it is a point of diminishing return where proportionally more habitat is lost with decreasing flow than is gained with increasing flow. Habitat methods are therefore useful for investigating and presenting the relative levels of protection offered by different minimum flow options.

Relationships between flow and the level of environmental protection offered by the different biological assessment methods for a hypothetical river



The level of environmental protection is measured in terms of the surrogate measures for biological response: flow for historic flow methods, wetted perimeter for hydraulic methods, and weighted usable area for habitat methods. (Source: Jowett, 1996).

Habitat-based methods differ from both historic and hydraulic methods in that they make no *a priori* assumptions about the state of the natural ecosystem. Historic and hydraulic methods assume that lower than natural flows will degrade the stream ecosystem, whereas habitat methods accept the possibility that a natural ecosystem, or at least some particularly valued target species, could be enhanced by other than naturally occurring flows. -

5.3.5 Levels of environmental protection

Method	Data and time requirements	Approximate duration of assessment	Relative confidence in output	Level of experience
Tennant Method	Moderate to low	Two weeks	Low	USA/extensive
Wetted perimeter method	Moderate	2-4 months	Low	USA/extensive
Expert Panels	Moderate to low	1-2 months	Medium	South Africa, Australia/extensive
Holistic Method	Moderate to high	6-18 months	Medium	Australia/very limited
IFIM	Very high	2-5 years	High	USA,UK/extensive

The use of surrogate measures for biological response means that the level of environmental protection offered by biological assessment methods does not necessarily increase linearly with minimum flow. Historic flow methods assume that the biological response, and hence level of protection, is directly related to flow, with the level of protection increasing with flow. Hydraulic methods assume that biological response is related to a hydraulic parameter such as wetted perimeter. Hydraulic parameters have a non-linear relationship with flow which is a function of channel geometry. Hydraulic methods therefore assume that environmental protection increases with increasing flow but that this relationship exhibits the law of diminishing returns.

Habitat methods have a non-linear relationship with flow which is a function of channel geometry and preferred habitat of the target species. Habitat methods therefore assume that environmental protection for the target species will be optimized at some flow and that increased or decreased flows will reduce the level of environmental protection.

Levels of protection for different biological assessment methods

Biological assessment method	Assumed relationship between level of protection and flow	Level of protection specified by:	Examples of increasing levels of protection
Historic methods • Exceedance	Linear increase with flow	Exceedance flow	10 year, 5 year, Mean annual low flow
• Tennant	Linear increase with flow	% of mean flow	10% of mean flow 30% of mean flow
Hydraulic methods	Non linear increase with increasing flow	Hydraulic parameters	Increasing percentage retention of hydraulic parameter values
Habitat methods	Optimum conditions at a given flow Reducing protection for flows greater than or less than optimum	Habitat quantity	Minimum habitat Inflection points Optimum

6. PROBLEMS IN IMPLEMENTING OTHER COUNTRIES' GUIDELINES IN INDIA

Experience in a number of countries has shown that recommendations arising from environmental flow assessments are not always implemented. The features that are likely to lead to successful implementation are summarized below (Box 1). These are extensive; few projects would be able to satisfy all of them. Nevertheless, the box provides a checklist that a project manager may want to consider when embarking on the implementation of an environmental flows assessment.

Conversely, some of the common reasons for the failure to implement assessments are:

- The perception among engineers and water managers that too much water was requested.
- Lack of flow related biological data that can be used to justify the environmental flows, resulting in a heavy reliance on expert opinion.
- Unwillingness or inability to incorporate innovative, and possibly more expensive, release
- Lack of political or legislative pressure to implement the environmental flows, usually because other demands were much more important.
- Last minute or ad hoc flow assessments that are made after most of the major decisions about the design and cost of the development, and the allocations of water, have already been made.
- Reluctance to move away from the established practices

A monitoring program is particularly important given the generally poor understanding of the links between flow and ecological response.
The implementation of an agreed flow regime should allow for adaptive management based on the monitoring. The monitoring program should be designed to provide essential feedback on whether:

- The agreed upon flow is being released
- The overall objective is being achieved
- The objectives for different components of the flow regime are being met
- The environmental flow allocations need to be modified in the light of the observed responses.

The monitoring program should be designed to allow the effects of environmental flows on different biota to be separated from the effects of other interventions-for example, improved water quality from sewage treatment plants-and from climatically induced variations in the river flows. In practice, this is extremely difficult to do, and the interpretation of any monitoring program will always rely on the experience of the hydrologists and ecologists involved.

Box 1
Desirable features for a successful EFR Implementation

Political will, legislation, and management strategies	* Recognition of tangible and intangible national costs of degraded rivers. * Acceptance of flow assessments as a tool for use in integrated river-basin management. * Supporting legislation to empower water managers to manage river flows according to recommendations. * The necessary tools to implement and enforce legislation. * A structured and transparent decision making process, whereby the results of engineering and economic studies environmental flow assessments, and stakeholder input, are jointly used to decide on future flow allocations and river condition * Ethical, moral, and other intangible considerations form important inputs to the final Decision making process. * Commitment of politicians, developers, and water resource managers to adhere to agreed-upon environmental flow objectives,
Data and tools	* Long-term accurate hydrological data. * Hydrological models with daily time-steps. Linked surface and groundwater models for intermittent rivers. * Long-term water chemistry records for rivers (and groundwater, where necessary), preferably linked to hydrographs. * Appropriate flow assessment methodologies. Comprehensive data on the distribution, life histories, and flow-related habitat requirements of riverine species in the rivers of concern. Similar data for the ablotic aspects of rivers and, where relevant, for estuaries and coastal marine environments. Data on the tolerance ranges of riverine biota to physical and chemical variables. A well-structured link between river and estuary flow assessments where appropriate,
Specialist expertise	If socioeconomic aspects are to be included in the assessment, specialists in the following disciplines may be required: sociology, human geography, anthropology, public health, domestic-stock health, resource and project economics, and public participation procedures. Also required are specialists with knowledge of the flow-related aspects of waterborne diseases, and those of parasites and/or their hosts. Recognition that ecological and socioeconomic aspects of water resource development are as important as engineering and direct economic aspects
Funds	* Sufficient planning to provide adequate funds for flow assessments.
Time Management	Suitable planning horizons for flow-related investigations

As already indicated, no guidelines are available in India for the release of certain minimum flows in the rivers. Even after certain guidelines are formulated, the difficulties mentioned above, which are faced by some other countries, are likely to be faced in India also. Moreover, the water demand in the country is fast increasing due to rise in population and change in lifestyles, and there are competing demands for various purposes such as irrigation, water supply, industries etc. The availability of environmental flows would be seriously restricted due to various reasons. For instance, it has been mentioned in the report prepared by the Chief Engineer, Krishna and Godavari Basin Organisation, CWC, Hyderabad that the Krishna Water Disputes Tribunal has not made any provision for minimum flows to be maintained in the river. Allocations have been made in bulk out of the available water in the basin at 75% dependability. Month wise or seasonal allocations have not been indicated. The States are free to use their share as they deem fit. Presently the States have committed for use almost all their share, primarily for irrigation. As the States have fully committed their share of allocated waters, releasing additional water for meeting minimum flows will be difficult.

Also, while assessing the global trends in quantification of EFR for their adaptation to India, it must be appreciated that there are six major factors in which India differs from many other countries that have taken a lead in addressing the problem of EFR.

1. In maintaining the flow dictated by EFR, eventually at some stage there has to be a tradeoff between EFR and other requirements. Agriculture being the largest user of water, a small reduction in agriculture use makes a large quantity of water available for other needs. This is easily possible in industrialized countries where the economy and the people are less dependent on agriculture. But India is primarily an agrarian economy; there are a large number of small farmers for whom every cubic meter of water is vital for their survival. In such a situation, any tradeoff between agriculture and ecology is extremely difficult.

2. In India most of rainfall and therefore 80 to 90% of the natural flow occurs in just four months. In the remaining 8 months, EFR are to be met from just 20 to 10% of the annual flow. This is extremely difficult unless the excess monsoon runoff is stored, for release during lean season. There are just two ways to store it, in surface storages created by dams, or underground storages in aquifers. In India the surface storage capacity of 213 bcm, which is just 11% of the annual flow of 1869 bcm, is pathetically low. (*in Murray-Darling basin in Australia the storage capacity is 150% of the annual flow*). Moreover, there is stiff resistance to creation of additional storage capacity.

3. Base flow in the river after the monsoon recedes is supplied by the storage in the aquifer. India is one of the countries that have exploited ground water to the hilt and falling ground water levels are a cause of major concern. Therefore it is futile to expect that ground water will help in contributing towards EFR.

4. Treatment of sewage to exacting standards is very expensive and therefore in a developing country this is rarely possible. Discharge of untreated waste water in the river makes the EFR unacceptably large and the entire process of determining the EFR becomes an academic exercise.

5. In India water is a State subject and most of the major rivers are interstate rivers. Even if EFR is somehow quantified, it will have to be taken out of the total water availability and the remaining water will have to be re-apportioned amongst the

States. Re-negotiating the State's shares is likely to be a long-drawn and painful process.

6. During lean season, most of the river channels lose water through percolation. Therefore maintaining a stipulated EFR requires release of much larger quantities of water from the head works. i.e. the loss of water to other users is much larger than the stipulated EFR.

In view of the above, guidelines formulated by the other countries may not be implementable in India. The recommendations of the present working group are, therefore, based on the studies undertaken for the Indian conditions as described in Section 7.

7. STUDIES UNDERTAKEN

Minimum Flows

The Minimum Flows in rivers are the discharge required for ensuring adequate flow downstream for environmental, abstraction and other purposes. In rivers without any man made controls the minimum flow will be a function of the prevailing meteorological and hydrological conditions. Where changes to the natural flow in a river are brought about at some location, it is necessary to provide for a minimum flow to sustain the downstream requirements.

Both water quality and water quantity characteristics have effects on ecosystems, and in some areas these are strongly inter related. Although the minimum flow guidelines focus on water quantity, some water quality factors should not be ignored.

Many water control structures were built before environmental flows were identified. These structures as presently constructed and as per allocation of water amongst the basin States cannot be operated to meet environmental flow requirements. In particular this relates to the flow variations to replicate natural conditions.

There are four components that constitute minimum flows;

- Low flows
- Flushing flows
- Special purpose flows
- Maintenance of impoundment levels

Low Flows:

Aquatic ecosystems are assumed to be adapted to periods of low flow or no flow. Such conditions are presumed to have occurred before human intervention and still occur in pristine catchments. It has been argued that natural low or no flow periods play an important role in stressing ecosystems, permitting re colonization and succession. However, this stress should not be exacerbated by unnatural long periods of low or no flow. Ecosystems are particularly sensitive to impact when stressed and further stress will result in harmful impacts. Low flows need to be maintained as close to natural levels as possible.

Selection of threshold that appropriately defines low flows has generated significant debate. For simplicity of calculation a single threshold is preferred. As per the **Environmental Flow Guidelines** of Australian Capital Territories (ACT – Appendix 1), (www.environment.act.gov.au/files/**environmentalflowguidelines**), this has led to the selection of 80th percentile as the threshold of low flows. The 80th percentile flows will be calculated on periods of not more than a month. 10% of flow above the 80th percentile has been selected as suitable portion of water for abstraction.

In the Tisza Basin (Appendix 2) legal requirements to provide 90% or 95% of the natural excedence flow (i.e. the flow equalled or exceeded for 90% or 95% of the time) are sometimes imposed. However, in rivers such as those in the Tisza River Basin the impact on the river due to impoundments, abstractions, diversions, etc. have become so significant that it is often not possible to specify with confidence the natural flow at a particular location. Climatic and environmental changes are such that the natural regime would have changed independently and therefore previously calculated excedence flows may not now apply.

At present in Slovakia the calculation of minimum flow depends solely on hydrological parameters and does not consider the requirements of ecology.

The minimum discharge, MQ value, is defined as follows:

$$MQ = 0.5\ (Q_{m99} + Q_{100min\ d})$$

Where,

Q_{m99} is the mean monthly natural discharge with 99% excedance probability

$Q_{100min\ d}$ is the100-year minimum daily discharge

The minimum needed discharge in a watercourse (MPP) for providing water abstraction requirements is then the sum of minimum balance discharge and water consumption (value X):

$$MPP = MQ + X$$

Minimum discharges are not included in any existing Slovakia bilateral agreements.

Flushing Flows:

These are flushes of fresh water following storm events, which are necessary for maintenance of aquatic ecosystems and channel structure. Flushing flows are of particular importance in streams downstream of water supply dams. Water supply requirements often drastically change natural flow regimes, causing damage to downstream aquatic communities and stream structure.

As per the **Environmental Flow Guidelines** of Australian Capital Territories, the discharge that was found to be the most critical at determining the width, depth and meander frequency of channels is in the 1 in 1.5 to 2.5 years annual recurrence interval flood event. Flood events of this size should be protected to ensure that channel structure and the dependent ecological processes are maintained.

Special purpose flows

These are flood flows for specific ecosystem requirements, for example the inundation of wet lands.

Maintenance of impoundment levels

These are flows required to maintain water level of urban lakes and ponds and to prevent water level lowering too far below spillway level for a significant period.

As already stated earlier, for the purpose of present study only requirements for low flows and flushing flows have been considered. The other two components of minimum flows are specific to a particular reach and not a general requirement.

Minimum flow studies in various Indian Rivers

Selection of Sites and studies for minimum flow

With a view to determine pristine flows in the rivers, it was decided that for the minimum flow study, the sites need be selected, which are not affected by upstream regulations and man made changes. In case, such affects are pronounced, the flow data needs to be corrected in order to obtain the flow data for near virgin conditions. For the selected sites, the following studies were carried out:-

- Flow duration curves of 90, 95 and 99%.
- Flow frequency curve
- Frequency analysis of the following minimum flow variables.

a) Minimum flow volume
b) Minimum flow discharge
c) Minimum flow stage
d) Minimum flow duration

A. KRISHNA AND GODAVARI BASINS

In Krishna Basin, there are no sites which are not affected by U/S Regulations and man made changes. Where ever possible computation of 10 daily near virgin flows were made by considering periods prior to major impoundments or by making correction for upstream utilizations.

Study was therefore carried with the observed flow data (about 30 years) at the following terminal / important sites (Map enclosed).

	Site	River	Data period
A	KRISHNA BASIN		
1	Warunji	Terminal site on Koyna	1980-81 to 2003-04
2	Sadalga	Terminal site on Dudhganga	1980-81 to 2003-04
3	Gokak falls	Terminal site on ghataprabha	1980-81 to 2003-04
4	Cholachguda	Terminal site on Malaprabha	1982-83 to 2003-04

5	Huvenhedgi	Major site on Krishna	1976-77 to 2001-02 (Before construction of Almatti)
6	Yadgir	Terminal site on Bhima	1965-66 to 1984-85 (Before construction of Ujjani)
7	Krishna graharam	Major site on Krishna	1981-82 to 2001-02 (Before construction of Almatti)
8	Bawapuram	Terminal site on Tungabhadra	1965-66 to 2003-04
9	Damercherla	Terminal site on Musi	1968-69 to 2003-04
10	Paleru Bridge	Terminal site on Paleru	1965-66 to 2003-04
11	Wadenapalli	Major site on Krishna	1965-66 to 2001-02 (Before construction of Almatti)
12	Vijayawada	Terminal site on Krishna	1965-66 to 2001-02 (Before construction of Almatti)
B	GODAVARI BASIN		
1	Yelli	Major site on Godavari	1978-79 to 2002-03
2	Dhalegaon	Major site on Godavari	1965-66 to 2002-03
3	Pathagudem	Terminal site on Indravathi	1965-66 to 2002-03
4	Tekra	Terminal site on Pranahita	1965-66 to 2002-03
5	Injaram	Major site on Sabari	1966-67 to 2002-03
6	Konta	Terminal site on Sabari	1966-67 to 2002-03
7	Polavaram	Terminal site on Godavari	1967-68 to 2002-03
C	WEST FLOWING RIVERS		
1	Ganjem	Major site on Mandovi	1979-80 to 2003-04

RESULTS OF THE STUDIES

Abstract of the results of a few selected sites is given below.

Site	River	Minimum flow as % of		Nonmonsoon flow as % of		Monsoon flow as % of		99%le Annual peak (cumec) as % of	
		Annual 75 %le	Annual mean	Annual 75 %le	Annual mean	Annual 75 %le	Annual mean	75 %le Annual discharge	Annual mean discharge
Sadalga	Dudhganga	0.00	0.00	0.00	0.00	53.21	37.35	1002	697
Huvinhedgi	Krishna	0.72	0.57	1.70	1.28	54.21	40.77	936	705

Yadgir	Bhima	0.00	0.00	0.46	0.34	40.68	30.52	747	562
K. Agraharam	Krishna	0.62	0.42	1.49	0.99	69.33	45.88	764	506
Pathagudem	Indravati	0.54	0.40	0.83	0.62	58.62	43.88	851	637
Tekra	Pranahita	0.56	0.36	1.29	0.83	50.36	32.21	706	452
Injaram	Sabari	4.60	3.50	4.42	3.36	52.05	39.52	652	494
Polavaram	Godavari	4.04	2.66	3.90	2.57	59.38	39.14	647	427

It may be seen that the minimum observed 10 daily flows with 99% excedence expressed as a percentage of the 75% dependable Annual Flow varies from zero to 4.8 % at various sites. Similarly the Annual peak flow expressed as a percentage of the 75% dependable Annual flow varies from 647% to 1002%.

B. Minimum flow studies in Yamuna, Tapi, Tambrapani, Shipra, Pennar and Sabarmati.

In Yamuna Basin except Naogaon, Yashwantnagar, Tuni there are no other sites, which are not affected by regulations and man-made changes. Most of the structures in the Yamuna Basin were constructed 100-150 years back. Due to non-availability of flow data prior to the construction of structure, non-availability of flow abstracted from the river, the analysis has been carried out on the basis of the release measured at Paonta, Kalanaur, Delhi, Mathura, Kalpi and Pratappur. In case of Naogaon, Yashwantnagar, Tiuni, studies were carried out on virgin flow data. Virgin flow data of Ganga at Rishikesh and Tehri on Bhagirathi has been considered for study. In case of Tapi Basin, flow data at Burhanpur site is available and the analysis has been carried out in both the cases. Similar analysis has been carried out at Murappandu (Tambrapani river) and Ujjain (Shipra river). Sufficient flow data were not available for Pennar and Sabarmati rivers at selected sites to carry out similar analysis.

The periods for which observed data was used for various sites (map enclosed) are tabulated below. Results of a few selected sites are given below:

Sl. No.	Site	River	Data period
A	**Yamuna River**		
1	Naogaon	Yamuna	1982-2001
2	Kalanaur	Yamuna	1976-2002
3	Delhi	Yamuna	1963-1998
4	Mathura	Yamuna	1974-2001
5	Kalpi	Yamuna	1982-2001
6	Pratappur	Yamuna	1959-2001
B	**Tapi River**		
1	Burhanpur	Tapi	1972-2004

			(Regulated release from Year 1982)
2	Gidhade	Tapi	1973-1998(Most of the data missing)
C	**Tambrapani**		
1	Murappandu	Tambrapani	1990-2002
2	A.P. Puram	Tambrapani	1979-1989(Most of the data missing)
D	**Shipra River**		
1	Ujjain	Shipra	1990-2003
E	**Pennar River**		
1	Chennur	Pennar	1999-2000(Most of the data missing)
2	Tadipatri	Pennar	1989-2000(Most of the data missing)
F	**Sabarmati**		
1	Kheroj	Sabarmati	1990-2003(Most of the data missing)

Results of the Studies : Abstract of the results of a few selected sites (excluding the sites for which adequate data were not available) is given below:

e	River	Min. Flow as % of		Nonmonsoon flow as % of		Monsoon flow as % of		99%le annual peak (cumec) as % of	
		Annual 75%le	Annual mean	Annual 75%le	Annual mean	Annual 75%le	Annual mean	75%le annual discharge	Annual mean discharge
Naogaon	Yamuna	21.93	18.70	5.93	5.07	50.15	42.91	250	214
Kalanaur	Yamuna	2.10	1.02	1.09	0.53	24.60	11.93	685	332
alpi	Yamuna	7.62	5.98	5.69	4.48	52.17	41.05	122	96
Delhi	Yamuna	0.00	0.00	2.60	1.47	27.12	15.34	461	261
athura	Yamuna	1.12	0.50	3.67	1.63	22.27	9.88	339	150
atappur	Yamuna	6.77	4.78	4.13	2.92	44.61	31.53	583	412
Burhanpur rgin ow	Tapi	0.74	0.48	0.24	0.16	43.92	29.05	620	410

may be seen that the minimum observed 10 daily flows with 99% excedence expressed as a centage of the 75% dependable Annual Flow varies from zero to 21.93 % at various sites. nilarly the Annual peak flow expressed as a percentage of the 75% dependable Annual flow aries from 122% to 620%. However excepting Naugaon all other sites excepting Burhanpur on i are affected by upstream diversions and hence cannot be taken as virgin sites. The Burhanpur e needs to be grouped with other peninsular rivers.

C. Additional Minimum Flow Studies in river Ganga & Yamuna

It is observed that the minimum flow criterion in case of hilly portion of Himalayan Rivers is more in comparison to (a) Peninsular rivers (b) in the flat portion of Himalayan Rivers. A careful consideration of the hydrology of the mountainous rivers and peninsular rivers or flatter portion of the Himalayan Rivers indicates that:

- The catchment area of mountainous sites is much less than the down stream sites/flatter portion.
- The contribution of snowmelt during non-monsoon period in comparison to base flow is much more in case of mountainous portion of the Himalayan Rivers. Whereas, in the flat portion (downstream) the snowmelt contribution is much less in comparison to base flow (large catchment area). In absolute terms the low flow (i.e. the snow melt contribution) shown a significant amount in mountainous gauging sites when compared with the annual dependable flow. Therefore, the percentage of low flow as percentage of 75 dependable annual flow is estimated as very high in upper Himalayan catchments. On the other hand, in the flatter portion of the Himalayan rivers the gauging sites are having large catchment areas and thus a higher value of dependable annual flows. However, in flatter portion, the non-monsoon flow is mainly because of base flow contribution. Therefore, quite a large difference is observed between low flows and annual flows at downstream gauging sites. Therefore, the low flow criteria for the mountainous reaches and downstream reaches of the Himalayan rivers may be different.

Accordingly studies were undertaken by CWC at sites which were uneffected by controlled structures together with the sites under effect of regulating structures. The results are given below:

Site	River	Minimum flow as % of		Nonmonsoon flow as % of		Monsoon flow as % of		99%le Annual peak (cumec) as % of	
		Annual 75 %le	Annual mean	Annual 75 %le	Annual mean	Annual 75 %le	Annual mean	75 %le Annual dis-charge	Annual mean dis-charge
Rishikeshn	Ganga	18.20	16.60	11.06	10.1	56.39	51.3	377	343
Tehri	Baghirathi	14.69	13.00	4.53	4.00	60.51	53.9	331	295
Rudrapayag	Alak-ananda	18.75	22.60	12.87	11.3	65.22	57.4	258	227
Tuni	Tons	24.22	24.40	15.00	12.2	51.02	41.4	231	187
Yaswantnagar	Giri	13.92	16.60	11.68	8.3	25.61	18.1	444	314

It may be seen that the minimum observed 10 daily flows with 99% excedence expressed as a percentage of the 75% dependable Annual Flow varies from 13.92% to 24.22 % at various sites. Similarly the Annual peak flow expressed as a percentage of the 75%

dependable Annual flow varies from 231% to 444%. These figures as well as the figures for Naugaon in the previous table can be taken as for near virgin conditions.

GUIDE LINES FOR MINIMUM FLOWS

In the 4th meeting of the Working Group held on 18th Feb., 05 it was decided that to begin with we may adopt methodology similar to Tennant method for recommending the minimum flows.

Naturally occurring minimum flows with 99% excedence can be taken as the minimum flows required for maintaining the in-stream environment. A range of minimum flows may be recommended as flushing flows during the flood period. The flows to be recommended may be expressed as a percentage of 75% dependable Annual flows.

It was also felt that since the Himalayan rivers carry large snow melt component during summer months the recommendations may be different for the rivers originating in the Himalayas and for others.

From the studies carried out, it is seen that in the case of Himalayan Rivers the virgin flows are very high due to snow melt contributions. However it may not be possible to maintain this condition in the lower reaches due to large existing utilisations. A lower value can be recommended as minimum flow to be achieved. For Himalayan rivers where the existing utilizations are low, a minimum flow of 2.5% of the 75% amnnual dependable annual flow is to be maintained.

Himalayan Rivers

- Minimum flow to be not less than 2.5% of 75% dependable Annual Flow expressed in cubic meters per second.
- One flushing flow during monsoon with a peak not less than 250% of 75% dependable Annual Flow expressed in cubic meters per second.

Other Rivers

Minimum flow in any ten daily period to be not less than observed ten daily flow with 99% excedence. Where ten daily flow data is not available this may be taken as 0.5% of 75% dependable Annual Flow expressed in cubic meters per second.

One flushing flow during monsoon with a peak not less than 600% of 75% dependable annual Flow expressed in cubic meters per second.

8. RECOMMENDATIONS

Quantifying the minimum flow is one of the most vexatious questions that, as of now, remains unresolved. The main purpose of the minimum flowis to enablesurvival of riverine flora and fauna. Therefore, the most appropriate approach would

1. An objective of restoring the flow in the river to what it was before any diversion projects were constructed is unattainable, for that would mean dismantling the existing irrigation systems. This is clearly impossible.

2. Ecology is just another claimant for water. Standard principle for resolving river water dispute is "existing use will be negotiated". Therefore, the existing irrigation use should be protected and the nature sector can only claim a portion of the balance water available.

With the above as guiding principles, the committee has concluded as below:

1. There.cannot be one single formula to determine EFR for all the rivers. Ecology of each river, some times different reaches within a river, has to be studied and EFR computed accordingly.

2. EFR concept is applicable only to such rivers that do not go completely dry during lean seasons. For rivers that go completely dry during lean seasons. For rivers.that go completely dry, the riverine ecology ceases to exist and this need not be corrected by artificial means.

3. The guidelines for assessment of minimum flow should outline a practical and commonsensical process for setting a flow regime in a river. They should serve to

present a range of options that decision-makers and others can use, whilst recognizing that methods used will need to vary on a case-by-case basis.

Important points for consideration

Maintenance of minimum flow in river has also to be considered as a water use since it restricts the quantity of water that can be diverted for other uses.

The maintenance of minimum flow in the river during the lean season should be accepted as an important objective for maintenance of river regime and water quality and thereby of pollution abatement.

Keeping in view, and considering all that has been discussed, the working group feels that, a simple method is to be adopted for working out the minimum flows to be maintained in the rivers in India. It is therefore, felt that the Tennant Method (described in para 5.2.1.2) is the only method which can be followed at present.

Water Management Institute (IWMI) and with the support of the Worldwide Fund for Nature (WWF), the Ministry of Environment and Forests, and the Ministry of Water Resources, and the Indian council of Agricultural Research, with the objective of bringing together different concerned departments, agencies, researchers and NGOs to discuss the subject in Indian context and formulate appropriate recommendations. The Workshop was attended by more than 60 participants belonging to the hosting and supporting organisations (MOEF, MOWR, CWC, ICAR, WWF, NIE, IWMI), various Indian Universities and Research Institutes (including the Energy and Resources Institute (TERI), the National Institute of Hydrology (NIH), Indian Institute of Management, Kolkata), the Challenge Program on Water for Food (CPWF), the World Bank (Delhi Office), the Shastri Indo-Canadian Institute, and several non-governmental organizations. The recommendations of the workshop are enclosed at Annexure-I for reference.

Recommendations

The details of the studies undertaken for Indian rivers and the basis for recommendations have already been presented in Section 7 (Studies undertaken). The relevant portions are reproduced here which form the final recommendations of the Working Group.

In the 4th meeting of the Working Group held on 18th Feb., 05 it was decided that to begin with we may adopt methodology similar to Tennant method for recommending the minimum flows.

Naturally occurring minimum flows with 99% excedence can be taken as the minimum flows required for maintaining the in-stream environment. A range of minimum flows may be recommended as flushing flows during the flood period.

It was also felt that since the Himalayan rivers carry large snow melt component during summer months the recommendations may be different for the rivers originating in the Himalayas and for others.

Himalayan Rivers

- Minimum flow to be not less than 2.5% of 75% dependable Annual Flow expressed in cubic meters per second.
- One flushing flow during monsoon with a peak not less than 250% of 75% dependable Annual Flow expressed in cubic meters per second.

Other Rivers

Minimum flow in any ten daily period to be not less than observed ten daily flow with 99% excedence. Where ten daily flow data is not available this may be taken as 0.5% of 75% dependable Annual Flow expressed in cubic meters per second.

One flushing flow during monsoon with a peak not less than 600% of 75% dependable annual Flow expressed in cubic meters per second.

Measures for maintaining River Water Quality

Extensive efforts on augmenting wastewater collection enhansing and treatment facilities and ensuring proper operation and maintenance of these facilities.

Use of wastewater after required treatment for irrigation, horticulture and other purposes..

Need for further studies

The above recommendations will have to be reviewed based on further detailed studies on the subject, preferably in collaboration with organizations such as the World Bank, International Water Management Institute (IWMI), UNEP, International Commission on Irrigation & Drainage (ICID) etc. The officials of World Bank and IWMI have already shown interest in the matter during informal discussions.

ANNEXURES

Annexure 1

WATER QUALITY ASSESSMENT AUTHORITY

(Created under Environment (Protection) Act, 1986 Order No. S.O. 583(E) dated 29.5.2001 of Ministry of environment and Forests)

WQAA Secretariate
B Wing, 2nd Floor,
Khan Market,
Lok Nayak Bhawan,
New Delhi-110003
Dated : 9.9.2003.

In exercise of the power conferred by sub-section (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Govt. has constituted the Water Quality Assessment Authority (WQAA) with effect from 29.5.2001 vide extraordinary Notification published in the Gazette of India dated 22.6.2001. During the 2nd Meeting of the WQAA held on 14.5.2003 it was decided to constitute a Working Group to advise WQAA on the minimum flows in the Rivers to conserve the eco-system.

Accordingly the Working Group is constituted with the following members:

1. Member (RM) Central Water Commission Sewa Bhawan, R.K. Puram, New Delhi.	Chairman
2.Mr. R.C. Trivedi Additional Director, Central Pollution Control Board Arjun Nagar, New Delhi.	Member
3. Sr. Jt. Commissioner (GW&MI) Ministry of Water Resources 2nd Floor, B-wing, Lok Nayak Bhawan, New Delhi.	Member
4. Dr. R. Dalwani Additional Director (NRCD) Ministry of Environment & Forests Pariyavaran Bhawan CGO Complex New Delhi	Member

5. Member Secretary
UP Pollution Control Board
Lucknow, Uttar Pradesh — Member

6. Director
NIH, Roorkee — Member

7. Member Secretary
Upper Yamuna River Board
Central Water Commission — Member

8. Prof. Brij Gopal
Professor
School of environment Studies
Jawaharlal Nehru University
New Delhi. — Member

9. Chief Engineer (P&D)
Central water Commission
Sewa Bhawan, R.K. Puram
New Delhi. — Member-Secretary

(1) The terms of reference of the Working Group shall be as follows:

i) To take up studies towards deciding minimum flows in rivers.
ii) To take up related issues and consider norms/standards being followed in other countries on the subject.
iii) Recommend criteria to be followed for minimum flow in different types of rivers from environmental and other considerations.
iv) Any other related issues.

(2) The Working Group may co-opt/invite/appoint experts in Water Management field with due approval of the WQAA.
(3) The Working Group shall finalise their recommendations within three months of this letter.

Sd/-(S.K. Chaudhuri)
Member Secretary (WQAA) &
Commissioner (GW&MI), MOWR
Tele. FAX 24694752

No. 12/2A/2002-WM/2306-2327

To

All the above Working Group members.

Copy to all the Members of WQAA for information.

1. Sh. Jeyaseelan, Chairman, CWC, Sewa Bhawan, R.K. Puram, New Delhi-110066.
2. Ms. Sushma Chowdhary, Addl. Secretary & Project Director, National River Conservation Dte., Ministry of Environment & Forests, Room No. 412, B-Block, Paryavaran Bhawan, CGO Complex, New Delhi.
3. Smt. Radha Singh, Additional Secretary, Ministry of Water Resources, Sharm Shakti Bhawan, New Delhi-110001.
4. Dr. M. Sengupta, Advisor, National River Conservation Dte., Ministry of E&F, Room No. 121, B-Block, Paryavaran Bhawan, CGO Complex, New Delhi.
5. Dr. G.K. Chaudhary, Jt. Director (RW&WM), Ministiry of Agriculture, Deptt.of Agriculture & Cooperation, Krishi Bhawan, New Delhi.
6. Sh. Vijay Dev, Director (WS)(C/o S. Sephuraman; Joint Adv.(PHEE), Ministry of Urban Affairs & Poverty Alleviation, Nirman Bhawan, New Delhi.
7. Sh. S.S. Chauhan, Chairman, CGWA, 11th Floor, Ansal Bhawan, Kasturba Gandhi Marg, New Delhi-110001.
8. Sh. D.K. Biswas, Chairman, Central Pollution Control Board, Parivesh Bhawan, East Arjun Nagar, Shahdara, New Delhi-110032.
9. Dr. P.S. Datta, Project Director, Indian Agriculture Research Institute, Pusa Campus, New Delhi-110012.
10. Director, National Environment, Engg. Research Institute, Jail Road (Wardha Road), Nagpur, Maharashtra.
11. Dr. S.P. Chakrabarti, Water Quality Expert, DHV Consultant, Hydrology Project, CSMRS Building, Hauz Khas, New Delhi.

Copy for information to:

1. PPS to Secretary, Ministry of Water Resources, Shram Shakti Bhawan, New Delhi.
2. PPS to Secretary, Ministry of Environment and Forests, Paryavaran Bhawan, CGO Complex, New Delhi110003.

Annexure-2

Recommendations of the Workshop on Environmental Flows, organized jointly by the NIE and IWMI (New Delhi, 23-24 March 2005)

1. The minimum flow cannot be equated with the Environmental Flow; hence the term 'Environmental Flow' (EF) which reflects the total requirement of water for maintaining the ecological integrity and the goods and services of the rivers and their associated ecosystems, needs to be used.
2. The EF assessments need to be an explicitly integral component of the water resource planning process at all levels. Further, both the surface and ground waters need to be considered together in an integrated manner.
3. The EF requirements differ considerably in different rivers and their different reaches, and have therefore to be assessed and prescribed separately but an integration between reaches and river-estuary should be ensured.

4. The assessment of EF requirements should employ comprehensive holistic (whole ecosystem-focused) methods. The hydrological methods for EF do not adequately account for the ecological requirements and therefore, recommendations based on the hydrological methods alone may be an immediate step in the right direction and suitable at planning/reconnaissance level but must be treated as only preliminary in character.

5. The EF assessment process should adopt a hierarchical framework, and should ensure public participation and socio-economic and cultural considerations at all stages.

6. The implementation of EF in rivers must ensure that the water released for this purpose is of appropriate quality. Polluted waters cannot be considered to meet the EF objectives.

7. The development of an appropriate methodology for EF in India, as well as the environ-mental management of the rivers and their associated ecosystems, has been constrained by the access to long-term hydrological data for different rivers. Therefore, the hydrological data for all river systems, together with other water quality and environmental data, should be placed in the public domain to facilitate research and development in EF-related areas. These data should be available freely to all researchers in different disciplines related to water and riverine ecosystems, as also recommended by the National Commission for Integrated Water Resources Development.

8. Whereas the EF requirements should be made mandatory for all new infrastructure (water resource) development projects, steps are also required to make possible interventions to remedy the shortcomings (e.g. those concerning fish migration) in the existing infrastructures.

9. Immediate action is required to undertake and fund research on EF requirements in different reaches of both Himalayan and Peninsular rivers, giving due emphasis on geomorphology, habitat, water quality, biodiversity and fisheries, socio-economic and socio-cultural aspects.

10. The concept and issues related to environment flow should be included in all education, training, and awareness programmes on environment and other concerned sectors.

Annexure 3

Summary record of discussions of the Ist Meeting of Working Group to advise WQAA on the minimum flows in the rivers under the Chairmanship of Shri M.K.Sharma, Member (RM), CWC, held at New Delhi on 08-12-2003

A meeting was held in the committee room of Member (RM), CWC on 08-12-2003 on the minimum flows in the rivers. List of the participants is attached.

Member (RM), CWC gave a brief account of the reason for calling the meeting and he highlighted that the criteria for the maintenance of minimum flows in the river will depend on input of the pollutionary load in to the river. It will also depend on the proposed use of water. He also pointed out that it is essential to know about the work done by CWC and other organisation in India and abroad. He requested the members to put their views on the subject.

Members opined that it is essential to establish the requirement of environmental flow which also include the maintenance of ecology of the river including water quality. Members also opined that that ecology is a complex subject and requires the input of many fetors like fisheries, non-point source of pollution, bio diversity, river flood plain management etc.

On viewing the complexity of the subject, Chairman suggested that initially the study can be based on water quality only and that ecological factor can be included later on. Members pointed out that there are various water quality model used for prediction of existing water quality in term of DO,BOD etc. Dr. K.K.S.Bhatia Scientist 'F'. HIH, Roorkee mentioned that NIH, Roorkee has worked on water quality model for Hindon River which include about 12 water quality parameters. Prof. Brij Gopal apprised the committee about a review of International literature for assessment of environmental flow and a copy of the review was made available in the meeting. Dr.M.C.Datta RO was requested to circulate the literature to all the members of the Working Group.

The Chairman requested NIH, Roorkee for preparing an approach paper on the subject which would include the option available through various model(in house and abroad) and suggestion for adoption of the model which may be suitable to our condition for maintaining water ecology. Dr. K.K.S.Bhatia informed that paper will be prepared by 15th Jan., 2004. It was also decided that paper will be circulated amongst all the members and the committee will tentatively meet during 1st week of February 2004 . A summary of the literature as given by Prof. Brij Gopal was made available to Dr.Bhatia.

In view of the volume of work involved in preparing the final report for submission of WQAA, it was decided to request for extension of 6 months to the committee.

The meeting ended with a vote of thanks to the chair.

Summary record of discussions of the 2nd Meeting of Working Group to advise WQAA on the minimum flows in the rivers under the Chairmanship of Shri M.K.Sharma, Member (RM), CWC, held at New Delhi on 09-02-2004

Member (RM) welcomed the members and asked Member Secretary of the Working Group to inform about follow-up action taken on the decisions of the 1st meeting and to highlight the agenda of this meeting. Director, CWC explained that in the 1st meeting Chairman had requested NIH, Roorkee to prepare an Approach paper on the requirement of minimum flows in the rivers to maintain the quality of water which would include the options available through various models (In house and abroad) and suggest the adoption of the model which may be suitable to Indian conditions. The paper has been received from NIH, Roorkee and the same was provided to the members of the committee for discussion.

Dr.Bhatia from NIH explained minimum flows are required for maintaining river ecology and water quality at desirable acceptable levels that will have to be implemented with consensus with water managers and stake holders. Minimum flow required to support healthy aquatic life should be worked on case by case basis by the concerned state pollution control boards by restricting abstractions. He also highlighted the co relation with the river stretch and criteria applicable for water quality requirements. Dr. Dalwani, Addl.Director, Min. of Environment & Forests pointed out that the criteria for use of water for various purposes has already been made available in the atlas prepared by Central Pollution Control Board and hence the aim of the committee should be focussed on the requirement of minimum flows for maintaining the standards as laid down by CPCB.

Prof. Brij Gopal, Jawahar Lal Nehru University, highlighted that maintaining minimum flows will not be sufficient to maintain the water quality in the river until the polluting agencies treat the wastewater sufficiently before discharging the effluents in the river. With the present pollutionary level, huge quantity of water will be required to maintain the quality of water which is not a practical solution.

Shri C.M.Pandit, Member Secretary, Upper Yamuna Board, pointed out that though the water users abstract the water as per the norms laid down during the developments of the projects, the availability of water in downstream is much less than expected due to unlimited withdrawal of ground water and causes the depletion of ground water level. This depletion can not be controlled.

A draft concept paper on minimum flows in the river prepared by CIA Directorate, CWC, New Delhi was also circulated to all the members of the committee. Shri R.K.Khanna, Director, EIA pointed out that the minimum flow inthe river should not be less than the average of 10 days minimum flow of the river in its natural state as suggested in the Guidelines for sustainable Water Resources Development and Management (CWC, 1992). He also mentioned that reservoir operation should be such that 2 or 3 spills of reasonable discharge are allowed in the river on regular basis. Measures may be taken to ensure a minimum flow of fresh water in the major rivers during lean season.

Chairman opined that the subject matter is very complex and attempt should be made to arrive at simple guidelines that could be easily implemented. He suggested that the minimum flow criteria may be kept as the minimum flow that persisted prior to the commencement of any water resources project such as construction of dam, barrage, power station etc in the particular stretches of the rivers. The members of the committee agreed with the proposal.

Dr.(Mrs) Dalwani, however pointed out that application of water quality model to determine the minimum flow requirement should also be kept as an option.

In the meeting it was decided that the study for three basins viz. Yamuna, Krishna and Sabarmati rivers may be taken up on a pilot basis. While NIH will do the study on Yamuna basin, the CWC with the assistance from NIH will carry out studies for Krishna and Sabarmati basins. For this purpose it was decided to convene a meeting of regional Chief engineers of CWC dealing with selected basins, NIH and others on 23-02-2004 at 11 A.M. to discuss the proposed study.

The meeting ended with a vote of thanks to the chair.

Summary record of discussions of the 3rd Meeting of Working Group to advise WQAA on the minimum flows in the rivers under the Chairmanship of Shri M.K.Sharma,Member (RM), CWC, held at New Delhi on 07-12-2004

The 3rd meeting of the Working Group to advise WQAA on the minimum flows was held under Chairmanship of Member (RM), CWC on 07-12-2004 at New Delhi. The list of the participants is at annex-I.

Member (RM) welcomed the participants and gave a brief account of reasons for calling the meeting. Drawing reference to the decisions taken during previous meetings, he desired to know the status of the Pilot studies for three river basins namely Krishna, Sabarmati, and Yamuna for ascertaining the minimum flow in the rivers. Director(RD),CWC informed the committee that studies have been carried out by NIH, Roorkee for Sabarmati and Yamuna basin and K&GBO, CWC for Krishna basin.

Sri A.K. Lohani, Scientist, NIH presented the trend study of Yamuna basin based on the data for 5 sites namely Naugaon, Delhi, Mathura, Kalpi and Partappur. Chief Engineer, K&GBO, Hyderabad presented the studies carried out for Krishna Basin. The results of these studies were discussed at length but the decisions could not be concluded, considering the complexity of the subject and it was felt that further studies would be needed.

Member Secretary, Upper Yamuna River Board was of the view that statistical analysis of flow alone will not determine the minimum flow, but it should be based on environmental objectives to be met. Prof. Brij Gopal, Professor, JNU pointed out that use of excessive groundwater affecting the sub surface flow, drastic changes in river morphology and changes in the ecology of the rivers with time may all effect the minimum flow requirement for river eco-system. Mr. Bhardwaj, CPCB informed that 71 river stretches have been identified as polluted by CPCB and these reaches could be studied for minimum flow requirement. The minimum flows need in the global scenario was also discussed.

Based on these detailed discussions and considering the complexities of the subject matter, Chairman opined that some simple norms of minimum flow to be provided in the river reach may be adopted depending upon the virgin situation as well as flow data availability and it could be some percentage of 75% of dependable flows as occurring in the basin.

It was decided that NIH, Roorkee will carry out studies for Shipra, Yamuna at Kalanaur, Tambraparani, Tungabhadra, Tapi and Pennar basins and Krishna & Godavari Basin Organisation, CWC, Hyderabad for Godavari basin.The report of the studies will be made available within one month. After the studies some general criteria to be followed for minimum flows could be worked out. Chief Engineer, Environmental Management Organisation, CWC volunteered that a draft report will be prepared by Director, EIA which will also include the norms /standards being followed in the other countries on maintaining the minimum flows in the rivers to conserve the ecosystem. In this connection a copy of the materials received from various resources by RD Directorate will be passed on to Director (EIA). It was decided that to seek the extension of the tenure of the Working Group till March 2005, the Working Group will meet again after about a month to discuss the further studies and finalise the recommendations. .

The meeting ended with a vote of thanks to the Chair.

Summary record of discussions of the 4th Meeting of Working Group to advise WQAA on the minimum flows in the rivers under the Chairmanship of Shri M.K.Sharma,Member (RM), CWC, held at New Delhi on 18-02-2005

The 4th meeting of the Working Group to advise WQAA on the minimum flows was held under Chairmanship of Member (RM), CWC on 18-02-2005 at New Delhi. The list of the participants is at annex-I.

At the outset Sh. M.K.Sharma Member (RM) Chairman of the Working Group welcomed the participants and requested them to introduce themselves. After that he gave brief account of the discussion on the studies so far held and also reasons for calling the meeting. Drawing reference to the decision taken during the previous meeting, he requested Chief Engineer EMO/Director EIA CWC to highlight the draft report prepared by EMO, CWC. Sh.R.K.Khanna, Director, EIA made a presentation on the various chapter of the report. The report highlighted the following points with regard to determine the minimum flows in a river system:

- Extent of the problem
- Need for minimum flows.
- Requirement of the minimum flows from various angles.
- Practices and guidelines at global level.
- Practices and guidelines at regional level in India.
- Problem of implementing other countries guidelines in India.
- Thumb rule for maintaining the minimum flow.
- Recommendations for arriving at reasonable flow.

Director EIA explained all the above points in detail.

Member (RM) wanted to know that whether the method of keeping certain percentage of average annual flow as environmental flow has been adopted globally to maintain the ecology and water quality of the river system. Sh. R.K. Khanna Director, EIA mentioned that in the global level, Tennant method which is based on the principle of keeping certain percentage of average annual flow required to achieve different objectives, has been adopted. Member (RM) appreciated the report prepared by EMO, CWC.

Chairman requested Chief Engineer K&GBO, Hyderabad to present the studies conducted by K&GBO, CWC, Hyderabad. Sh.V.K. Jyothi Chief Engineer K&GBO, Hyderabad informed the members that the K&GBO has carried out the studies of the following sites with observed flow of about 30 Years data.

A. Krishna Basin

(1) Warunji (2) Sadalga (3) Gokak Falls (4) Cholachguda (5) Huvenhedgi (6) Yadgir (7) Krishna Agraharam (8) Bawapuram (9) Damercherla (10) Paleru Bridge (11) Wadenpalli (12) Vijaywada

B. Godavari Basin

(1) Dhalegaon (2) Pathagudem (3) Tekra (4) Injaram (5) Konta (6) Polavaram

C. West Flowing Rivers

(1) Ganjem

Percentile value of 99,95, 90 and 75 dependability for annual flows during the period under consideration have been worked out for each site. Minimum flows are considered for six months at the rate of 99 percentile value of ten daily average flow and is compared with annual flow by projecting the figures as percentage of 75 and 50 percentile and mean of annual flow. The studies concluded that minimum flows are the order of 0.46 to 0.8 of 75% dependable flow in case of Krishna and 0.28 to 2.02 % of 75% dependable flow in case of Godavari basin. In case of small west flowing rivers, Mandovi, the value is less than 0.12%. The report recommends that the minimum flow to be maintained in major river basin in any 10 daily period to be not less than 0.25% of 75% dependable flow distributed over non monsoon period which will be about 9.3 Cumecs (approximately 10 Cumecs) for Krishna and Godavari basin.

Sh. C.M. Pandit, Member Secretary, Upper Yamuna River Board pointed on that there should be a clear demarcation in calculation of the figure in BCM (Total Volume) and the flow in cubic meter /sec. He also pointed out that if the specified water is released from barrage it may not necessarily be able to maintain the flow in down stream due to transmission losses like seepage/evaporation loss and abstraction for various purposes enroute to down stream locations. Member (RM) opined that the committee will suggest only to maintain a certain reasonable percentage flow on 75% dependability as minimum flow. It is the task of Basin Manager to maintain this flow. Dr. R.C. Trivedi Additional Director CPCB pointed out that due to over exploitation of the ground water, reverse flow from surface to ground water occurs which will also reduce the flow in the river and it may not be possible to maintain the minimum flow as expected by release of water from the barrage.

Chairman then requested to the representative from NIH Roorkee to present the study carried out by NIH, Roorkee. Sh. A.K. Lohani, informed the member that the available daily flow data of Delhi, Naugaon, Pratappur , Mathura and Agra were carried out and the flow duration curve has been developed using the General Extreme Value Distribution (GEV) Standard procedures . The annual maximum deficit volume and annual maximum deficit duration series are derived considering the demand level as 50%, 75% and 90% dependable flow .GEV is fitted with annual maximum deficit volume and annual maximum deficit duration for each site. The minimum flow requirement varies from 2 to 8% from site to site. Chairman opined that for determining a reasonable and practically adaptable percentage of 75% dependable annual flow, NIH, Roorkee and K&GBO, CWC, Hyderabad should discuss and correlate the studies. He also requested that the study should be carried out taking minimum time and the recommendation be incorporated in the report prepared by EMO, CWC which could be circulated to the members a week before the final meeting of the Working Group.

The meeting ended with vote of thanks to the Chair.

List of the Participants

Sh M.K. Sharma, Member (RM),Chairman

S.No.	Name	Organisation	Telephone No.
1.	Sh S.C.Awasthy Chief Engineer(P&D) & Member Secretary	CWC, Sewa Bhawan, New Delhi	
2.	Sh. Ravinder Singh, Chief Engineer(EMO)	CWC, Sewa Bhawan, New Delhi	
3.	Prof. Brij Gopal	School of Env. Science, J.N.U, New Delhi	26704324
4.	Dr.K.K.S.Bhatia	NIH, Roorkee	
5.	Sh Chetan Pandit, Member Secretary	Upper Yamuna River Board, New Delhi	26109956
6.	Dr.(Mrs.) R.Dalwani, Addl. Director	NRCD, MOEF, New Delhi	24364789
7.	V.N.Wakpanjar,. Sr.Jt. Comm.(GW&MI)	MOWR, New Delhi	
8.	Dr. M.C.Datta R.O.	RDD, CWC, New Delhi	26108075

Report of the Team on Water Quality Consideration in Minimum Flow of Rivers

Background

Water Quality Assessment Authority Constituted a Working Group on Minimum Flows to recommend minimum flow required to be maintained in Indian rivers. The Group submitted its report and made a presentation in the fifth meeting of WQAA. The WQAA decided as recorded in the minutes as follows:

"The Working Group may carry out studies including the water quality aspects, most critical stations and justification of the norms recommended and CPCB be involved with the work."

In compliance with the above decision of WQAA, a team comprising of following members was constituted to give its recommendations on the above decision:

1. Chief Engineer (EMO), CWC – Chairman
2. Dr. R.C. Trivedi, CPCB – Memebr
3. Dr. (Mrs) R. Dalwani, NRCD – Memebr
4. Prof. Brij Gopal, JNU – Memebr
5. Director, RD Dte, CWC – Member Secretary

The terms of reference for the team was "to include water quality aspects in the study for fixing minimum flows of the rivers in India".

To consider water quality while recommending minimum flow involves following facts:

1. A large Quantity of Uncollected and Untreated Wastewater

The main cause of water quality degradation in India is discharge of untreated domestic wastewater. Today about 33,000 million litre/day of domestic wastewater generated in our country. Out of which treatment capacity exists only for about 7,000 million litre/day.

Similarly out of about 15,500 million litre per day of industrial wastewater about 6,500 million litre mostly generated from small scale industries is not getting treatment. Thus there is a large gap between sewage generation and its treatment. This gap is continuously widening. A large part of this wastewater (about 70%) is not even collected. The un-collected wastewater flows in storm water drains (unlined mostly) or stagnate in the urban areas causing cess-pools (good breeding ground for mosquitoes), percolating in the underground and pollute the ground water. In order to protect the ground and surface water quality, it is very important that proper collection and treatment system is in place.

2. Legal Considerations related to Water Quality

The basic objective of the Water (Prevention and Control Pollution) Act, 1974 is to maintain and restore the wholesomeness of the national aquatic resources. Due to large variation in type, size, shape, quality and quantity of water available of our aquatic resources, each one has got a very specific waste load receiving capacity. This implies the need for prescribing different effluent standards based on assimilative capacity of receiving systems. Notwithstanding its merits, it is difficult to administer compliance of much varying standards specific types of effluents. To reduce administrative difficulties of relating effluent quality to ambient water quality the concept of Minimum National Standards (MINAS) was evolved by the Central Pollution Control Board whereby minimum effluent limits are prescribed for each category of discharge, regardless of receiving water requirements. Where water quality standards cannot be reached by imposition of a standard level of treatment alone, then and only then will the conditions of the receiving waters dictate more stringent controls (State Boards can make the MINAS more stringent). The conventional methods of treatment cannot cope with these specific situations and the polluters are required to go for introduction of new methods for specific requirements. The number of such situations in our country is gradually rising due to water scarcity in many water bodies and some times due to the nature of effluents.

3. Water Quality V/s Quantity Considerations

Although, the MINAS, is mainly technology based, but some consideration is given to the receiving water body based on the assumption that in the receiving water body at least 10 times dilution is available to achieve the ambient water quality objective in the immediate vicinity of the downstream. In the recent past due to over use of surface and ground waters to fulfill the ever increasing demand of agriculture, industrial and domestic uses, the water level in our aquatic resources is gradually decreasing. As a result, the assumption of 10 times dilution is no more valid in many parts of our country. This poses great difficulties to achieve the ambient water quality objective (wholesomeness) even after implementing MINAS. This is a challenge before the Pollution Control Boards and the polluters. Thus, it has become necessary to achieve progressive reduction or elimination of effluent discharges. It implies, adoption of no waste or low waste technologies through new treatment methods which can fulfill the above objective.

In the recent past due to over-exploitation of groundwater, water table has gone down in the catchment areas of many rivers resulting in reduced water level in rivers. In many rivers the water table has gone down below the river bed resulting in reverse flow. In such cases, even if water is released to fulfill the requirement of minimum flow, the water will percolate and can not be maintained in the course of the river as minimum flow.

4. Treatment Technologies

There are a large variety of treatment techniques designed to remove pollutants from wastewater. The objective of wastewater treatment is to separate wastes from water. In one sense, all wastewater treatment processes can be considered separation processes. There are physical, chemical and biological separation processes. Sedimentation, screening and distillation are examples of physical processes. Coagulation, ion exchange and pH adjustment are typical chemical processes, while various forms of biological digestion belong to the category of biological processes. In the biological processes organic wastes are metabolized by living organisms, while in the physical and chemical processes physical and chemical properties are utilized for waste separation. Conventional wastewater treatment consists of pretreatment, primary sedimentation, secondary biological treatment, secondary sedimentation, chlorination and discharge.

Historically, biological techniques have been widely utilized since they are generally cheaper to build and operate as composed to physico-chemical techniques. Moreover, they are more efficient as natural means of treatment are utilized in optimized conditions.

5. Experience from Industries

Many industries inspite of adopting conventional treatment, are not able to achieve the MINAS either due to high BOD or presence of xenobiotics like lignin, phenols, cyanides, pesticides, PAH, PCB etc. or toxic substances which are not easily degradable. In such situations specific techniques are required to handle these wastes in which combination of several treatment techniques could achieve the targeted quality of final effluent. Specific genetically engineered microbes are now a days becoming popular to cope with such specific wastes. Many techniques are being employed wherein microbes are fixed on a media and are subjected to the effluent treatment in a defined specific condition. Many such microbial systems are being imported in our country by the industries and consultants on trial basis for treatment of effluents from pharmaceutical and organic pesticide industries. The effluents are thus treated to the targeted level. Several modifications are developed in the conventional treatment methods to tailor the specific requirement of the industrial effluents.

Small scale industries in India are facing great difficulty in achieving the MINAS due to variety of problems. The most important one is the financial hardship. It is difficult for small scale industry to afford the cost of the conventional treatment. Secondly, even if they establish a treatment system they cannot run it properly due to lack of skill which is very important for running such plants. Moreover, many of the small scale industries operate on job basis. Hence, the wastewater is generated intermittently. But conventional treatment plants are generally effective when operated on continuous basis. Interrupted operation results in conditions where microbes to die-off which may take long time to regenerate. Till such time, the final effluent is unable to achieve the targeted quality. The problem is more acute in handling of specific wastewaters like the effluents from H-acid plants, dye intermediate plants, electroplating, textile hand processing units etc.

6. Experience from National River Action Plan

Under the Ganga Action Plan, several sewage treatment plants have been constructed, besides renovating the existing ones. During operational phase, several problems are being faced. Apart from the administrative problem of operation and maintenance, there are technical problems. Amongst others, inadequacy in the design of treatment plants leads to a host of problems that are being faced in construction, operation and maintenance. This is due to the fact that the characteristics of sewage actually reaching the plant are much different than the design criteria. The plant designs are based on population based estimated BOD load, which is different than the BOD actually reaching to the plants. Thus the plants were over-designed. The treatment plants need skill operation and maintenance, besides being energy and cost intensive. All these factors may result in malfunctioning of the STPs and jeopardize the very objective of the GAP. Therefore, now in the implementation of second phase of GAP and National River Action Plan more focus is placed on such systems which are less expensive, simple to operate and capable of functioning without high operational skill.

Conclusions and Recommendations:

As clear from the above presentation, none of the technologies which are economically viable can remove all pollutants from water. Some residual pollution is bound to be there in the treated effluent. Thus there is a need for some dilution water to assimilate the residual pollution to achieve water quality target in the receiving water body. The quantum of affluents generated by major urban countries is such that the amount of fresh water requiredfor dilution is not avaible in the rivers. Moreover,The rainfall is highly uneven with time and space. To feed our growing population we need to grow more food grain. To achieve that, we need to use the stored water (both river storages and underground storages) in our agriculture, which uses almost 85% of our water. We can not afford to reduce or stop our agriculture need. Our demand in other sectors i.e. industrial, domestic and power sector is also growing. In such situation providing dilution water for ever increasing wastewater even if it is fully treated (presently very small fraction is being treated) is becoming more and more difficult. Thus, in order to maintain water quality in our water bodies following measures are inevitable:

a. All water conservation measures in agriculture, industry and domestic uses
b. Regulation of groundwater withdrawal
c. Massive efforts on augmenting wastewater collection and treatment facilities and ensuring proper operation and maintenance of these facilities
d. Rain water harvesting and storage at local level
e. Massive effort on revival of village ponds
f. Use of wastewater for irrigation after required treatment
g. Achieving zero discharge from industries
h. Diversion of all wastewater presently being discharged into the rivers or lakes to other alternative use.
i. To carry out detailed studies in different rivers and required to identify the need for evolving the minimum flow, if required..

APPENDICES

Appendix 1

Environmental Flow Guidelines 27 May 1999

ACT GOVERNMENT

ENVIRONMENTAL FLOW GUIDELINES

TABLE OF CONTENTS

INTRODUCTION

1.1 Background

Increasing demands for the allocation of water for off-stream uses has resulted in substantial changes in the streamflow regimes in many streams across Australia. These changes in streamflow have contributed to major impacts on aquatic habitats and ecology. In some Australian streams allocation of water for off-stream uses can exceed flow resulting in patterns of flow that reflect the rights of water users rather than the requirements of the streams and their ecological processes.

Consumptive uses are often given priority with water rights, entitlements, and licenses having legal and commercial status. With the growing use of market forces as the basis of resource allocation, there is a need to ensure that environmental quality and ecological requirements are not disadvantaged. Recently, there has been an acceptance of the need to give explicit recognition to an environmental flow allocation through the establishment of water entitlements for the environment. Similarly, it is accepted that there is a relationship between surface and ground water and that ground water abstraction can impact on base flows of surface streams. These environmental entitlements should be based on the best available scientific information to protect the health and viability of the river systems and groundwater basins.

Environmental flows are defined as the streamflow necessary to sustain habitats (including channel morphology and substrate), encourage spawning and the migration of fauna species to previously unpopulated habitats, enable the processes upon which succession and biodiversity depend, and maintain the desired nutrient structure within lakes, streams, wetlands and riparian areas. Environmental flows may comprise elements from the full range of flow conditions which describe long term average flows, variability of flows including low flows and irregular flooding events. Many aquatic ecosystems in the ACT are highly modified as a result of changes in land use, changes to river channels and floodplains, streamflow diversion, discharges to streams, introduction of flora and fauna, and recreational fishing. Some of these systems, particularly urban lakes and streams, are created ecosystems. Some of these created ecosystems are valued more highly by some than those that existed in the same places before development. Other aquatic ecosystems are in a condition close to that prior to European settlement. Depending on the condition of a stream and the environmental values specified for that stream, the planning and management issues in respect to environmental flows might be:

• to manage streamflow diversion and discharges so as to maintain the current status of the aquatic ecosystems; or to manage streamflow diversion and discharges so as to restore aquatic ecosystems to a standard to meet the community's environmental values. It should be recognised that the guidelines for environmental flows in this document are based upon the best scientific knowledge available at the time they were drafted. The determination of environmental flows is an active research field and this document will be refined and amended as the knowledge base grows.

1.2 Purpose of the Guidelines

These Guidelines are an administrative document that sets out a methodology for the calculation of environmental flows to be used as the basis of a Water Resource Management Plan for the ACT. While the Guidelines have been developed using the most up to date scientific information available, some pragmatic assumptions have been made.

1.3 Ecologically Sustainable Development

The *Inter Government Agreement on the Environment (1992)* sets out clear guidance on land use decision and approval processes to ensure development is ecologically sustainable. *The National Strategy for Ecologically Sustainable Development (1992)* sets the goal of Ecologically Sustainable Development (ESD) as 'development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends'. When applied to ecosystems this core objective is expressed as 'protection of biological diversity and the maintenance of essential ecological processes and life support systems'. These guidelines have been prepared with these principles in mind. In line with the ESD precautionary principle, the guidelines for natural systems, modified systems and created systems are conservative and may need to be reassessed in light of further knowledge and experience.

1.4 Statutory basis for Environmental Flows in the ACT

1.4.1 Water Resources Act

The preparation of environmental flow guidelines is a requirement of the *Water Resources Act 1998.* This act has the objectives of:

- ensuring the use and management of water resources sustain the physical, economic and social wellbeing of the people of the Territory while protecting the ecosystems that depend on those resources;

- protection of waterways and aquifers from damage and, where possible, to reverse damage that has already occurred; and
- ensuring that water resources are able to meet the reasonably foreseeable needs of future generations.

To achieve these objectives the *Water Resources Act* sets out a process for the sustainable allocation of water to environmental and human uses. The Act requires that Environmental Flow Guidelines be prepared to set out the flows necessary to ensure environmental values in ACT waterways. The Act also requires a Water Resource Management Plan, which describes the water resources of the ACT and actions to be taken by the Environment Management Authority to manage those resources, be prepared. The Act further provides that the Environment Management Authority may make allocations, of both surface and groundwater, for off-stream use as provided for in the Water Resource Management Plan.

1.4.2 Territory Plan

Implementation of the *Water Resources Act* needs to be consistent with the Territory Plan. Three types of water use catchments are identified in the Territory Plan; "conservation", "water supply", and "drainage and open space". Part C2 of the Territory Plan specifies the primary environmental and use values of water bodies in the ACT for each of these types of catchment. Within each of these catchments, secondary environmental and use values are also specified and include provision of recreational amenity, supply of potable or second class water, provision of aquatic habitat, and remediation of low quality urban stormwater (Part C2, Schedules 1 to 6 of the Plan).

Where several secondary uses are specified for a water body, that water body should be managed to achieve the use with the most stringent requirements so that no uses are compromised by relaxation of standards. Under the general principles and policies, the Territory Plan requires that planning be guided by the principles of ecological sustainability and exclude catchment land and water uses which impact on the sustainability of identified environmental or water use values. It is therefore necessary that appropriate flows be provided to protect the environmental and use values of ACT water bodies. The Territory Plan explicitly requires that environmental flows be maintained to ensure that the stream-flow and quality of discharges from all catchments protect environmental values of downstream waters. Three policies are elaborated to achieve this objective:

- land use and management practice shall be cognizant of streamflow and water quality impacts downstream;

- stream-flow diversions shall be restricted to authorised diversions; and
- lake and reservoir releases shall be consistent with the protection of downstream ecology and water uses. Implementing these policies necessitates defining quantitative environmental flow guidelines for all streams, rivers and lakes in the ACT and the control of abstraction to flows not required by the environment.

1.4.3 Supporting Legislation and Strategies

The objectives of the Territory Plan and the *Water Resources Act* are supported by the provisions and strategies contained in the *Environment Protection Act 1997*, the *Nature Conservation Act 1980* and the ACT Nature Conservation Strategy 1998. The *Environment Protection Act* provides support by the enforcement of water quality and chemical use standards. The *Nature Conservation Act* and ACT Nature Conservation Strategy support the conservation of native species, communities and habitats essential to the protection of the wellbeing of aquatic habitats.

1.4.4 National Waters

These Guidelines include environmental flows for Lake Burley Griffin and releases from Scrivener Dam, the management of which are Commonwealth responsibilities. This approach has been taken in light of the ACT's responsibility for water resources under the *Australian Capital Territory (Self-Government) Act* and to ensure consistency across the ACT, given the impracticality of considering the management of Lake Burley Griffin in isolation. The role of these Guidelines is explicitly recognised in the Lake Burley Griffin Management Plan (National Capital Planning Authority 1995). The Guidelines therefore specify environmental flows for all waterways lying within the ACT.

1.4.5 Paramount Rights to Queanbeyan and Molonglo Waters

By the Agreement between the Commonwealth and NSW for the surrender of territory by NSW for the Seat of Government, the Commonwealth gained paramount rights to the waters of the Queanbeyan and Molonglo Rivers and their tributaries for all the purposes of the Territory. The Commonwealth developed the waters of the Queanbeyan River for the purposes of the ACT and through self-government legislation, the Territory Executive exercises the rights to these waters. The Council of Australian Governments' agreement on water reform, and the Commonwealth *Canberra Water Supply (Googong Dam) Act 1974,* require that environmental needs are taken into account in water resources management. In this context, these guidelines also specify the environmental flows, which are seen by the ACT as appropriate downstream of Googong Dam and on other parts of the Queanbeyan and Molonglo Rivers. These guidelines are not legally enforceable for NSW waters. Rather, they provide ACT's view on how it considers NSW should manage these waters which are of interest to the ACT. In addition, they assist in providing a basis to assess whether the Commonwealth's paramount rights to the waters of the Molonglo and Queanbeyan Rivers are being protected.

1.4 Review of the Guidelines

Actual flows and their effect on stream structure and ecology will be the subject of an ongoing monitoring and evaluation program. The program will be used to evaluate the effectiveness of the Guidelines. The Guidelines will be reviewed after the initial five years of operation to determine if targets and thresholds chosen are the most appropriate for individual water bodies. The review may be conducted earlier if evidence indicates it is warranted.

2 DETERMINATION OF ENVIRONMENTAL FLOWS

2.1 Basis for Determination of Environmental Flows

The concept of environmental flow is based on the recognition that stream biota is adapted to certain flow conditions and modification of the flow regime will impact on the ecosystem. Additionally, the structure of streams is strongly influenced by flow regimes producing secondary effects on stream biota in terms of substrate type, available habitat, etc. Flow regime refers not only to average flows but also to the variability of flow and incidence of flood events. For long term viability of some ecosystems there may be a need for 'stressing' flows, low flows that stress the aquatic ecosystem and allow succession. In practice it may be difficult to consider an 'environmental flow' component in isolation from other flows and from water quality. The environmental flows have been determined by bringing together the Territory Plan requirements to protect specific environmental values associated with aquatic ecosystems, and the scientific basis for sustaining significant ecosystems or species.

Water Quality Issues

Both water quality and water quantity characteristics have effects on ecosystems, and in some areas these are strongly interrelated. Although these environmental flow guidelines focus on water quantity, some water quality factors should not be ignored in this discussion. In particular, water quality problems can arise when water is released from impoundments to meet downstream environmental flow requirements. Water from the lower layers of deep, stratified reservoirs can have a much lower temperature and oxygen content than surface waters. If this bottom water is released to meet environmental flow requirements, its quality may compromise its value in the maintenance of aquatic ecosystems. For example most native fish species use both water temperature and flow as cues for reproduction, and the temperature of water released to meet an environmental flow requirement may severely disrupt spawning migrations and reproductive activity. The algal biomass (and potential for nuisance blue-green algal blooms) of lakes is a function of the nutrient loading on the lakes and the residence time of water in the lake. Consequently, a diminution of inflow as a result of water abstraction, for example, can result in extended residence time and associated elevation in algal biomass levels. The sustainable nutrient loads on each lake identified in the ACT Water Quality Guidelines are premised on the existing inflow regimes. Any decision which leads to a reduction in inflow would need to consider the impact of altered nutrient loadings.

2.3 Modification of Water Control Structures

Many water control structures were built before environmental flows were identified and as presently constructed cannot be operated to meet the environmental flow requirements of these guidelines. In particular this relates to the temperature and flow variations to mimic natural conditions. The major water storage structures, Corin, Bendora and Googong Dams all have the capacity to draw water from a variety of depths. However, each has only one water release structure. The depth from which water is drawn is determined by the quality requirements for water supply which are not always the same as the temperature requirements of special purpose environmental flows critical to fish reproduction during spring and early summer. The natural filling of the dams during spring often leads to over spillway flows removing the need for specific releases. Googong is only used during peak summer demand periods reducing the possibility of conflict between water supply and environmental flow requirements. It is expected that existing infrastructure will be managed so as to comply as closely as possible with the Guidelines. Cotter Dam also has a multi-level off-take but as currently operated is not used for water supply. Any change to the use or method of operation of Cotter Dam should not adversely affect the quality of future environmental flows. Scrivener and Captains Flat Dams on the Molonglo River do not have multilevel off-takes but are able to release water from the base of the dam wall. To comply with these guidelines, multi-level off-takes should be retrofitted to these dams. The priority for this work should be to Scrivener Dam and the work should be undertaken within a reasonable time. Urban lakes and ponds only have the capacity to release water by spilling.

Where minor changes to the infrastructure will produce a significantly better environmental outcome, it is expected that changes will be undertaken within an appropriate time. In the future as opportunities arise to modify any of these structures, through maintenance or redevelopment, it is expected that modifications will be undertaken so as to maximise possible improvements in environmental flows. It is not expected that major structural changes will be undertaken specifically to meet these guidelines.

2.4 Consideration of Return Flows

In urban situations flows returning to natural streams from sewage treatment, increased stormwater flows and other impacts can significantly increase flow volume and change flow variability, particularly at the lower end of the scale. These changes can be detrimental to the environment and it is appropriate to encourage the net abstraction of water to more closely approximate the flow prior to urbanisation. At the same time it needs to be recognised that part of the value of some created ecosystems in urban areas arises from flows which are higher than they would have been in natural conditions Currently, the ACT diverts an average of 65 GL a year for urban water supply. Of the 65 GL around 55% is returned as treated waste water. Increased run-off resulting from lower infiltration rates in urban-areas provides an additional 30% to 45% of the volume abstracted for water supply back to streams. The sum of returns to stream and additional run-off results in net abstraction of around 15% of the 65 GL originally abstracted. This is less than 2% of the mean annual flow at Burrinjuck Reservoir. While the overall loss of flow in the system in the longer term is low, the changes in the median to low flow regimes on rivers downstream of water supply diversion dams and Scrivener Dam, is significant. Conversely, downstream of the sewerage treatment works on the Molonglo River there is a significant increase in base flows as a result of the return of treated wastewater to the stream. The Guidelines address these changes in two ways:

- by managing further abstraction from streams so as to minimize impacts on the flow regime within this median to low flow band; and
- by requiring releases from Water Supply Reservoirs to protect low flows downstream.

Separately, the re-use of stormwater and treated waste water is being promoted as a means of reducing the return flows during low flow periods, thus restoring in part a more natural flow regime downstream of the treated waste water discharge point. Reuse also reduces the diversion from existing dams and defers the need for the construction of additional water supply dams.

ENVIRONMENTAL FLOW GUIDELINES

2.5 Relationship to Groundwater

Aquifers in the ACT fall into two types, aquifers in fractured rock and aquifers in alluvium. Abstraction of groundwater from both types of aquifers will ultimately affect surface water flows and consequently such systems should be considered as integrated systems. With aquifers in alluvium there is often a direct connection with surface waters and the importance of a joint consideration of surface and groundwater in such systems is clear. With fractured rock aquifers the connection between surface and groundwater may be less direct. The boundaries of such aquifers may not be related to the catchments which overlie them and the transit time of water through such aquifers may be so slow that it is not relevant to surface processes. Further work needs to be done to establish the importance of this type of aquifer in sustaining base flows, and of their recharge rates. Until further work is done, environmental flow requirements and allocations from fractured rock aquifers will be conservative.

2.6 Type of Ecosystems

There has been extensive changes to land use in some parts of the ACT resulting in substantial changes to stream flow. Restoration of natural aquatic ecosystems is no longer practical. In recognition of this situation, aquatic ecosystems have been categorised into four broad types in order to clarify differences in management goals and techniques that can be used to arrive at these goals (Table 1).

Table 1. - Types of aquatic ecosystems and their location
Type of Aquatic Ecosystem
Description Management goal Water bodies in this category
Natural ecosystems

Ecosystems that have persisted from a period prior to European settlement.
Primary goal: Maintain
ecosystems in their pristine state, Secondary goal: recreation.
Water bodies in Namadgi National Park, excepting the Cotter River catchment Modified ecosystems Ecosystems modified by catchment activities (land use change, discharges) or by changes to the flow regime. Should meet a range of functions; recreation, conservation. Rivers, lakes and streams outside Namadgi and the Canberra urban area including Molonglo (except Lake Burley Griffin) and Queanbeyan Rivers. Water supply ecosystems Ecosystems in catchments that provide the ACT water supply. Primary goal: Provide water supply, Secondary goal: conservation. Cotter River catchment.

Created ecosystems

Ecosystems in urban lakes, pond and streams that have developed since urbanization Should meet a range of functions; recreation, conservation, irrigation. All urban lakes and streams. Different approaches were used to set environmental flow guidelines for each of the types of ecosystem referred to in Table 1, natural, modified, water supply and created. These approaches are discussed in detail in Section 3. For the purpose of setting environmental flow guidelines, major rivers and streams are divided into reaches delineated by major confluences, lakes or reservoirs. This procedure assumes that a degree of homogeneity applies within reaches. It also acknowledges that there are links between reaches of a river. Specific environmental flow requirements can then be determined for each reach. This procedure is applied to all river reaches. These guidelines also establish water levels at which lakes in the ACT should be maintained. Excessive draw down of lakes may result in an impact on ecosystems as does changing flow regimes in rivers. The approaches used to set environmental flow guidelines for lakes and reservoirs in the four types of aquatic ecosystems are discussed in Section 3.

3 ENVIRONMENTAL FLOW APPROACH ADOPTED

A holistic approach has been used for the setting of environmental flow guidelines in the ACT. This approach aims to consider the complete river ecosystem including catchment, channels, storages, riparian zone ground water and wetlands to maintain integrity, natural seasonality and variability of flows (see Figure 1).
Flushing flow
Low flow
No flow
Flow in the Murrumbidgee
1994-95
Flow m3/sec
Figure 1 Flow at Lobbs Hole in the Murrumbidgee over 1994-95 illustrating flow variability and flow elements to be considered in an environmental flow.
A holistic approach has the following advantages;
- the philosophy underlying this technique is the maintenance of the aquatic ecosystem as a whole, rather than some selected component, eg. fish;
- this approach makes explicit provision for natural variability in river flow including seasonal variation and flood flow; and

• when more information on flow requirements of particular ecosystem components becomes available, eg. fish diversity, it can be readily incorporated into the approach.

3.1 Determination of Environmental Flows

For the purpose of these Guidelines, the following methods shall be adopted as the basis for determining flows. The method selected for a catchment will depend on the availability of data, its reliability and relevance. In determining flows percentile flows will be based on "time weighted" recorded flows and gauged data should be of a suitable length of record (preferably 10 years), have no significant dams or other flow modifications, and should be stable catchment conditions.

Cumulative gauged flow based method

Where an abstraction point is located upstream or downstream of a gauging station, the flow can be calculated on the basis of the gauged flow for the nearest appropriate station, multiplied by a catchment area ratio raised to the power 0.7 to account for flows from tributaries; that is:

$Flow_{abstr} = Flow_{gauge} \times (A_{abstr}/A_{gauge})^{0.7}$

Paired catchment based method

Where gauging is not available on a stream, and a calibrated 'paired catchment' station exists for the stream, the flow can be calculated on the basis of the flow for the paired stream multiplied by the calibrated flow coefficients for the abstraction stream. If no calibration factor is available, the closest hydrologically similar catchment will be selected and the flows determined by the Cumulative gauged flow based method above.

Regional rainfall-run-off model based estimates

Flow can also be calculated on the basis of the application of rainfall data for the catchment of the stream to a Rainfall-Run-off Model calibrated to regional parameters.

3.2 Components of Environmental Flows

For ACT waterbodies there are four elements that should be built into any environmental flow, these are:

- low flows,
- flushing flows,
- special purpose flows, and
- maintenance of impoundment levels.

3.2.1 Low Flows

Aquatic ecosystems in ACT rivers are assumed to be adapted to periods of low flow or no flow. Such conditions are presumed to have occurred before European settlement and still occur in pristine catchments. It has been argued that natural low or no flow periods play an important role in stressing ecosystems, permitting re-colonisation and succession. However, this stress should not be exacerbated by unnatural long periods of low or no flow. Ecosystems are particularly sensitive to impact when stressed and further stress will result in harmful impacts. Low flows need to be maintained as close to natural levels as possible.

A critical decision in determination of any flow, including low flows, is the period over which it is calculated. If a low flow guideline were based on a statistic calculated for the entire year, it would ignore the natural seasonal variability in river flow; ACT flows are naturally higher in winter.

Calculation of a percentile flow for each week better reflects natural variability, but if this flow forms the basis for the environmental flow, administration of environmental flows could become impractical. As a pragmatic compromise, statistics based on the monthly flow are used in these guidelines as the measure of low flow component of the environmental flow.
Selection of a threshold that appropriately defines low flows has generated significant debate. For simplicity of calculation a single threshold is preferred. A pragmatic approach has led to the selection of the 80th percentile as the threshold of low flows. The 80th percentile flows will be calculated on periods of not more than a month. The collection of flow data from continual monitoring will provide additional information as to the appropriateness of this threshold. Similarly, 10% of flows above the 80th percentile has been selected as a suitable portion of water for abstraction. These thresholds will be subject to the review outlined in Section 1.5. Actual guidelines for protection of low flows are discussed in detail in Section 4. 1. The 80th percentile flow is the flow which is exceeded 80% of the time. (also see Glossary)

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3.2.2 Flushing flows

These are flushes of fresh water following storm events, which are necessary for maintenance of aquatic ecosystems and channel structure. Flushing flows are of particular importance in streams downstream of water supply dams. Water supply requirements often drastically change natural flow regimes, causing damage to downstream aquatic communities and stream structure. An example of this is the riffle - pool structure of the Murrumbidgee River in the ACT, which would evolve to a system without deep pools and associated aquatic communities if flushing flows did not occur. The discharge that research elsewhere has found to be the most critical at determining the width, depth and meander frequency of channels is the 1 in 1.5 to 2.5 years annual recurrence interval flood event. Flood events of this size should be protected to ensure that channel structure and the dependent ecological processes are maintained.

In ACT rivers, other than water supply catchments, the short duration of high volume flows and a limit on abstraction of 10% of flows over the 80th percentile will ensure that flushing flows occur with this frequency. This 10% threshold has been selected using the best available scientific advice on the provision of habitat diversity and quality, nutrient and sediment cycling, movement of biota and connectivity between aquatic and terrestrial habitats. For simplicity of calculation a single threshold has been selected. The collection of flow data from continual monitoring will provide additional information as to the suitability of this threshold. The threshold will be subject to the review discussed in Section 1.5.

3.2.3 Special purpose flows

These are flood flows for specific ecosystem requirements, for example the inundation of a wetland. The ecological requirements for special purpose flows in ACT rivers are not well understood. Except for the requirement of spawning flows in the Cotter River, explicit special purpose components of environmental flows have not been set at this stage.

3.2.4 Maintenance of impoundment levels

The stability of water levels in lakes, ponds and reservoirs determines success of submerged and emergent macrophytes. Macrophyte stands are a significant component of aquatic habitat, and their destruction affects dependent biota and associated ecosystem processes. If the water level of urban lakes and ponds is lowered too far below spillway level for a significant period, macrophytes will be damaged or killed, compromising the ecological values of those water bodies and their capacity to support other environmental functions.

4 ENVIRONMENTAL FLOWS FOR PARTICULAR ECOSYSTEMS

2.1 Water Supply Ecosystems

2.2

The Cotter River catchment from its headwaters to the wall of the CotterDam is the only catchment in this category. The primary use of waterbodies in water supply catchments is provision of a potable water supply. Although protection of aquatic habitat is a designated secondary goal in these areas, their primary function may require substantial drawdown of reservoirs and abstraction from streams. No guidelines are set for maximum drawdown of reservoirs in water supply ecosystems.

The specific objective of environmental flows in water supply catchments is to ensure that existing downstream ecological values are retained. Environmental flow guidelines for river flow in this catchment also acknowledge the primary water supply role of the catchment. Nevertheless, as a consequence of the protected nature of the Cotter catchment, this system contains valuable aquatic ecosystems. For example, the Cotter River has the highest number of threatened fish species of any stream in the ACT or surrounding region. Guidelines have been set for three categories of river reach in the water supply catchment; Category A - river reaches above all impoundments in the catchment (eg. above Corin Dam);

Category B - river reaches between impoundments used as a conduit for water intended for water supply (eg. between Corin and Bendora Dams - water in Corin Dam intended for domestic supply is not pumped directly from there, but is allowed to flow downstream to Bendora Dam and from there gravitated to Canberra); and

Category C - river reaches below impoundments not used as a conduit for water intended for water supply (eg below Bendora and Cotter Dams).

Category A (above Corin Dam)
Within this region there is to be no interruption to natural flows.

Category B (Corin Dam to Bendora Dam)

The approach taken has been to base guidelines on the minimum flow requirements for maintenance of viable native fish populations in these regions. The health of native fish is considered a good indicator for typical aquatic ecosystems. A critical period for native fish is the breeding season in the spring months. At other times of the year lower flows will suffice to maintain fish populations. A flow adequate for spawning has been defined as the 50th percentile [2] monthly flow during the spring months (September, October and November) and the 80th percentile monthly flow for the months August and December to March.

- In two out of every five years flows are to be at or above the spawning level for each month in the August-to-March period.
- In addition, in all months in all years the defined low flow is to be protected. The low flow is defined as the 80th percentile of water flowing into the reservoir. That is, flows entering the reservoir, up to and including the 80th percentile, are to be released. Where the water supply service provider can demonstrate the need for further supplies, the Environment Management Authority may reduce this level of protection. Where the level of protection is reduced flow should not be permitted to fall below 50% of the inflow when flows are below the 80th percentile, except as specified under drought conditions.

- Reservoir releases to meet environmental flow requirements should mimic natural flows as far as possible.
- Temperature of released water should approximate as closely as possible temperature of water flowing into reservoirs. Once flow requirements are met, all other water is available for abstraction.

Drought is defined for the purpose of these Guidelines as occurring when in nine of the preceding 12 months flows into Corin Dam and Googong Dam were less than the median monthly inflows, and the total amount of water in ACT water supply reservoirs is less than 50% of total storage capacity. It is accepted that during a period of drought, specified environmental flow guidelines may need to be modified by the Environment Management Authority, subject to appropriate consultation, to ensure security of Canberra's water supply. Parties involved in such consultation should at least include the service provider, and the Government agencies responsible for water resource planning and regulation.

Category C (below Bendora Dam)

There is recognition that releases of water below impoundments to meet environmental flows may conflict with the water supply function of the catchment. Nevertheless the Territory Plan explicitly states that reservoir releases in this and other water supply regions shall be insistent with maintenance of the downstream ecology.

- In all months in all years the defined low flow is to be protected. The low flow is defined as the 80th percentile of water, which would have flowed into the reservoir prior to the development of upstream impoundments. That is, flows entering the reservoir, up to and including the 80th percentile, are to be released. Where the water

[2] The 50th percentile flow is the flow which is exceeded 50% of the time. (also see Glossary)

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supply service provider can demonstrate the need for further supplies, the Environment Management Authority may reduce this level of protection but flow should not be permitted to fall below 50% of the inflow when flows are below the 80th percentile, except as specified under drought conditions (see Category B). Once flow requirements are met, all other water is available for abstraction.

Implementation

Environmental flows below impoundments should be met by releases from the impoundments. Water released to achieve environmental flow targets should be at a temperature approximating as closely as possible that of inflow water. If inflow water temperature is unknown, surface water should be used to meet environmental flow requirements. Percentile flows should be calculated on not more than a monthly basis but releases should be made to mimic natural short term, daily or within month variability as much as possible.

100th Percentile Flows

Flows close to the 100 percentile flow should be allowed to occur at some time and this approach provides a mechanism to approximate their natural frequency of occurrence. Abstraction or diversion that would reduce flows below the 100 percentile flow would not be permitted. This mechanism enables the water supply service provider to access more than 50 percent of the flow below the 80 percentile flow in extreme circumstances. In such circumstances, significant water use restrictions would be expected to apply.

4.2 Natural Ecosystems

Rivers, lakes and streams whose catchments are wholly in Namadgi National Park, with the exception of the Cotter catchment, fall into this category.

Protection of low flows;

- For rivers and streams the flows below the 80th percentile flows are to be protected from abstraction;
- Abstraction from rivers and streams shall never exceed flow rate; and
- No abstraction is permitted from lakes and ponds in which natural ecosystems are to be maintained.

Protection of flushing flows:

- for rivers and streams, 10% of the flow volume in events above the 80th percentile is available for abstraction.

Implementation

Restrictions on abstraction are the major strategy adopted to maintain streamflow. In practical terms, abstracters would not be permitted to use their water allocation during a period of low flow, but would be able to pump or divert water in other parts of the flow regime. Percentile flows should be calculated on not more than a monthly basis.

4.3 Modified Ecosystems

Rivers, lakes and streams outside Namadgi National Park and the Canberra urban area fall into this category. Lake Burley Griffin and the Molonglo and Queanbeyan Rivers are included here even though the major use of the Queanbeyan River is for water supply purposes. This recognises the established uses in the catchment before the construction of Googong Dam. The guidelines for these ecosystems aims to manage of flows and abstraction from streams, so as to maintain modified ecosystems in as natural state as possible. The objective acknowledges recreation related ecosystem attributes including recreational fishery and the absence of algal scums and odours. Modified Ecosystems fall into three categories "Water Supply Reaches", "the Murrumbidgee River" and "Other Reaches": Some guidelines are common for all three categories.

Protection of low flows;

- For rivers and streams the flows below the 80th percentile flows should be protected from abstraction except for stock and domestic needs; and
- Abstraction from rivers and streams should never exceed flow rate.

Protection of flushing flows:

- for rivers and streams, 10% of the flow volume in events above the 80th percentile is available for abstraction.

4.3.1 Water Supply Reaches

The Queanbeyan River at Googong Dam and the Molonglo River at Captains Flat Dam fall into in this category. The defined low flow should be protected. The low flow is defined as the 80th percentile of water flowing into the reservoir. That is, flows entering the reservoir, up to and including the 80th percentile, are to be released. For Googong Dam, where the water service provider can demonstrate the need for further supplies, the Environment Management Authority may reduce this level of protection after consultation with the Commonwealth, NSW and local authorities. Where the level of protection is reduced flow should not be permitted to fall below 50% of the inflow when flows are below the 80th percentile except as specified under drought conditions (see Section 4.1).

Reservoir releases to meet environmental requirements should mimic natural flows as far as possible. Once flow requirements are met, all other water is available for abstraction.

4.3.2 Murrumbidgee River Environmental Flows

For the Murrumbidgee River in the ACT, percentile flows are calculated from gauged data taken subsequent to construction of the Tantangara Dam. This is an interim approach and may be modified as more information becomes available or the pattern of releases from Tantangara Dam is changed. An agreement between the former NSW Water Conservation and Irrigation Commission and the Snowy Mountains Hydro-electric Authority (1961) on releases from Tantangara provided for a base flow of 0.20 cumecs at the Cotter Crossing in the ACT. However, there is no requirement to release more than 0.96 cumecs at the dam, or more than is flowing into the dam. This agreement and abstractions in NSW result in flows which are often well below 80 percentile monthly flows in the ACT section of the Murrumbidgee River. Environmental flows for the Murrumbidgee River consist of the sum of the Murrumbidgee flow entering the ACT and the end of valley environmental flows from all tributaries that join the river within the ACT including those

ACT

Murrumbidgee
flow leaving
the ACT
Murrumbidgee
flow entering
the ACT

Figure 2: Components of Murrumbidgee RiverFlow

Flow from ACT
tributaries
Flow from NSW
tributaries
Available for
abstraction in
ACT
Environmental
flow from ACT

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that originate in NSW. This is illustrated in Figure 2.

4.3.3 Other Reaches

All other waterbodies including the Queanbeyan River above Googong Dam and the Molonglo River above Captains Flat Dam fall into in this category. The guidelines for these reaches are:

- Abstraction or diversion of water above Googong and Captains Flat Dams should be limited to that permitted as a riparian right;
- For lakes and ponds in modified ecosystems the maximum drawdown is 0.2 m below spillway level; and
- Temperature of water released from reservoirs should approximate as closely as possible the temperature of water flowing into reservoirs.

Implementation

For river reaches immediately downstream of reservoirs, controls on abstraction together with low flow releases from the reservoirs are seen as the appropriate mechanism for achieving guideline environmental flows. Water released from reservoirs should be at a temperature approximating as close as possible that of inflow water. If inflow water temperature is unknown, surface water should be used to meet environmental flow requirements. For other river reaches, controls on abstraction are seen as the appropriate mechanism for achieving guideline environmental flows. In practical terms abstracters would not be permitted to withdraw their water allocation during a period of low flow, except for stock and domestic needs, but would be able to pump or divert water in other parts of the flow regime. Storages, including Captains Flat, Googong and Lake Burley Griffin, should not be required to make releases to provide flushing flows as tributary inflow will provide adequate flushing and the frequency and volume of spills from Lake Burley Griffin will provide an acceptable replication of pre-urban flushing flows.

Lake and pond water levels should be maintained principally by controls on abstraction. Abstraction should be permitted only if the lake level is above the maximum drawdown specified in these guidelines. Percentile flows should be calculated on not more than a monthly basis but releases should be made to mimic natural short term, daily or within month, variability as much as possible.

100th Percentile Flows

It is recognised that flows close to the 100 percentile flow should be allowed to occur at some time and this approach provides a mechanism to approximate their natural frequency of occurrence. Abstraction or diversion that would reduce flows below the 100 percentile flow should not be permitted. This approach enables the water supply service provider to access more than 50 percent of the flow below the 80th percentile flow in extreme circumstances. In such circumstances, significant water use restrictions would be expected to apply.

4.4 Created Ecosystems

All streams, lakes and ponds within the urban area excluding the Molonglo River and Lake Burley Griffin fall into this category. The specific objective of for created ecosystems is the management of stream flows, and constructed water features, to maintain a range of urban aquatic ecosystems.

Protection of low flows;

- For rivers and streams the flows below the 80th percentile flow are to be protected from abstraction, except for stock and domestic needs;
- Abstraction from rivers and streams shall never exceed flow rate; and
- For urban lakes and ponds the maximum drawdown as a result of abstraction is 0.20 m below spillway level. The limit acknowledges that there will be further losses through evaporation in dry seasons. Lake edges are sloped at approximately 1 in 10 for stability, safety and public health. A draw down of 0.2 m represents a band of some 2 metres, within which macrophytes could be lost, if draw down was sustained for long periods. There will be a need to monitor the impact of this guideline on lake and pond macrophytes, and to review it over time.

Protection of flushing flows:

- for rivers and streams, 10% of the flow volume in events above the 80th percentile is available for abstraction.

Implementation

In the absence of upstream ponds and lakes, control of abstraction is seen as the appropriate mechanism for achieving guideline environmental flows. In practical terms abstracters would not be permitted to withdraw their water allocation during a period of low flow but would be able to pump or divert water in other parts of the flow regime. While some storages do not have the capacity to make releases without inflow, the frequency and volume of spills from those storages is considered to provide an acceptable replication of pre-urbanisation streamflow. Lake and pond water levels would be maintained principally by controls on abstraction. Abstraction would be permitted only if the lake level were above the maximum drawdown specified in these guidelines. There is already a significant demand for use of water from these waterbodies from the ACT Government for irrigation of parklands and playing fields, and for irrigation of golf courses. If increased demands were accommodated without consideration of environmental requirements, they could impact severely on other functions of the waterbodies. Absolute drawdown levels are considered to be the most effective form of guideline for the protection of urban lakes and ponds.

5 FUTURE WORK

Further investigation is needed to confirm the flow requirements of local aquatic biota. The holistic approach, recommended here as the soundest available procedure on which to base environmental flow guidelines, requires the identification of different riverine ecosystems and the flows necessary to maintain their biota and processes. This is a major task. Furthermore, in Australia we cannot rely heavily on approaches pioneered on very different northern hemisphere ecosystems, or on approaches focusing exclusively on maintenance of fish habitat. Of particular importance in our streams with highly variable flows is an understanding of the impact of daily, seasonal, annual and event based flow variability to long-term health of and changes in aquatic ecosystems. There is a significant amount of research currently being undertaken into environmental flows in the Australian context. The expanding knowledge base resulting from the research and increased quantity of data obtained from monitoring of stream flows will both influence and impact on the review of these Guidelines.

An ongoing monitoring and evaluation program of actual flows is required to determine if targets and thresholds nominated in the Guidelines are the most appropriate for individual water bodies. Future review of the Guidelines must be based on information gathered from the monitoring and evaluation program.

In addition, investigations are needed into ACT groundwater resources to establish the impact of increasing groundwater abstraction on river and streamflow, particularly base flows, the distribution of groundwater resources in the ACT, the vulnerability of these resources, and the sustainable yield. It is recognised that controls on surface water abstraction alone cannot guarantee base flow requirements in the medium to longer term.

GLOSSARY

Abstracter
An abstracter is a person or corporation that abstracts water from a waterway, dam or bore.
Abstraction
Abstraction refers to the removal of water from a natural waterway, dam or bore.
Aquatic Ecosystem
For the purposes of these guidelines, an aquatic ecosystem is an ecosystem bounded by the riparian zone.
Aquifer
An aquifer is a layer of rock or soil that is permeable and has the capacity to convey significant amounts of groundwater.
Baseflow
Baseflow describes the quantity of flow in a waterway that exists purely as a result of seepage into the upstream channel from groundwater. Practically, baseflow is determined from either field investigation after a prolonged period without precipitation or one of several quantitative baseflow separation models.
Biota
Biota is a general term describing the animal or plant life of an area.
Created Ecosystem
A created ecosystem is an ecosystem that has been significantly altered.
Discharge
Discharge refers to the release of water from a detention structure into a waterway.

Diversion
See abstraction.
Drawdown
Drawdown refers to the change in water surface elevation in a dam during a certain time period.
Ecosystem -
An ecosystem is a biological community of interacting organisms and their physical environment.
Ephemeral Streams
Ephemeral streams are waterways that are temporary in nature. That is, waterways that exist for a relatively short period of time, usually a matter of days, after a storm event.
Flow Regime
Flow regime commonly describes the distribution of flow rate magnitudes over time for a particular waterway. In this capacity it is similar to a unit hydrograph.

Flushing Flows
Flushing Flows are flows, resulting from storm events, which typically comprise high flow rates
over a relatively short duration. Flushing flows are crucial to establishment and maintenance of
channel structure.
Fractured Rock Aquifer
A fractured rock aquifer is an aquifer that exists where the geological structure is characteristically impervious rock with sediment filled fractures. These fractures allow the conveyance of groundwater.
Macrophytes
Macrophytes are large water plants. Emergent macrophytes are plants that are rooted in the riverbeds or lakebeds, and protrude from the water surface. Submerged macrophytes are plants
that are rooted in the riverbeds or lakebeds, but do not protrude from the water surface.
Modified Ecosystem
In the context of this document a modified ecosystem is an ecosystem that has been somewhat
altered by direct or indirect human influence.
Multi-level Off-takes
Multi-level Off-takes are structures that allow the release of a controlled quantity of water from
a variety of depths in a dam thus allowing water of a desired temperature to be released.
Natural Ecosystem
A natural ecosystem is an ecosystem on which there is minimal human impact.
Percentile
A percentile is a value between 0 and 100 that indicates the proportion of measurements that fall
above the percentile value. In this document the range of stream flows are expressed in percentiles. The 80th percentile is that flow that is exceeded 80% of the time, that is it is those commonly occurring (low) levels of flow. The 50th percentile, or median is that flow that is exceeded only half of the time, the less common and higher flows. Percentile flows are represented graphically in Figure I.

Percentage

Where a percentage is used in conjunction with a percentile such as 10% of the flow above the
80th percentile, this refers to the portion of the water available for abstraction (10%) when certain flow conditions prevail (the flow exceeds the 80th percentile). It refers only to a portion
of the water above the threshold level, not a portion of all water flowing at the time.

Riparian vegetation

Riparian vegetation is terrestrial vegetation that is influenced by its proximity to a body of water.

Figure I A graphical representation of percentile flows.

Special Purpose Flows

A special purpose flow refers to a particular flow regime that is required to meet a specified purpose. For example, some fish require a relatively unique flow regime, in terms of flow and temperature, to occur before spawning is initiated.

Stratified Reservoir

A reservoir becomes stratified when the water forms a layered structure, each layer having a distinct temperature and water quality.

Stressed Stream

A stressed stream is a stream that has endured a prolonged period of low flow. These conditions
are often detrimental to stream health yet are a necessary component of the flow regime because they improve the resistance of local organisms to periods of low flow or drought conditions.

A stressed stream may also refer to a stream that is suffering from pollution.

Sustainable Yield

Sustainable yield refers to the quantity of water that may be diverted without having an adverse effect on dependent ecosystems.

Territory Plan

The Territory Plan is the primary planning document that implements the *Land (Planning and Environment) Act* and provides a framework for the sustainable growth of the ACT region. It provides specific guidelines and restrictions on land use.

PERCENTILE FLOWS

0

50

100

150

200

250

Percentile

50 80 0 10 100

Urban Lake or Pond

An urban lake or pond is a dam that was constructed for the purposes of recreation, pollution control and minimisation of peak storm flows. In the ACT they are Point Hut pond, Isabella pond, Upper Stranger pond, Lower Stranger pond, Lake Tuggeranong, Lake Ginninderra, Gungahlin pond, Yerrabi pond.

Water Supply Ecosystem
A water supply ecosystem is an ecosystem in a catchment, which is primarily used as a water supply catchment.

Water Use Restrictions
Water use restrictions are rules that are put in place during periods of drought or near-drought to prevent the excessive drawdown of water supply reservoirs. Examples of water use restrictions include limited sprinkler hours and prohibition of outdoor watering.

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Appendix 2

Tisza River Basin Management

An Overview of Water Resources, Flood Protection and Navigation

This overview was prepared for the workshop International Co-operation in the Tisza River Basin held in the frame of the Project International Co-operation in Danube River Basin Management, (PHARE Contract No. 98.0446.00).

The workshop International co-operation in the Tisza Basin focused on water resources, flood protection and navigation issues and was held in Uzgorod, Ukraine on 4-6 November 1999. The workshop was held jointly with the TACIS project Team and was well attended, with 25 representatives drawn from the projects team, Ministry personnel of the Phare and TACIS countries of Hungary, Romania, Slovakia and Ukraine as well as representatives from the Federal Republic of Yugoslavia.

Project Flyer

1. Water Resources

1.1 Background

The River Tisza (966km, 157,220km^2) is with respect to its length and catchment area, the largest Danube tributary. From its total length about 160km lies in the Ukraine and Romania and about 800km in the Great Hungarian Plain (650km in Hungary, 150km in Yugoslavia). The mean annual discharge (1931 - 1970, Senta, Yugoslavia) at the confluence with the Danube is 766m3/s ranging from 371m3/s to a maximum of 1644m3/s.

Romania has 46.2 percent of the catchment area, Hungary 29.4 percent, Slovakia 9.7 percent, Ukraine 8.1 percent and The Federal Republic of Yugoslavia (FRY) 6.6 percent. The distribution of population (14.4million) between the countries corresponds closely to their share of the catchment.

The rate of runoff from the contributing catchment varies substantially along the route of the Tisza. A significant proportion of the rainfall contributing to this runoff falls on the upper catchment, and although Hungary has more than 25% of the area, it receives only 5% of the rain.

Table 1 summarises the national water balance for the Tisza catchment. The volume of flow passing across international boundaries demonstrates the requirement for transboundary co-operation on the integrated management of the Tisza River Basin.

	Average Annual Flow		
	m^3/s	m^3/s	m^3/s
Ukraine			
from Romania	61		
in Ukraine		235	
to Slovakia			92
to Hungary			205
Slovakia			
from Ukraine */Uh, Latorica)*	92		
in Slovakia *(Laborec, Ondava, Bodrog, Hornad, Bodva, Slana)*		122	
to Hungary*(Bodrog, Hornad, Bodva, Slana)*			214
Romania			
in Romania *(Somes, Crisuri, Mures)*		453	
to Ukraine *(Tisza)*			61
to Hungary *(Somes, Crisuri, Mures)*			380
to Yugoslavia			12
Hungary			
from Slovakia	214		
from Ukraine	205		
from Romania	380		
in Hungary		56	
to Yugoslavia			855
Yugoslavia			
from Hungary	855		
from Romania		12	

in Yugoslavia			7

(ref. Hydrology of the River Danube, 1988, Stancik, Jovanovic et al.)
Table 1: Average Surface Water Resources Budget (1941/1971) in the countries within the Tisza Drainage Basin

1.2 Minimum Flows

The Minimum Flow on a watercourse is the discharge required ensuring adequate flow downstream for environmental, abstraction or fisheries purposes. In rivers without any man induced controls the minimum flow will be a function of the meteorological and hydrological conditions pertaining. Where changes to the natural regime on a river are brought about at some location it is usual to provide for a minimum flow to sustain the downstream requirements. Legal requirements to provide 90% or 95% of the natural exceedance flow (i.e. the flow equalled or exceeded for 90% or 95% of the time) are sometimes imposed. However, in rivers such as those in the Tisza River Basin the impact on the river due to impoundments, abstractions, diversions, etc. have become so significant that it is often not possible to specify with confidence the natural flow at a particular location. Climatic and environmental changes are such that the natural regime would have changed independently and therefore previously calculated exceedance flows may not now apply.

1.2.1 Slovakia

At present in Slovakia the calculation of minimum flow depends solely on hydrological parameters and doesn?t consider the requirements of ecology.

The minimum discharge, MQ value, is defined as follows:

$MQ = 0.5 * (Q_{m99} + Q_{100min\ d})$
where
Q_{m99} is the mean monthly natural discharge with 99% exceedance probability
$Q_{100min\ d}$ is the100-year minimum daily discharge

The minimum needed discharge in a watercourse (MPP) for providing water abstraction requirements is then the sum of minimum balance discharge and water consumption (value X):

$MPP = MQ + X$

Minimum discharges are not included in any existing Slovakia bilateral agreements.

1.2.2 Romania

The understanding of the minimum flow in Romania is given by the following definitions:

- *Sanitation discharge*: The minimum discharge required in a certain section on the watercourse, to provide the natural conditions for the existing aquatic ecosystems.
- *Servitude discharge*: The minimum flow required to be permanently provided downstream of a dam, consisting of the sanitation discharge and the minimum water flow necessary for the downstream users.

According with the provisions of the a bilateral agreement between Romania and Hungary the values of the established minimum flows, so called *salubrity flow*, are as follows:

River	Salubrity flow m^3/s
Tur	0.25
Somes	4.20
Crasna	0.10
Barcau	0.15
Crisul Repede	0.25
Crisul Negru	0.35
Crisul Alb	0.20
Mures	6.50
TOTAL	12.00

These specified flow values take account of the water consumption of the users located on the Romanian territory and consider the monthly average flows recorded on the border section of the rivers. The total minimum flow of $12.0m^3/s$ is less than 5% of the combined mean annual flow on the Romanian/Hungarian Tisza Rivers.

There is not yet established a minimum flow for the Tisza between Romania and Ukraine - however once the new Romanian-Ukrainian Agreement comes into force, both parties will probably agree a value.

1.2.3 Ukraine

1.2.4 Hungary

1.2.5 Conclusion

Despite variations in the national definitions it would seem reasonable to consider minimum flows as consisting of two parts:-

1. the minimum flow to meet the ecological and environmental requirements downstream.
2. the minimum flow to meet the requirements (domestic, industrial, agricultural, etc.) of the downstream users.

Each river sub-catchment needs to be assessed independently to determine the downstream ecological and environmental needs. Once agreement between parties is reached on an environmental minimum flow discussions can take place on additional domestic, industrial and agricultural requirements.

Agreement on values for minimum flows is particularly important on transboundary rivers such as the Tisza. The basis for determining the agreed minimum flows needs to be clearly defined and understood by both parties. Agreement on the equitable allocation of water resources and minimum flows is required. Procedures for re-evaluating minimum flow values should be incorporated into any agreement.

1.3 Water Demand

Assessment of the existing water demand and predictions of future demands have been made by all countries. These predictions take account of such factors as population change, increased connection levels and changes in industrial and agricultural requirements.

1.3.1 Slovakia

The Bodrog is the only Slovak Tisza sub-catchment enriched by waters from an upstream located country - Ukraine.-- by means of two rivers - the Uh and Latorica. Water from the Bodrog and its tributaries is used for power production (thermal power plant at Vojany abstracts $9.7m^3/s$) and irrigation (at present to a small extent due to economic factors). Other Slovakian tributaries include the Laborec and Ondava.

The total abstraction in 1996 from the Slovak Tisza basin was $13.3m^3/s$ of which 10.5% was for domestic use, 89% for industrial use and 0.5% for irrigation. 82% of the industrial abstraction ($9.7m^3/s$) was for the Vojany thermal power plant of which an estimated 5% was consumed.

The latest available forecasts for water consumption were made in 1992 with forecast horizon 2010. These forecasts, which were based on analysis of existing consumption, consumer surveys and expert judgement, give estimates of the demand in both the growing season (dry year) and the non growing season. The forecasts were compared with the calculated minimum discharges on the rivers. For those rivers with a partial catchment in the Ukraine the situation can be summarised as follows:-

- River Uh - sufficient water to meet demand
- River Latorica - insufficient water to meet growing season demand (approx. 30% shortfall). Not possible to increase discharges on the Slovak side.
- River Bodrog - sufficient water to meet predicted demand. Reservoirs on tributaries have positive impact (Zemplinska Sirava - 334 million m^3 on the Laborec; Velaka and Mala Domasa on the Ondava)

The situation for those rivers passing into Hungary can be summarised as follows:-

- River Slana - insufficient water to meet predicted demand in growing season (approx. 2% shortfall). Deficiency met from Teply vrcg reservoir or by water transfer from Hornad River Basin (Palcmanska Masa reservoir)
- River Bodva - insufficient water to meet predicted demands at all times (90% - 100% shortfall). Deficiency solved on an operational level by drinking water reservoir.
- River Hornad - sufficient water to meet predicted demand. Reservoirs Ruzin I and II have a positive impact.

1.3.2 Romania

The total estimated domestic demand within the Tisza sub-catchments increased by nearly 10% in the period 1994 to 1996 (ref. Table 2). However, on a national level during the same period domestic demand remained static while industrial consumption fell by 25% and agricultural consumption by 40%.

	Total Annual Demand (m^3)		
Tisza River Basin	1994	1995	1995
Somes/Tisza	133	147	146
Mures	143	151	159
Crisuri	56	58	58
Total	332	356	363

Table 2 - Total Domestic Demand (1994 - 1996)

Taking account of the most recent water balance reports (Apele Romane) the projected demands (2005, 2015 and 2025) within the Tisza sub-catchments were estimated. While allowing for declining populations these projections provide for significant increases in rural population connections. (Tables 3a, 3b and 3c).

	Present	2005	2015	2025
Population	2,003,000	1,961,000	1,863,000	1,797,000
Domestic Demand (million m^3/year)	224	239	279	306
Industrial Demand (million m^3/year)	102	113	145	170
Zootechnics Demand (million m^3/year)	4	5	7	9
Fisheries (million m^3/year)	74	75	90	115
Total (million m^3/year)	404	432	521	600

Table 3a - Predicted Water Demand: Somes-Tisza River Basin

	Present	2005	2015	2025
Population	2,190,000	2,143,000	2,036,000	1,936.000
Domestic Demand (million m^3/year)	238	275	375	412
Industrial Demand (million m^3/year)	577	704	1058	1152
Irrigation Demand average/drought (million m^3/year)	94/160	94/159	90/152	73/145
Zootechnics Demand (million m^3/year)	4	9	23	47
Fisheries (million m^3/year)	36	41	57	86
Total (million m^3/year)	948/1014	1122/1187	1603/1666	1769/1841

Table 3b - Predicted Water Demand: Mures River Basin

	Present	2005	2015	2025
Population	910,850	881,300	828,500	794,400
Domestic Demand (million m^3/year)	79	81	89	104
Industrial Demand (million m^3/year)	66	90	117	147
Zootechnics Demand (million m^3/year)	1	2	3	4
Fisheries (million m^3/year)	33	54	110	174
Total (million m^3/year)	179	227	320	429

Table 3c - Predicted Water Demand: Crisuri River Basin

These forecasts provide for total growth in water demand within the Romanian Tisza catchment of 16% to 2005, 60% to 2015 and 83% to 2025. The Romanian report states that in general the minimum flows are adequate to satisfy the projected demands. Based on Romanian catchment areas of 15,015km^2, 27,830km^2, and 14,880km^2 for the Somes, Mures and Crisuri respectively the predicted 2025-Year demand equates to a net runoff of between 30mm and 60mm. For the whole Tisza catchment the net runoff is estimated to be 177mm.

The length of the Tisza river on Romanian territory is quite small and it forms the border with Ukraine on some sectors on which water use is limited due to border restrictions.

Regarding the rivers which flow from Romania to Hungary, the Romanian report states that agreed minimum flows meet the existing demands in Hungary. The agreed salubrity flows, which are based on the worst drought in the period 1945-1969, do not seem severe. The agreement includes provisions for joint measurement of flows when the parties disagree.

1.3.3 Conclusions

The forecasts of water demands indicate substantial growth over the next number of years. In recent years there has been significant reductions in water demand in Slovakia and Romania (in 1997 on a national level there was a reduction of 50% in water consumption) due to the economic decline. Taking these factors into account the forecasted demands may be conservatively high.

Water resource availability within the Tisza sub catchment does not present a problem in Romania. While there are substantial shortfalls on some of the Slovak tributaries the supply on only one of these - River Latorica - is influenced by another country.

2. Flood Protection

2.1 Background

Flooding throughout the Tisza Catchment is a major problem. The floods of last winter (1998/99) caused millions of dollars of damage in Slovakia and Romania. The frequency and severity of flooding would appear to be worsening with the impact of floods in terms of human health and economic losses rising.

Historically attempts to reduce the extent and severity of flooding impacts within the Tisza have concentrated on engineering solutions. However as with other major river systems, such as the Mississippi in the USA and the Rhine, these solutions are not sustainable in the long term.

The extent of river control works undertaken during the last century has clearly had an adverse effect on parts of the Tisza catchment. A large number of dams, dikes, and other hydraulic structures, built to serve various important human activities, have inevitably caused changes in flow pattern and damage to the functions and biodiversity of the river system. These factors along with changes in land use throughout the catchment will have caused significant environmental damage, such as reduced sediment transport, increased erosion and reduced self-purification capacity.

Within the watercourses, dams, reservoirs or special flooding areas may possibly influence the flood's water level either positively or negatively. The retention capacity of the flooding areas is changing the water level and propagation time of the flood wave and consequently the coincidence of flood waves of main river reaches and tributaries are influenced. Man-made influences on watercourses may have beneficial or negative consequences. Beneficial effects in small sub-catchments may be negative for the main river reaches.

While the construction of large reservoirs on rivers within the Tisza catchment will have some flood attenuation impacts these may have been counteracted by changes to the natural conditions of storage due to

- urbanisation
- changing landuse (changing vegetation, depressions, soil water holding capacity)

- deforestation
- compaction of soil on arable land reducing water infiltration and water holding capacities
- straightening and impoundment of water courses
- reduction of natural flooding areas

The construction and enhancement of dikes has preserved areas from catastrophic flooding. However urbanisation and increased activity in flood protected zones have accumulated possible losses in areas prone to inundation. The consequences of floods in excess of the design flood protection standard are now more severe than ever. Localised or even national flood protection standards may have become significantly reduced by gradual changes in the catchment's physical and hydrological characteristics over a number of years.

2.2 Slovakia

The territory most vulnerable to flooding is the East Slovakia Lowland where significant floods on the Laborec, Latorica, Uh and Bodrog occur frequently. For example severe damage resulted following floods in October/December 1998 and again in February/May 1999.

Extensive river control works undertaken in this area include the Zemplinska Sirava Reservoir, Besa dry reservoir, 13 pumping stations, dikes and canals. The capacity of trained watercourses was designed in the 1950?s according to agreements with Hungary and the former Soviet Union. Values of discharges, water levels and dike levels on the Bodrog, Latorica and Uh were agreed. In the 1960s further flood protection works, principally the construction of dikes, in Ukraine and in the Hungarian part of the Bodrog, were carried out. Due to the reduction/elimination of flood plains there has been a significant increase in flood levels and frequency. The right dike of the Bodrog in Hungary reduces the channel capacity and causes a backwater effect on the Slovak territory while elimination of flood plains and deforestation in Ukraine has increased runoff with a 20% increase reported in the River Uh flood peaks.

The Slovak-Hungarian bilateral agreement specifies procedures for the conveying of flood waters from the Bodrog. For example if the water level reaches a specified level then it is required that the Slovaks open the filling structure at the polder Besa. The multi-purpose water reservoirs - Zemplinska Sirava reservoir on the Laborec River and Domasa on the Ondava River - are also used for flood control in the catchment.

There has been some agreement with Ukraine and Hungary on ? Co-operation on protection against flood by internal waters and ice?. Within the scope of these agreements countries co-operate and maintain direct contact during floods exchanging information on water stages, discharges and determined degrees of flood activity.

The Slovak Report recommends that,

- Water management measures be implemented in Ukraine, Slovakia and Hungary to provide a degree of protection to the East Slovakia lowland.
- A modern flood forecasting and control system be developed and operated
- The agreement with Hungary on conditions of conveying floodwater from the Bodrog be re-evaluated.

2.3 Romania

Floods occur almost every year on the Romanian part of Tisza basin. The extent of flood control works is extensive. In the Somes-Tisza river basin approximately 300,000 ha would be vulnerable to natural flooding but flood control works protects half of this area. In the Crisuri river basin approximately 262,000 ha of a vulnerable 310,000 ha is protected. In the Mures river basin, flood control works protect 210,000 ha out of a total of 340,000 ha.

More than 60% of the total flood damage in Romania in 1998 occurred in the Tisza basin with the biggest damages occurring in the Mures and Tisza river basins. The following list of properties and infrastructure damaged during the 1998 Flood demonstrates the severity of the flooding problem within the Romanian Tisza catchment.

Houses	2213
Households	7038
Social and economic units	211
Agricultural land	141,620 ha
National roads	21.64 Km
County and local roads	1669.72 Km
Forestry roads	485.3 Km
Railways	28.1 Km
Bridges and footbridges	1209
Hydrotechnical works	269
Water supply networks	25 Km
Electricity distribution networks	31.12 Km
Gas distribution networks	5.18 Km
Phone wire networks	60.07 Km

The bilateral exchange of meteorological and hydrological data between specific units of Romania and Hungary targets the effective and detailed communication of hydrological and meteorological phenomena which are likely to occur. Data on rainfall, temperature and snow thickness are exchanged and Romania/Hungary transmit mutual meteorological warnings. Information on flood levels at a number of gauges is transmitted to Hungary regularly the frequency increasing when levels are higher. The amount of meteorological and hydrological information transmitted is considerable and should be adequate for flood forecasting purposes.

At presence there is a lack of information from Ukraine regarding meteorological and hydrological data. However given the recent agreement between Romania and Ukraine concerning the co-operation in boundary water management it is expected that the bilateral exchange of both meteorological as well as hydrological data will take place

The Romanian report states that the forecasts and warnings have been transmitted with an anticipation period of 6 - 36 hours with forecast errors of about 10% except when floods occur due to snow melting when errors have reached 25%. Difficulties have arisen in areas where in order to have a good forecast information from Ukraine is required.

2.4 Conclusions

According to the European Commission's Framework Directive on water policy one of the four main objectives of a sustainable water policy is the alleviation of the impact of floods and droughts. Prevention and alleviation of floods and droughts depend extensively on regional and local physical planning and action in which the various specific conditions play a major role. Flood management as part of the River Basin management must be undertaken on a catchment basis rather than within administrative boundaries.

Flooding within the Tisza catchment is a major problem and consequently there is a need for a holistic approach to flood management. Such a holistic approach must be based on multilateral and international co-operation, including interdisciplinary planning for the whole catchment areas. This approach should address the following issues.

A modern flood forecasting and control system

There is a significant amount of meteorological and hydrological information available within the Tisza catchment. Flood forecasts are already made on the Romanian/Hungarian tributaries and the reported reliability is quite good. Difficulties with respect to snowmelt predictions and information from the upper catchments in Ukraine have been identified. Areas lacking information should be identified and the development of an integrated model of the entire Tisza catchment initiated.

A comprehensive flood warning system

An integrated flood warning policy should be developed to (1) provide information on the flood risks associated with different locations and (2) to provide real time warnings to population within the inundation zone.

A current European Union project, RIPARIUS, is looking at the development of a pan-European approach to flood risk mapping for planning and operational use on rivers.

Flood warnings, information and forecasts should be forwarded and circulated in real time between the Tisza countries following an agreed procedure. Relevant information should also be made available to the public through the media, the Internet or other appropriate means. This should include information on what the public should do.

Comprehensive national and local contingency plans to respond to flood events should be properly prepared in due time. The authorities should have the capacity to respond to such events, in accordance with the relevant contingency plan.

The relevant authorities should inform the public about risk assessments. For example, flood maps indicating areas prone to flooding and detailing the extent, frequency and severity of flooding should be made available to the general public and, where appropriate, information based on geographic information system (GIS) should be distributed. Emphasis should also be placed on improving the means by which historical flood information is made available. Historical flood information displayed in an easily understandable format would help reduce the development of unprotected facilities in areas vulnerable to flooding. The benefits would include the reduction in funding required to make good any subsequent damage and the removal of hardship imposed on unsuspecting occupiers of the inundation zone.

A catchment view of flood defence activities

A policy on flood defence activities should be agreed between the Tisza countries fully integrated with environmental effects, rather than a collection of unconnected individual measures. Any project which would cause further changes to the Tisza flow regime should be assessed on a catchment rather than localised basis.

Flood defence works are an intervention in natural processes and therefore a balance must be struck between maintaining and supporting natural floodplains and reducing flood risk. The prominence of non-structural measures for flood defence will increase as part of the sustainable management of rivers and the restoration of flood plains to their natural function should be encouraged where socially and politically acceptable.

The Strategic Action Plan for the Danube River Basin includes as policy - the conservation, restoration and management of the wetland and floodplain areas of the tributaries and main stream of the Danube River Basin. In general it states:-

1. Flood protection by dikes and flood control during floods is important but not the only way to cope with the flood induced damages. They may be overcome when the design flood is exceeded.
2. The management of the floodplain i.e. the areas endangered with flooding, in terms of where to permit construction or development as a preventative and precautionary measure are effective in reducing damages.

An integrated floodplain policy.

The flooding of floodplain areas is both natural and desirable where it can occur without risk to human life. The objectives of an agreed policy should ensure

- development should not take place which has an unacceptable risk of flooding, lead to danger to life, damage to property and wasteful expenditure on remedial works.
- development should not create or exacerbate flooding elsewhere
- development should not take place which might prejudice flood alleviation works.
- development should not cause an unacceptable detrimental effect on the environment
- natural floodplains are retained and where practicable restored in order to fulfil natural functions.

European concerted action RIBAMOD (River Basin Modelling, Management and Flood Mitigation) included the following recommendations which are relevant to the Tisza River Basin.

- There is a need for a holistic approach to flood management (pre-flood planning, operational flood management and post-flood response)
- There is a need for a catchment view of flood defence activities, fully integrated with environmental effects, rather than a collection of unconnected individual measures.
- The special status of trans-border rivers must be recognised so that their management is undertaken as a whole rather than within administrative boundaries.
- There is a need for inter-disciplinary working between meteorologists and hydrologists to improve flood forecasting and between engineers, planners and ecologists for the design of flood defences.
- The prominence of non-structural measures for flood defence will increase as part of the sustainable management of rivers.
- The restoration of flood plains to their natural function should be encouraged where socially and politically acceptable.

3. Erosion

Deforestation of the upper catchment has led to increased soil erosion. As a consequence of the erosion phenomena, in the framework of the river basin the transport of the alluvial deposits involve big quantities of sediments causing serious problems by reservoir and rivers silting.

3.1 Slovakia

Riverbank changes were observed in the rivers Tisza and Hornad. Common Slovak-Hungarian Commission for measurement and tracing of the state border decided on measurement of the common boundary section of the Tisza River. On the basis of results from the measurements executed on the Tisza and Hornad Rivers it will be possible to define, whether the damaging of riverbanks caused such changes of the course of the state border which would require a necessary technical measures.

3.2 Romania

Soil erosion processes affects significant areas in the Crisuri, Mures and Tisza/Somes River Basins and anti erosion works are extensive. For example in the Somes-Tisza river basin there are about 700,000 ha affected by erosion (32% from the entire river basin surface), The total surface arranged with erosion control works is about 320,000 ha (about 43% from the affected surface). The length of the erosion control works on the river basin is about 184 Km, of which 19 Km in the Tisza river basin, 115 km in Somes river basin and 49 in Crasna river basin. The erosion phenomenon has significance for the national borders only on some sections of the Tisza River.

4. Navigation

4.1 Romania

There are just few preliminary studies which identified possibilities for navigation on both Mures and Somes rivers in long term- about 2020.

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